

Chapter One

Overview of a Research Journey through a Complex Landscape

1.1 Introduction

Mathematics teaching improvement is a priority to improve the Mathematics competencies of teachers and learners South Africa (Mahlong, 2012). Through many initiatives and results from comparative studies, the Department of Basic Education (DBE) and the former Department of Education recognizes ICT can be used to improve the quality of Mathematics education and to enable South Africa to become competitive, in relation to other education systems worldwide. Results from the Second International Information Technology in Education Study (SITES) 2006 and from a secondary data analysis (SDA) from the SITES 2006 results reveal the pedagogical use of ICT in Mathematics teaching is insufficient (Leendertz *et al.*), nor on par with the goals stipulated in the *White Paper on e-Education* (Department of Education, 2004b). The White Paper on e-Education specifies a fully ICT integrated system at all education levels by 2013. A transformation in ICT Mathematics education should occur at system, school and teacher levels in order to address the unsatisfactory performance of Mathematics learners in national assessments and international comparative studies. As South Africa embarks on the final phase of the e-Education plan, aimed at system wide integration of ICTs into teaching and learning (Department of Education, 2004b:23), many facets should be dealt with to coherently compete in a global society while adhering to the quality targets envisaged by the e-Education policy.

The following sections give an overview on the motivation and problem statement of the study, the research design and methodology followed during the study, the conceptual framework that guided the study, the ethical issues that underpinned the study, as well as clarification of some of the terminology used during the study, and how the remainder of the thesis will be presented.

1.2 Motivation and Problem Statement

The Professional development (PD) of teachers is topical as part of and emphasised in the National Department of Education's (NDoE) initiative to encourage school communities to improve the quality of teaching (Department of Education, 2010). *Profession* refers to a career that requires high levels of education and training (Burgess, 2002:50) and *development* necessitates individual growth and expansion in order to increase occupational performance of the individual (Barnhart & Barnhart, 1990:572). Therefore, *Teacher Professional Development* (TPD) involves the acquisition and development of skills and knowledge in order to effectively practise teaching and learning (Becta, 2004:1). TPD refers to the multiple opportunities and activities for teachers to engage in for improving their professional teaching competencies for improved education. TPD should be continuous so that

teachers could effectively integrate their competencies across all areas of teaching and learning (Da Ponte, 2010:1). *Continuing Professional Teacher Development* (CPTD) specifies that teachers should constantly expand their capacity to assist learners during their journey of exploring, learning, understanding and developing while simultaneously renewing their own professional skills and knowledge sets (Da Ponte, 2010:1; Department of Education, 2010:9).

In the Western Cape, only province who conducts a systemic evaluation, yearly determines empirical evidence on learners' Mathematics competence (Department of Basic Education, 2012a:18-35). The underpinning of Mathematics conceptual knowledge formally starts at pre-school level and can only be successful when teachers have a sound base of mathematical conceptual knowledge (Wu, 1999:535). The DBE envisages that, in order to decrease the high percentage of learners who are not adequately equipped with Mathematics skills to embark on university study (European Commission, 2012)`.

Dedicated CPTD programmes intend to raise the level of Mathematics teaching and learning in schools, aiming to improve results during Annual National Assessment (ANA) and other comparative studies (Department of Education, 2010).

The former Minister of Education, Naledi Pandor, emphasises the importance of TPD which should meet the requirements of a democratic South Africa during the 21st century. She emphasises a CPTD programme for ICT integration designed to bridge the technology gap between South African and other education systems (Klopper, 2007) as CPTD in ICT is a key to education systems across the world (Law, 2008). In order to determine the status of teachers' ICT Mathematics pedagogical use, South Africa, amongst 21 other education systems, participated in three of the International Association for the Evaluation of Educational Achievement's (IEA) research modules relating to SITES studies (Module 1, Module 2 and SITES 2006); four of the Trends in International Mathematics and Science Study (TIMSS); and all three of the Southern and East Africa Consortium for Monitoring Education Quality (SACMEQ) programme (South African Government Information, 2010).

SITES 2006 investigated the pedagogical use of ICT in grade 8 Mathematics and Science classrooms of 22 educational systems across the world (Law *et al.*, 2008). Overall, only 18% of South African grade 8 Mathematics teachers integrated ICTs into their teaching and learning practices (Law & Chow, 2008) (Addendum 1.1 and attached article on results from a secondary analysis). About a third (32%) of teachers accessed introductory ICT courses, and 15% of teachers participated in ICT integrated pedagogical training (Pelgrum, 2008). Although in 2002, 60% of high school teachers were trained in ICT use, only about half of primary school teachers had received ICT training. However, 87% of Mathematics teachers indicated that they wanted to attend ICT pedagogical training (Reynolds *et al.*, 2003:159). Embarking on the final phase of the e-Education policy (Phase III, 2010-2013), which is aimed at system wide integration of ICTs into teaching and learning, many facets of the previous two stages are not in place and fully functioning (Department of Education, 2004b; Leendertz *et al.*). From this unsatisfactory position of Mathematics Education, it becomes clear that CPTD of Mathematics

teachers on ICT integration in Mathematics can support Mathematics teachers in their teaching and learning practices. Khanya, established in 2001, was an ICT initiative of the Western Cape Education Department (WCED) to determine whether technology can address the human capital issues in schools. Its aim was to supply all schools with ICT resources and training so as to marginalise the inequities in human capital and schools across the province. Khanya, which provided ICT services in the Western Cape, achieved many of its objectives like supplying schools with ICT infrastructure, providing ICT training, and creating support services (Western Cape Education Department, 2013b). After the completion of the Khanya project at the end of December 2011, there was a concern that the more than 28 000 teachers who received ICT training in the Western Cape Province—in spite of ICT training they received—do not link to the enhance Mathematics teachers' technological pedagogical and content knowledge (Western Cape Education Department, 2011). As Khanya aimed to equip all schools in the WCED with a technology support system to increase critical thinking and train Mathematics teachers to integrate ICT to move towards a fully ICT integrated system, the WCED needs to urgently address the shortcomings concerning CPTD (Western Cape Education Department, 2013b).

In 2011 TIMMS evaluated the achievement of learners in grade 8 Mathematics in 42 countries (Mullis & Martin, 2011). TIMMS assessed the three cognitive Mathematics domains: knowing facts, concepts and procedures; applying concepts and procedures; and reasoning, of the learners. South Africa achieved the second lowest of the participating countries (Mullis *et al.*, 2012:50; Rademeyer, 2012). Only two per cent of learners could apply their understanding and knowledge in a wide variety of complex situations. However, at national level there was an increase in the grade 9 learners' performance from 261 points in 2003 (Mullis *et al.*, 2004:18) to 352 points in 2011, which is a significant increase, but still below the international benchmark of fifty per cent (Ditsem.net, 2012; Mullis *et al.*, 2012:46).

As one of fifteen education systems, South Africa participated in the SACMEQ programme. Participation in SACMEQ assists the DBE in benchmarking the quality of South Africa's education against other comparable systems in the Southern and Eastern African regions; reassigning skills—a recommendable feature of the SACMEQ projects—and strengthening capacity to evaluate the schooling systems. SACMEQ confirms the levels and quality of educational outcomes and indicates that learners are below the national target of sixty per cent for Mathematics and Literacy, and that the average achievement in Mathematics was 24% in 2000 and 31% in 2007. These scores are below the SACMEQ average of fifty per cent in 2000. During this comparative study SACMEQ assessed the TPD of Mathematics teachers as well and the results disclosed that 69% of teachers had received in-service training for Mathematics (Department of Basic Education, 2010:40).

The more recent ANA of 2012 involved almost seven million learners. It substantiates the findings of large scale studies: SITES, TIMMS and SACMEQ. ANA aims to improve learning at schools, meet the national targets for Mathematics and Literacy, and evaluate the performance of schools at national

and district level. The national average score for learners in grade 6 Mathematics was thirty per cent in 2011 and decreased to 27% in 2012: the Western Cape had the highest average of 41% in 2011, and a significant drop to 33% in 2012. In 2012 nationally only 13% of grade 9 learners achieved in Mathematics during the ANAs (Department of Basic Education, 2012b:3). The results confirm that schools perform poorly in Mathematics and Literacy, and show how often learners from one school make the same or similar mistakes; thus illustrating the shortcomings in teaching practices. Most important, the ANA national report guides the DBE on TPD to improve teaching and learning in schools (Department of Basic Education, 2012a:27).

In-service TPD is essential for improved pedagogical practices at schools (Reynolds *et al.*, 2003:159). The South African Council of Educators (SACE) takes accountability for the Code of Professional Ethics for educators and all teachers adhere to this code. Despite of the assurances made by this Code, many teachers have not received pre-service or in-service ICT training as part of TPD (Department of Education, 2006:1). The introduction of a *CPTD* Management System is currently assessed through a pilot project conducted at 145 schools in thirteen districts across all nine provinces. SACE describes criteria for the CPTD programmes: they should align with system-wide needs; strengthen learning area content and outcomes; and promote system transformation. Imbedded in these system-wide criteria are directions of the White Paper on e-Education (Department of Education, 2004b:23) which aims at system-wide ICT integration and use by 2013. SACE also monitors progress and expects all state employed and privately employed teachers to accumulate a total of 150 professional development (PD) points on their PD scorecards over a period of three years (Department of Education, 2010:13).

CPTD through Open Distance Learning (ODL) proposes to be a viable mode of CPTD in ICT pedagogy. Distance learning (DL) is an area of education that focuses on formalised teaching and learning systems and technology with the aim of delivering teaching to students who are not physically present at the place of training (Phelps *et al.*, 2004:50; The Open University, 2013). Open learning (OL) encompasses a versatile learning approach which allows learners to select what, when, where, how and at what pace their learning should take place (UNISA, 2008). ODL as a medium of education delivery comprises numerous characteristics: separation of teacher and learner, institutional accreditation, use of mixed-media software, two-way communication, possibility of face-to-face meetings for tutorials and the use of industrialized processes. Through ODL barriers created by time, geographical, economic, social, education and community distances can be bridged, enabling students to communicate with their institution, faculty, peers and the curriculum (UNISA, 2008). ODL provides organisational and pedagogical methods of delivering systemic education by using multiple forms of communication technology. ODL makes use of learning technologies to improve access to learning, enhance learning processes and facilitate learning outcomes (Pearson & Trinidad, 2004:60) through communication by print, electronic, mechanical or other devices assisting the separated teacher and learner throughout (Kanuka & Conrad, 2003b:385). When making use of ODL, remote learners can be reached; the location for teaching is not limiting; and the shortage of trainees per

sessions will not influence the success of the training; it can deal with differentiation in the abilities of teachers to be trained; and it allows the provider to make an analysis of the training requirements (Commonwealth of Learning, 2011a:1).

From the comparative results from SITES 2006, TIMMS, SACMEQ, ANA, and the results from the South African SDA of SITES 2006, it becomes clear that there is a dire need to address the CPTD for Mathematics teachers in ICT pedagogy. However, there are currently no guidelines for CPTD of Mathematics teachers in the pedagogical use of ICT in ODL. This research aims to generate guidelines for the CTPD in the pedagogical use of ICT through ODL. Therefore, the main research question this study will address is: *What are the guidelines for the professional development of Mathematics teachers in the pedagogical use of information and communication technologies through open distance learning?*

1.3 Research Design and Methodology

The question that guides this research is of a complex nature (Burrell & Morgan, 1979:50) and should be addressed by means of a multi-mode of methodological approach. Complexity has various interpretations which exclusively depend on the context in which it is used. According to Edwards (1999:72) complexity relates to models rather than genuine settings; defines the characteristics of a model; identifies elements of the general behaviour; symbolizes the difference between section knowledge and knowledge of developing behaviour. When a study represents complex systems the focus is on: how the system is structured, how the various parts relate to one another, and how they are connected to form a holistic unit. This research required using a multi-mode of methodological approaches as there was a high level of interaction among the components, and patterns emerged during the research process. The multi-method approach allowed the researcher to integrate different theoretical stances of viewing a problem, provided access to more types of data in conducting both confirmatory and exploratory research, and strengthened the processes and outcomes of the analysis (Cohen *et al.*, 2011:21-25).

I therefore affirm my stance from the classical work of Burrell and Morgan (1979) to establish the theoretical foundation of the study. Studies of sociological nature consider two dimensions (subjective-objective dimension and regulation-radical change dimension) and four sets of assumptions throughout research thinking: ontological, epistemological, human nature and methodological assumptions. Each paradigm represents a “social-scientific reality of viewing a problem based on different meta-theoretical assumptions with regard to the nature of science and of society” (Burrell & Morgan, 1979:24). Within each paradigm there is an awareness of *where you are*, *where you have been* and *where you can go in the future*. Figure 1.1 displays Burrell and Morgan’s (1979:22) model of four paradigms (functionalist, radical humanist, radical structuralist, and interpretivist) for the analysis of social theory. The functionalist paradigm views a problem from an

objectivist point of view, entrenched in the sociology of nature and study aspects related to organisations. The radical humanist focuses on the sociology of radical change, modes of domination, emancipation, deprivation, and potentiality from a subjectivist point of view, and has some attributes in common with the interpretivist paradigm.

To explain my theoretical position and assumptions for this study, I therefore used the interpretivist and the structuralist paradigm to explicate the appropriate world view for my research (Figure 1.1) (Burrell & Morgan, 1979:22-26). Addressing the complex research question relates to two phases: (i) an interpretivist phase to describe and understand the world from the point of view of those directly involved in the social process (Denzin & Lincoln, 1994:22) of CTPD. Theorists from the interpretive paradigm adopt an approach consonant with the code of belief described as the sociology of regulation. It is a subjectivist approach concerned with how people go about the task of seeing, describing, and explaining the world (Burrell & Morgan, 1979:28-32); and (ii) a structuralist phase rooted in a materialist view of the natural and social world that advocates sociology of radical change from an objectivist standpoint. Theorists from the structuralist paradigm adopt an approach which emphasises change, built into the very nature and structure of existing society, and they search for explanations of the basic interrelationships within the context of total social formulation (Burrell & Morgan, 1979:34-35).

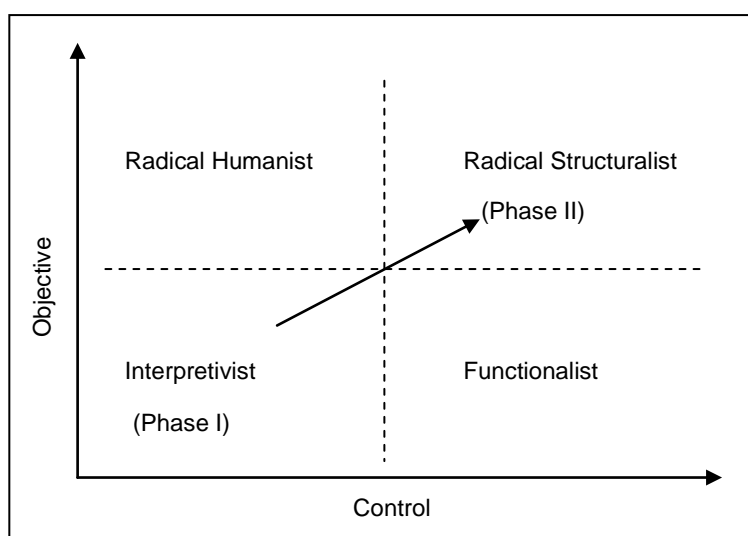


Figure 1.1: Choosing a Multi-Mode Research Design According to the Four Paradigms of Social Theory (Burrell & Morgan, 1979:22)

This research study will follow a *fully multi-mode sequential equal status* research design, consecutively using qualitative and quantitative and research methods. With this fully multi-mode equal status design the qualitative and quantitative phases occur sequentially and the phases have equal value in the research process. Both of the research methods provide a description of the data, constructively explain the data, and hypothesize on the outcomes (Bryman, 2006:111-126).

Combining these two research methods, the researcher will merge findings in order to develop the guidelines (Sechrest & Sidana, 1995:77-87).

Using the sequential procedure, the researcher intends to develop the findings of the previous phase. The research design starts with a methodology of systematic literature review analysed inductively according to qualitative constant comparative content analysis with the aim of exploring the literature for aspects of ICT integration in Mathematics teaching and learning through ODL (Phase I); followed by quantitative methods comprising a large scale survey whereby the researcher will generate guidelines through a process of structural equation modelling (Phase II) (Leech & Onwuegbuzie, 2007:271).

To address this research question, a conceptual framework provides the initial background in terms of the four main concepts indicated in the title of the study: (i) professional development, (ii) Mathematics education, (iii) the pedagogical use of ICT, and (iv) open distance learning.

1.3.1 Conceptual Framework

The conceptual framework of this study relates to Engeström's Third Generation Activity Theory Model (Commonwealth of Learning, 2011b) as it addresses interrelated aspects of the activity system: subject, motives, tools, rules, community and division of labour. The Third Generation Activity Theory Model is an extension of the original Cultural-Historical Activity Theory (CHAT) first developed by Sergey Rubinshtein and expanded by Aleksei Leont'ev and Yrjö Engeström. The activity theory is primarily based on the social cultural perspectives of Lev Vygotsky's universal law of development and Sergey Rubinshtein's principle of unity and inseparability of consciousness and activity (Yamagata-Lynch, 2010a). Activity theory was developed in 1978 by Russian psychologist Aleksei Leont'ev with its roots in the Russian psychology of the 1920's and 1930's. Aleksei Leont'ev developed the activity theory to breach the gap between the human mind, culture and society and Yrjö Engeström expanded it from an academic discourse to a multidisciplinary theory (Engeström, 1987).

Mathematics teachers are the *subjects* in the activity, while ICT and ODL comprise the *tools* to facilitate the activity. *Motives* are the goal-directed activity for this study (guidelines for the PD of Mathematics teachers in the pedagogical use of ICT in ODL). The motives guide the subjects' activities. Motives are subdivided into *outcomes* and *aims*. Outcomes are more distant and on-going towards achievement whereas aims will be realized within a shorter time span. The title of the study indicates the compilation of guidelines for the professional development of Mathematics teachers in the pedagogical use of ICT in ODL in order to achieve 2013 e-Education outcomes (Department of Education, 2004b:22-23). *Rules, community, and division of labour* constitute the social basis of the activity system. The *White Paper on e-Education, CPTD Management System* and SACE code of conduct stipulate the requirements for guiding the roles and responsibilities of stakeholders

(Mathematics teachers, DBE and service providers). The requirements will divide the obliged labour fairly among members of the community in order to achieve the required outcomes (Kain & Wardle, 2011:3).

The following section provides background on the origin of the activity theory, how it developed from CHAT to the third generation activity theory, and the rationale for using Engeström's third generation activity system model for this research.

1.3.1.1 Origin of Cultural–Historical Activity Theory

In the Russian context *activity* refer to a goal-directed logical system with a combination of internal mental processes, external behaviour and motivation (Bedny *et al.*, 2000:170; Higgins, 2003). It is not a physical activity but a system with unique structures of how the individual interact with its environment through organization intervention, and regulation (Brushlinskii, 2004:69-81).

Activity theory conceptual framework found its origin in the cultural-historical tradition of Russian psychology. The cultural–historical activity theory (CHAT) evolved through three generations from a framework used in Russian social psychology to being used in studies relating to education, language socialisation and computers (Russell, 1997). Since the introduction of computers CHAT has been one of the prominent frameworks and theoretical backdrops in a post-cognitive approach for Human–Computer Interaction (HCI) and interaction design. This theory is synonymous with studies relating to ICTs (Kaptelinin, 2006). The rationale for using activity theory analysis for this research is to give insight on solutions to solve complex research problems (Brushlinskii, 2004:69-81) and even though activity theory cannot address all the challenges of this research it presents an initial framework to understand the multifaceted dataset of this research.

1.3.1.2 Vygotsky's First Generation Activity Theory

Lev Vygotsky was the founder of the Soviet *cultural-historical school of psychology* and in 1924 he started to work in developmental psychology. His work shows an extensive interest in psychology, social sciences, philosophy, linguistics and literature (Kaptelinin, 2006). He wanted to transcend psychology from the pitfall of psychoanalysis and behaviourism to artifact-mediation and object-oriented action (Center for Activity Theory and Developmental Work Research University of Helsinki, 2004; Vygotsky, 1978b:52-57).

He challenged the view of Marxists who believed human beings are controlled by their immediate environment and their society (Kaptelinin, 2006). There are similarities to Vygotsky's theory, which states that children develop differently at each stage of their growth, and the work of Piaget's on the individual cognitive processes (Luria, 1979). Vygotsky believed that humans develop firstly through interaction with others within their environments and then within themselves (Kaptelinin, 2006). He

had two fundamental philosophies: “man is not only the product of his environment, he is also an active agent in creating the environment and the main social experience determines the structure of human conscious activity” (Luria, 1979).

Vygotsky’s psychological approach was known as *cultural, historical or instrumental psychology*. The instrumental aspect of his approach refers to the method in which people (teachers) respond and adapt to the stimuli in their environments, and how their thinking patterns alter as they grow. Cultural refers to the structured way in which society (DBE and school management) organises the tasks (PD) to attain the objectives. The historical connect with the cultural and include the instruments (tools) which are used by man (teacher) to master their environment (Cole *et al.*, 2006; Luria, 1979).

The basis of Vygotsky’s theory started with the stimulus-response framework which developed into the model of mediated act. In the stimulus response framework the stimulus (S) and the response (R) are connected and surpassed by the mediating act (X). “The psychologist seeks to confront the subject with some kind of stimulus situation designed to influence him in a particular way, then the psychologist examines and analyses the response elicited by the stimulus situation” (Vygotsky, 1978b:40).

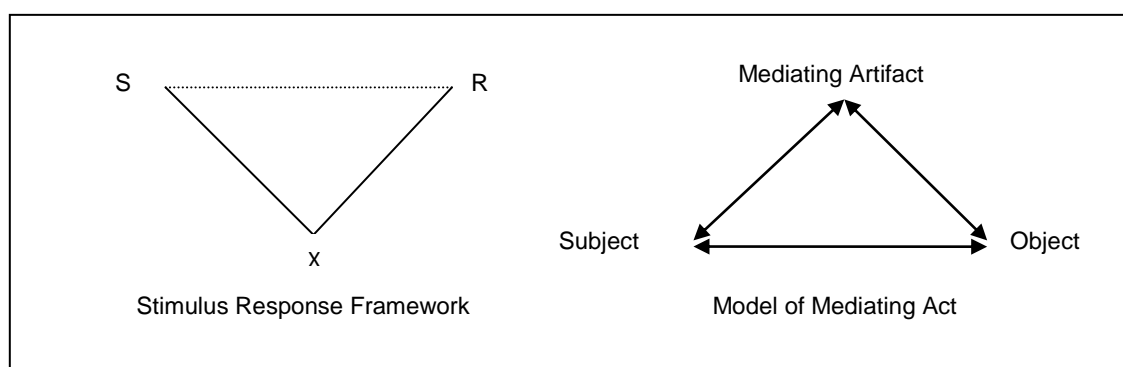


Figure 1.2: Vygotsky’s First Generation CHAT (Engeström, 2001)

Figure 1.1 illustrates Vygotsky’s amendment from the stimulus-response framework to the model of mediated act also known as the first generation CHAT. Mediation is the central dimension of Vygotsky’s human psychology and is representative of all the active instruction designs for a cognitive domain. With the inclusion of the mediating artifact in the model it bridged the gap between the individual and the community. In order to understand the environment it is imperative to understand the individuals who use and produce the artefacts (tools) (Engeström, 2001; Zurita & Nussbaum, 2007:214). The restructured model of mediating act (Figure 1.2) represents three components: *subject*, *object*, and *mediating artefact* (tools). Mediation prompts the interaction between the individual (*subject*) and its environment enabling the person to make sense and create meaning in their world. The *object* represents the goal of the activity. *Mediating artefacts* can include: artefacts (instruments, signs, procedures, machines, methods, laws), peers, and prior knowledge which add value to the subjects’ experience during the activity (Yamagata-Lynch, 2010b).

Rooted within the cognitive functions is the zone of proximal development (ZPD) which is the distance between the actual level of an individual's cognitive development and the potential level of the individual's development as he/she engages in tasks (Barab *et al.*, 2004; Bozhovich, 2009:51). The ZPD of each person is recognised as unique as the level of cognitive development differs from those of peers. The ZPD does not imply the acquisition of one particular skill, but on the holistic development of the individual. ZPD defines the cognitive functions which have not yet reached maturity. Humans are by nature social beings, therefore productive learning and intellectual growth will mostly occur in a social context where they can interact, communicate, share, and reflect on their learning (Barab *et al.*, 2004; Bedny *et al.*, 2000:170-171; Bozhovich, 2009:51; Engeström, 1987; Vygotsky, 1978a:88). Mathematics teachers' learning occurs mostly in the context where they teach and interact with their peers within their environment. In the school context there are Mathematics teachers with diverse ZPD. The CPTD strategies should take the ZPD of the teachers into consideration and it should be a guided process adjusting to the actual level of the Mathematics teachers' development to achieve their potential level of development. Therefore any PD must accommodate Mathematics teachers with varied ZPD. As teachers' ZPD vary, their PD requirements will be unique depending on their individual needs. PD through ODL can accommodate Mathematics teachers with various ZPD as the teachers can decide at which level of the ODL model they can start their PD, depending on their actual level of development to reach their potential level of development (Bozhovich, 2009:52).

Even though the philosophical views of Vygotsky relate to some of the aspects of this study the CHAT model has limitations as it mainly focuses on the development of the individual (Yamagata-Lynch & Haudenschild, 2009). As this study has four main interactive components of which only one part relates to the Mathematics teachers (individual), the first generation CHAT model is not appropriate for this study.

Two of Vygotsky's colleagues, Alexander Luria and Alexsei Leont'ev, assisted him in developing his theory in Russian psychology and as they had insight in his work and thought processes they were able to expand and develop his theory (Barab *et al.*, 2004:200). Between 1928 and 1934 Luria focussed on social origin and the mediated structure of psychological processes, but he did not broaden the CHAT framework developed by Vygotsky (Luria, 1979).

Servey Rubinshtein was another psychologist whose theory linked closely to that of Vygotsky and his work contributed to the development of CHAT. He focussed on pedagogical as well as psychological aspects (Kaptelinin, 2006).

1.3.1.3 Rubinshtein's Psychological-Philosophical Activity Theory

Servey Rubinshtein, was influential in Russian psychology and studied the individual as a *subject of consciousness and activity, consciousness and unconsciousness, knowledge and suffering* (Luria, 1979). The *psychological-philosophical activity theory* was created by Rubinshtein in the early twentieth century. In 1922 he developed the subjective activity approach in psychology and pedagogy which was known as *the principle of creative spontaneous activity, or the principle of unity of consciousness and activity*, which became recognized as a form of *activity theory* after Rubinshtein's death (Brushlinskii, 2004).

Rubinshtein's theory supports determination and self-regulation from a subjective approach. He believed that the internal and external interactions and influences are both critical of and interdependent on one another (Kaptelinin, 2006) and form the foundation of human development. He was convinced that learning takes place when humans separate themselves from their surroundings (people and environment), interact internally and self-regulate based on a system of feedback. The subjective activity approach consists of three components: *subjects, objects* and *activity*. Deep-rooted thinking (activity) occurs when teachers (subjects) interact with the objects during action. Throughout this action process teachers will embrace all their experiences, secrets and goals to achieve an objective. Rubinshtein recognises action as the fundamental and authoritative means for learning to take place. Teachers (subjects) acquire knowledge and skills not through verbal speech interaction with other people or conceptual thinking, but when they explore and communicate independently and creatively using their sense of touch and vision (Brushlinskii, 2004). After the action the teachers will reflect and give feedback on their learning.

As Vygotsky's model of mediating act function as individual components Leont'ev aspired to create a collective activity. Leont'ev used the basic principle from Vygotsky and Rubinshtein which presumed "*the social nature of human mind and inseparability of human mind and activity*" (Kaptelinin, 2006), and created a unique and reliable conceptual framework which is known as a *system of social-interpersonal relations* (Higgins, 2003). He applied Vygotsky's idea of cultural mediation which consist of a three components: *subject, object* and *mediating artifact* and expanded the model (Engeström, 2001) to bridge the gap between the human mind, culture and society (Kaptelinin, 2006).

1.3.1.4 Leont'ev's Second Generation Activity Theory

Even though the second generation activity theory as a conceptual framework found its roots in the theories of Vygotsky, Luria and Rubinshtein, it is a unique and steadfast framework developed by Leont'ev (Wilson, 2006; Zurita & Nussbaum, 2007:214). All the key qualities of activity theory materialized from his work. Leont'ev wanted clarity on the assumption of the existence of unobservable mental phenomena and the nature of consciousness (Wilson, 2006). The underlying principle of Leont'ev's *object-oriented activity theory*, the activity of human beings, which is goal-

directed, adaptable and manifests interaction between the actors (subjects) with its world (objects). He believed psychological studies must consist of three connected aspects: placing the subject in the objective reality; altering this reality in the structure of subjectivity; and analysing the conscious and unconscious mental phenomena to distinguish the relationship between mind and activity (Kaptelinin, 2006). Figure 1.3 displays the Leont'ev's *second generation activity theory* (human activity system) and the additional level which he expanded to the activity theory: *rules, community and division of labour*.

Leont'ev defines *activity* as processes “that realise a person’s actual life in the objective world by which he is surrounded, his social being in all the richness and variety of its forms” (Leont'ev, 1978). There are two aspects which make this *activity* unique. Within this framework firstly the interaction differ from an ordinary interaction as the subjects have needs which must be met through interaction with the objects. Secondly, the subjects and the objects connection is important to ensure growth and the development of the subject and object within their context (Kaptelinin, 2006; Yamagata-Lynch, 2010b).

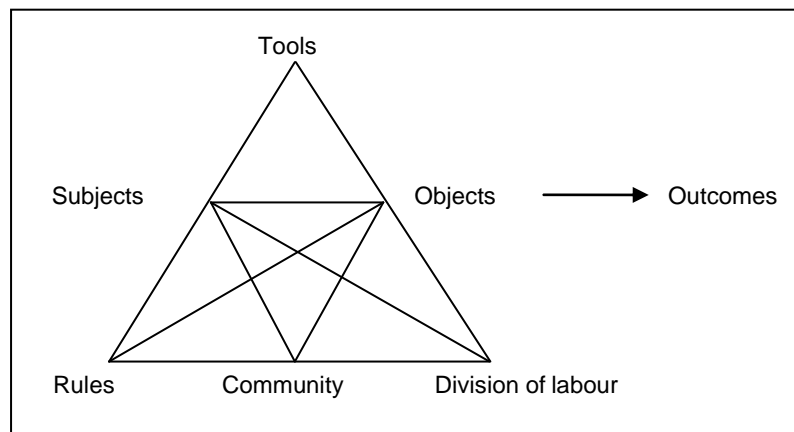


Figure 1.3: Leont'ev's Second Generation Activity Theory (Engeström, 2001)

Leont'ev's activity theory, focus on the subjects and the objects, and how these function within the *activity*. Subjects exist in an objective world where they must complete activities through interaction with the objects to meet their needs. The subjects develop their skills and knowledge as they communicate with the objects. Objects of the activity have two functions: it must have an independent existence but must not function in isolation, and as a representation of the object. Objects can be both physical things as well as abstract as long as they exist objectively in the world. The objects stimulate and drive the activity. The subject-object is animatedly aligned and does not always match. Through the alignment a progressive development can occur i.e. ICT will be challenging to master in the beginning, but the more teachers engage with the tools they will develop their skills on how they can use and apply the tool in their teaching practices (Kaptelinin, 2006).

Human activities illustrated in Figure 1.3 are known as units of life structured in three levels: (i) the *activity* which is acquainted with the motive related to a certain need, (ii) the *actions* which are time

restricted conscious procedures to achieve the goals and (iii) the *operations* which are the subordinate level of actions. Figure 1.4 displays Leont'ev's three levels analysis of social-psychological functioning known as the hierarchical model of human activity (Russell, 1997; Wilson, 2006).

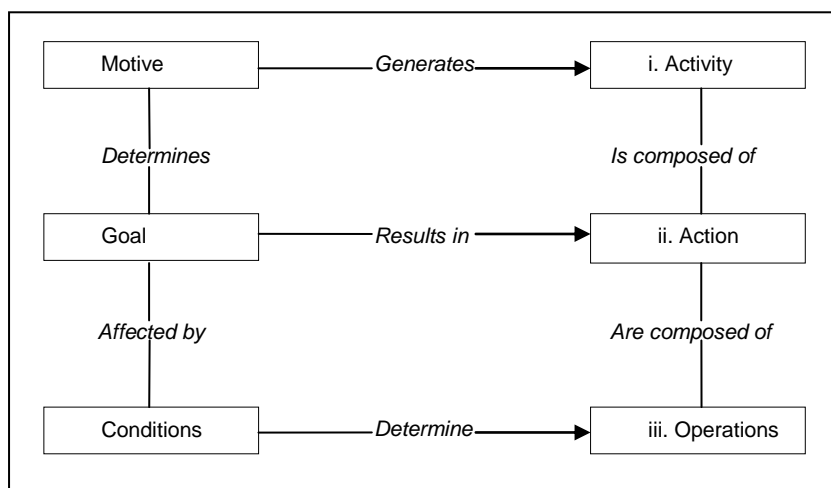


Figure 1.4: Hierarchical Model of Human Activity (Wilson, 2006)

The *activity* is accountable for the growth of the subject and the activity is affected by the characteristics of the objects. The *motive* is the object which the subject must achieve. *Goals* are conscious and time bound which the individual, dyad or group embark on to fulfil the object. It can be extended into different levels as sub-goals and sub-sub goals. The *operations* (ICT integration) are routine procedures where the individual, dyad or group are unconscious and not aware of their operations. Operations are adjusted to adapt to the conditions where the subject analyse and adjust the constraints and affordances of the activity towards achieving the goals. It can either occur in a structured way or can be constantly adapted depending on the circumstances (Kaptelinin, 2006; Russell, 1997).

At the base of the triangle (Figure 1.3): *rules*, *community*, and *division of labour* constitute the socio-historical aspects of the mediated action (Engeström, 2001). The rules refer to the laws, policies and regulations which guide the subject to attain the object. The *White Paper on e-Education*, *CPTD Management System* and SACE code of conduct stipulate the some of the requirements for this study guiding the roles and responsibilities of community (Mathematics teachers, DBE, provincial department (WCED), schools and service providers). The requirements will divide the obliged labour fairly among members of the community in order to achieve the required outcomes (Kain & Wardle, 2011).

With the implementation of Leont'ev's activity theory in studies relating to ICT it became obvious that the theory should be expanded to give a more detailed description of how it functions and can be applied in research projects. As Leont'ev did not graphically expand on Vygotsky's model of

mediating act except for reconstructing it with an additional level, Yrjö Engeström used the second generation model and further developed into a third generation model to create networks of interacting activity systems (Engeström, 2001; Robertson, 2008). Previously the model was mainly used in academic discussions and the aim was to adapt the theory to apply to organisations, in an e-learning environment, and in PD in educational surroundings. Engeström developed it further to accommodate more than one plane of analysis which is a prerequisite for this research as four components are addressed in this study.

1.3.1.5 Engeström's Third Generation Activity Theory

Engeström initially used the second generation activity theory model (Commonwealth of Learning, 2011a) as it addresses interrelated aspects of the activity system: subject, motives, tools, rules, community and division of labour. Engeström was inspired by Vygotsky's philosophy but CHAT has its limitations particularly in cross-cultural research and during research analyses of complex datasets (Engeström, 2001; Yamagata-Lynch, 2010b). The disregard of CHAT towards culture diversity represents challenges to researchers from post-Soviet regime or non-Russian psychological belief system. In 1987 Engeström further developed the analytical methods within the activity theory by including the *activity systems analyses* (Yamagata-Lynch, 2010b). Including the activity system analysis broadens the scope of research and creates the opportunity to identify activities critical to finding answers to specific research questions as well as to study combined processes (Yamagata-Lynch & Haudenschild, 2009). This study is a combination of processes which firstly identify activities significant to the research question. In the context of this research the activity systems are used as an analytical tool to analyse qualitative data to comprehend human learning conditions in their natural settings (Yamagata-Lynch, 2010b) and secondly as a framework for the developing of a survey questionnaire which will be distributed to senior phase (grades 7-9) Mathematics teachers in the Western Cape province.

The *third generation activity theory* is an extension of the Leont'ev's *object-oriented activity theory* model that include the social aspects within the system to describe and understand the relationship among the elements particularly in research relating to contradictions in educational technology (Robertson, 2008). The third generation system can constitute of a minimum of two interacting activity systems. Figure 1.5 (next page) shows the third generation activity theory designed by Engeström. In this model there is a common object-orientated activity that moves through the activity systems. Each activity system has its individual outcomes and aims linked with the object-orientation of the activity.

The relationship among the elements in the activity system relates to a community of sharing of knowledge that operates widely across elements of the education system (Russell, 1997:3). The most basic activity theory lens is the *activity system*, constitute of people (Mathematics teachers) with a common goal (PD of Mathematics teachers) in mind using tools (ICT and open distance learning) to

achieve outcomes (ICT fully integrated in the system regarding administration, teaching and learning) that are:

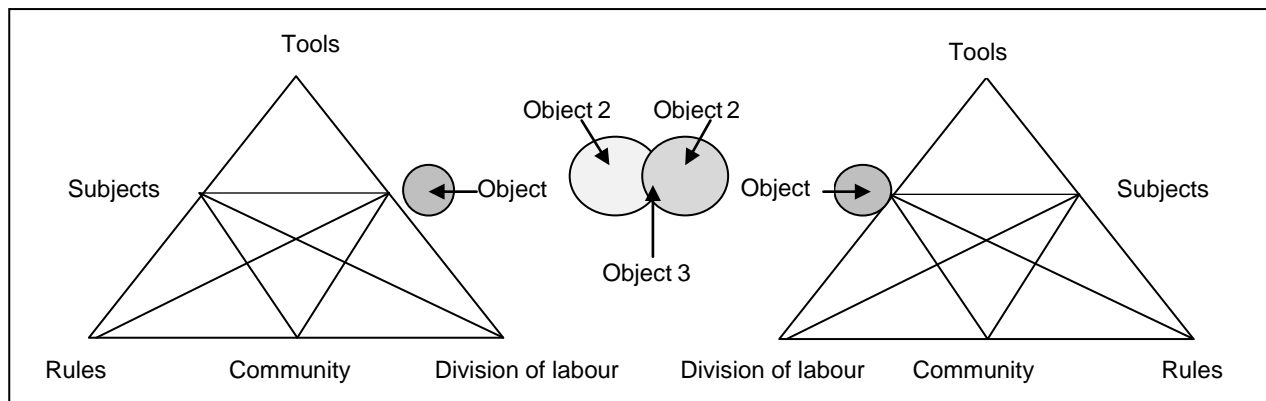


Figure 1.5: Engeström's Third Generation Activity Theory (Engeström, 1987)

- on-going actions within the system
- object-directed activities within the system
- human activities within the system
- historically conditioned
- tool-facilitation activities (Engeström, 1999; Kain & Wardle, 2011).

The complex nature of this research will include four conceptual activity systems with two planes of cultural-historical analyses: organisational and personal planes. A fifth activity system concatenates the findings from the factor analysis. All the activity systems are bounded, but allow the researcher to zoom in on one plane of analyses at a time and still combined form an object-oriented activity. The personal plane the subject of the activity system is the individual (PD of Mathematics teachers), and the organisational plane the subject specify the organisation or community (Governance, School environment, and ODL) (Yamagata-Lynch, 2010b).

The third generation activity systems will be used during the constant comparative analysis of the qualitative data of this research and during the factor analysis of the quantitative data. Activity Theory (AT) assist both qualitative (interpretative) (Hashim & Jones, 2007) and quantitative (structuralist) research as the objects of the activity can be either subjective or objective of nature (Bedny *et al.*, 2000:177). AT is a generic and versatile conceptual system which can be a foundation for more precise theories. Embedded in the AT are some basic principles: "hierarchical structure of the activity; object-orientedness; the twofold concepts of internalisation and externalisation; tool mediation; and continuous development" (Wilson, 2006). These basic principles form the basic structure and numerous activities can fit comfortably within the structure (Wilson, 2006).

1.3.1.6 Principals of Activity Theory

The third generation activity aims to cultivate conceptual tools to comprehend dialogue, various viewpoints, and networks of interactive systems (Engeström, 2001:135). When there is more than one activity system then the object of the activity is a moving object and not reduced to short-term goals. There are five principles in activity theory. The first *principle* is that each object-directed activity system functions in a network with other activity system, but still individually functions as a unit of analysis. The goal-directed actions (individual or group) and the operations in the activity system are somewhat autonomous, but a secondary unit of analysis and perceived only against the backdrop of the complete activity system. The *second principle* is that an activity system consists of a community with various viewpoints, practices and interest. Each member of the community has their own unique history and a role within the activity. The division of labour in the activity allows for each member of the community to contribute to the activity which forms *multiple layers and strands* of history fixed in its artefacts and rules. *Historicity* is the *third principle* in activity theory. The activity systems are formed and transformed over an extended period (PD should be analysed against the history of its local organisation) and the abilities and shortcomings of the organisation can be grasped alongside their own history. The *fourth principle* is the fundamental role of contradictions (the pressures in the organisation accumulated over a long period within and between activity systems). Certain contradictions create conflict and instabilities within the activity, but also ground-breaking endeavours to change the activity. Contradictions in the activity systems have two purposes—to indicate disagreement, and recognise the prospects for intervention and improvement. There are four levels of contradictions in an activity system: (i) primary, (ii) secondary, (iii) tertiary, and (iv) external quaternary. Primary indicates the contradiction within each code of the activity system. Secondary shows the contradiction between the components of the activity system (e.g. the subject and community). Tertiary specifies the contradictions between the object of the activity and the culturally expansive form of the neighbouring activities, and external quaternary indicates contradictions between the central activity system and the neighbouring activities (Barab *et al.*, 2004:208; Barab & Plucker, 2002:172). Expansive transformation is the *fifth principle* theory. The individual members of the activity start to query and stray from the traditional norms. In many cases this creates a platform where the members of the community (DBE, PDE, and schools) work together (PD initiatives) to bring about change (pedagogical use of ICT in Mathematics teaching and learning to achieve Phase III of the e-Education policy). An expansive transformation is accomplished when the object and the outcome of the activity are reformulated and the community adopt the potential of the new activity (Engeström, 2001:135-136).

This research embodies a system of activity and integrate the idea of *boundary objects* which function at the interface of many context (DBE, provincial, school, ODL) (Edwards, 2005; Robertson, 2008:819). AT therefore for this research supports the researcher to understand the outcome when activity systems come into contact with one another (Robertson, 2008:819). AT observes the

foundation within the dialectic process between: subjectivity and objectivity, teaching and learning, the teacher and the DBE, the technological and the societal, and also the implicit and the explicit knowledge (Crawford & Hasan, 2006).

Figure 1.6 outlines the two dimensions of expansive learning of this research. The two dimensions demonstrate the known disposition of the object versus the innovative and emerging features of the object. The *adjustable exploration* (Phase I) focus on the on-going attainment and internalisation of existing knowledge and skills rooted in the known activity (Engeström, 2004:13).

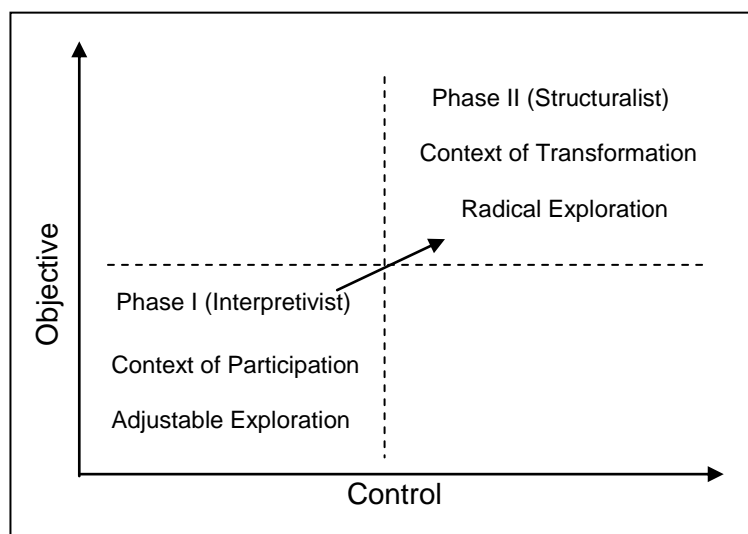


Figure 1.6: Two Dimensions for this Multi-Mode Research Design (Adapted from (Burrell & Morgan, 1979:22) and (Engeström, 2004:13-14))

The research thus in the *context of participation* explores through the inductive analysis of the mixed systematic literature the known knowledge and skills of the phenomenon (PD of Mathematics teachers for the pedagogical use of ICT in ODL). *Radical exploration* (Phase II) concentrates to broaden the horizon of the current knowledge of the phenomenon through construction of new knowledge (Engeström, 2004:14). In the *context of transformation*, thus research aim to develop guidelines for the PD of Mathematics teachers for the pedagogical use of ICT in ODL.

Using this system as a foundation to conceptualise the data and grasps the relationship among the elements in between the various planes and unified represent a common object-directed activity (guidelines for the PD of Mathematics teachers in the pedagogical use of ICT in ODL). Chapter Two outlines the activity systems developed after the constant comparative analysis and the exploratory factor analysis (adjustable exploration phase) and Chapter Five delineates the activity system from the quantitative analysis (radical exploration phase).

1.4 Population and Sample

The population for this study were teachers in schools in the Western Cape Province. The study envisaged: (i) to select 200 schools by means of a systematic stratified sample of schools presenting Mathematics in the Senior Phase (Grade 7-9); and (ii) two Mathematics teachers per school from all the districts which participated in the study. This study comprised of a population of (N=300).

The rationale for selecting Grade 7-9 is that the study population and the population selected used for other large-scale studies like SITES 2006, TIMMS, SACMEQ, and ANA are comparable. During compilation of guidelines for CPTD, the findings of these studies may be useful. The Western Cape is the only province where teachers received substantial ICT training through the Khanya Project and currently the only province in South Africa on par regarding the provision of ICT tools and resources for Phase III implementation, but there is a shortage of human capital to manage the ICT facilities and give subject-specialized training (Western Cape Education Department, 2011). As indicated, these teachers did however not receive training for ICT integration in the teaching and learning of Mathematics. Defining the Western Cape as a study population enables the researcher to treat the sample as a population during statistical analyses (Strydom, 2005:204).

The research made use of a systematic random cluster sample where schools represent the cluster and the teachers are the elements within the cluster. The study covered a large geographical area (Western Cape Province) and each strata represents Mathematics teachers within the districts and the province. During a systematic sample the schools were ordered by number of learners and then stratified per district—the first was selected randomly and all the subsequent schools thereafter systematically to a particular interval each fourth school on the list of schools (Strydom, 2005:200-201).

1.5 Ethical Aspects of this Research

Researchers should be aware that the ethical issues of any research are pervasive and intricate. Information obtained during research should not be used at the expense of others. There are two basic categories of ethical responsibility researchers have to adhere to: responsibility to those (both human and non-human) who participate in a project; and the responsibility to the discipline of science, to be accurate and honest in the reporting of their research (Strydom, 2005:56-69).

During Phase I of this study, the documents of the systematic literature are in public domain and the researcher will acknowledge authors in the customary fashion. A report on the findings of the systematic literature review will be compiled with accuracy, objectivity, clarity, unambiguously, and contain all the critical information.

The North West University Ethics Committee will scrutinise the questionnaire for Phase II of the research. The researcher obtained permission from the WCED, as well as from the principals of the selected schools and the individual teachers to submit the survey during the first quarter of 2013. The researcher informed the participants about the need of the study, their anonymous participation, and their right to withdraw from the study at any point in time. The results of the study will be made available in the public domain for all participants to obtain information on the findings of the study. The research was dedicated to ensure that all the research processes were completed with utmost care and accuracy to ensure reliability and validity of the results (Cohen *et al.*, 2011:228-229; Strydom, 2005:65). Detailed information on ethics issues are discussed in Chapter 2.

1.6 Contribution of this Study

1.6.1 Mathematics Education

As Mathematics teaching and learning in the South African school context is an area of great concern, the guidelines will contribute towards the CPTD of Mathematics teachers in the pedagogical use of ICT, a national education priority. The guidelines from this statistical model will contribute towards the aims of the 2004 White Paper on e-Education (Department of Education, 2008) which states a fully ICT integrated system at all levels of the education system- management, teaching, learning and administration by 2013 (Department of Education, 2004b:22-23).

1.6.2 Proposed Research Niche Area: Technology Enhanced Learning for Higher Education (TELHE)

The study will contribute towards the development of ODL as a delivery method of CPTD of Mathematics teachers in South Africa, as well as to the research output of the newly envisaged research entity relating to ODL.

1.7 Clarification of Important Terminology for this Study

Term	Clarification of Term
Professional development	Is a complex and ongoing process where the teacher is involved as a person in his/her professional, cultural and social context. It is a means to support teachers in their workplace to identify with the environment where they work, their professional, and how to advance their knowledge and skills to achieve the outcomes and adhere to the roles and responsibilities of their profession (Da Ponte, 2010:1).
Professional identity	Teachers assume the fundamental roles, norms and values of the teaching profession (Da Ponte, 2010:2).
Social identity	Teachers belong to a world and are identified with that world. The social identity constitute multiple features: language, culture, social group, political and religious beliefs, and the role teachers start to have in the social division of labour (Da Ponte, 2010:2).

Term	Clarification of Term
Social professional identity	Teachers communicate with their peers—operating individually or collaborating to develop their identity (Hargreaves, 1997).
Information and communication technology	An umbrella term that includes any communication device or application (radio, television, cellular phones, computers, and network hardware and software) (Dictionary.com, 2014).
Pedagogical use of ICT	Refer to the profession of teaching, which includes how the teaching occurs, the approach to teaching and learning, the way the content is delivered and what the learners learn as result of the process (Oakland, 2010).
Distance learning	Focuses on formalised teaching and learning systems and technology with the aim of delivering teaching to students who are not physically present at the place of training (Phelps et al., 2004:50; The Open University, 2013)
Open distance learning	Teaching is conducted where the teacher and learner is geographical removed from each other and teachers has open access to organisational structures, delivering methods of PD, and communicating mediums used to support learning (Bollinger & Martindale, 2004:61).
Mathematics education	The process to engage learners in problem solving situations, which require reasoning, discovering, inventing and communicating of ideas, to critically evaluate the results and reflect on the whole teaching and learning process (Thompson, 1988:128).
Technological pedagogical and content knowledge	Describes the effective integration of ICT in teaching and learning where teachers understand how to presents Mathematical concepts with technology; have the pedagogical techniques to use ICT in constructive ways; have the knowledge of technologies to accommodate diverse learners; and knowledge of how technology can be used to build on their existing knowledge and build on new philosophies (Mishra & Koehler, 2006:1026).
Activity theory	Is a descriptive framework for a system that considers the whole activity system to breach the gap between the human mind, culture and society (Engeström, 2000).
Activity system	Activity systems are in constant movement and internally contradictory driven by communal motives that are often difficult to articulate for individual participants (Engeström, 2000).
Zone of proximal development	It is the distance between the actual level of an individual's cognitive development and the potential level of the individual's development when they participate in activities (Barab <i>et al.</i> , 2004; Bozhovich, 2009:51).
Mixed systematic literature review	Is a structured method of identifying, evaluating and interpreting all valid (qualitative, quantitative or mixed-method) research relating to the phenomenon of concern (Kitchenham, 2004).
Fully multi-mode sequential equal status design	The qualitative and quantitative phases occur sequentially and the phases have equal value in the research process; the research methods provide a description of the data; constructively explain the data; and hypothesize on the outcomes of the research (Bryman, 2006:111-126).
Constant comparative analysis	A systematic inductive data analysis to systematically make sense of data through selecting, categorizing, comparing, synthesizing and interpreting (McMillan & Schumacher, 2001).
Quantise	IS to bound variables describing a physical system to discrete and distinct values (Your Dictionary Science, 2013).
Exploratory factor analysis	The objective of the research explore the factorial structure of the domain and the hypothesis of the research is clearly defined (Tucker & MacCallum, 1997:143).
Structural equation modelling	It is a theoretical model to test and explain the complex relationship between variables (SPSS, 2012:1-1).

1.8 Summary of the Chapters

This chapter provides an overview of the research study through a complex research landscape and addresses the introduction to the research, the motivation and problem statement, the multi-mode research design, the development of the activity theory, the ethical aspects, the clarification of the terminology used throughout the study, the contribution of the study to Mathematics as a learning area and to ODL, and the outline of the chapters.

Chapter 2 describes the qualitative aspects of the fully mixed sequential equal status multi-mode research design and methodology. The chapter gives a detailed description of the systematic literature process to obtain the documents of the expert authors for constant comparative analysis and the non-interactive basic (generic) qualitative design. Furthermore it explains: (i) the role of the researcher, (ii) the trustworthiness of the research, and (iii) the ethical considerations of the research.

Chapter 3 provides a culminant retrospect of the systematic literature probe of the inductive analysis process of the selected documents of the expert authors (Phase I of the study). The four central themes analysed form the basis for writing the literature probe. The activity systems compiled after the exploratory factor analysis will supply a structure for writing the literature probe.

Chapter 4 describes the quantitative phase (Phase II) of the fully mixed sequential equal status multi-mode research design and methodology. This chapter also explicates: (i) the process of compiling the survey instrument using the third generation activity theory and the constraints of the constant comparative analysis, (ii) the distribution of the survey to 300 senior phase (grades 7-9) Mathematics teachers in 179 schools in the Western Cape province, (iii) the data collection process, and (iv) the credibility of quantitative research, and (v) the ethical aspects of the research.

Chapter 5 models the quantitative measures and results of the analyses using descriptive statistics, factor analysis, and hierarchical linear modelling.

Chapter 6 concludes the research process, with an overview of the research journey, a synopsis of the adjustable and radical exploration phases of the research, validates the phases of the research through SEM, maps the guidelines for the PD of senior phase (grades 7-9) Mathematics teachers in the pedagogical use of ICT in ODL, reflex on the research journey, and provides recommendations for future research.