Chapter Six

Mapping Guidelines for the Professional Development of Mathematics Teachers in Pedagogical Use of Information and Communication Technologies in Open Distance Learning

6.1 Introduction

Chapter Six provides a comprehensive overview of the research journey of this study through a complex landscape of a multi-mode research design and methodology. This chapter also provides an overview of the first five chapters of the research, presents a synopsis of the adjustable and radical exploration phases of the research, validates the two phases of the research (§4.5.13.4) by means of SEM, explains the expansive learning cycle, and maps the guidelines for the professional development of Mathematics teachers in the pedagogical use of ICT in ODL. Additionally, this chapter offers questions for future research as they emanated from this research, as well as the researcher's reflection on her journey through a PhD.

6.2 Summary of Chapters

The following sections (§ 6.2.1-6.2.5) provide a summary of the foregoing five chapters of the research report.

6.2.1 Chapter One: Overview of a Research Journey through a Complex Landscape

Chapter One outlined the comprehensive plan for this research, including the context of the research, a brief literature review, the rationale and the aim of this research. As this research was of a complex nature, the researcher employed a multi-mode research design and methodology—a fully mixed sequential equal status research design. The qualitative and the quantitative phases were of equal value in the successful completion of the research process. The sequential research design commenced with a subjective analysis according to the interpretivist paradigm, followed by an objective approach rooted in the radical structuralist paradigm which follows a defined method to obtain information from a large population. The chapter introduced and discussed the development of CHAT from the first generation, to the second generation CHAT, and the rationale for using Engeström's third generation activity theory as conceptual framework for this complex research. This study included multiple processes and AT comprised the overarching analytical tool for this complex research. AT as a conceptual framework assisted the qualitative phase of the research known as the adjustable exploration phase and the quantitative part of the research identified as the radical exploration phase. Chapter One also captured the terminology of importance to the research and the contribution of the research to Mathematics education and TELHE.

6.2.2 Chapter Two: Fully Mixed Sequential Status Multi-Mode Design and Methodology: Qualitative Aspects

Chapter Two discussed Phase I (adjustable exploration phase) of the fully mixed sequential status multi-mode research design and methodology rooted in the interpretivist paradigm. Phase I followed a non-interactive qualitative design with a document analysis as data collection strategy. The same stringent process applied for document selection as for the selecting of research participants. The researcher conducted a systematic literature review to locate documents with adequate detail on diverse contexts in order to obtain a holistic picture of the PD of Mathematics teachers in the pedagogical use of ICT in ODL. The step-by-step procedure of systematic literature review yielded a distinct structure, produced the maximum range of evidence, and generated documentation for validation in such a fashion to be repeatable for other researchers. The researcher accessed various databases, retrieved 101 documents and assessed these documents according to selection process criteria of which she included 23 documents in the inductive analysis with Atlas.ti™. Engeström's activity theory provided the conceptual tool for the qualitative analysis. The findings of the qualitative analysis formed the basis for the culminant retrospect of a systematic literature probe and the code counts comprised the numerical values for an exploratory factor analysis of the construct to search for patterns. Four themes emerged from the exploratory factor analysis as the configuration of the literature probe and the simultaneous compilation of the questionnaire. The researcher assumed the role of complete observer, and conducted the systematic process with precision. An audit trail confirmed the validity and reliability of the process in terms of: (i) maximum variation, (ii) criteria for inclusion and exclusion, (iii) a process of peer coding, and (iv) triangulation. All the documents related to the public domain which required no ethical clearance. The qualitative research process adhered to intellectual rigour, professional integrity, and methodological competence.

6.2.3 Chapter Three: Culminant Retrospect of a Systematic Literature Probe

Chapter Three discussed the integrated literature of PD of Mathematics teachers while integrating ICT in their teaching and learning practices, developing their TPACK, and using an ODL platform content delivery and participant interaction. The inductive process conceptualised four overarching themes: (i) governance, (ii) school environment, (iii) ODL and (iv) PD. The literature probe discussed each theme with its codes and concatenated the literature results according to the elements of AT: object, subject, tools, rules, community and division of labour. AT served as an analytical tool to understand the conditions of governance, school environment, ODL and PD, to grasp the mediated interaction between the elements of AT, and to identify the primary and secondary contradictions in the activity systems. The governance activity system questioned the existing context on national, provincial, and school levels in terms of Phase III of the e-Education policy implementation for Mathematics teaching and learning. The school environment activity system analysed the objectives of PD and the TPACK of Mathematics teachers' aspiration to integrate ICT constructively during their teaching and learning practices. The ODL activity system assessed the practices of Mathematics teachers in ODL and how teachers gained TPACK, and built their SPI while engaging in PD in an ODL platform. Governance, school environment, and ODL activity systems related to aspects of the organisation and consequently grouped on the organisational plane of cultural-historical analysis. The organisational plane aimed to foster a proficient organisation, and create a supportive school environment and access to a platform to achieve the object-directed activity. The PD activity system directed the personal plane of cultural-historical analysis and addressed the integrated aspects which related to PD through ODL. The PD activity system evaluated the existing PD models from different context and made recommendations for the PD of Mathematics teachers through ODL. These four activity systems constituted the conceptual activity systems for the adjustable exploration phase of the research.

6.2.4 Chapter Four: Fully Mixed Sequential Status Multi-Mode Design and Methodology: Quantitative Aspects

This chapter discussed Phase II (radical exploration phase) of the fully mixed sequential status multi-mode research design and methodology rooted in the radical structuralist paradigm. Phase II followed an objective, scientific approach to gain knowledge to address the complex research question. The quantitative data collection strategy of the research included the development of a questionnaire which was distributed in the WCED to produce precise, dependable and valid data. This research used an exploratory questionnaire and followed an intricate process to compile an original custom-made questionnaire as a suitable instrument to obtain information the literature could not retrieve. The researcher followed the fourteen stages of questionnaire development. A cross-sectional questionnaire aimed to examine the attitudes, beliefs, opinions and practices of the Mathematics teachers. It was a viable method to collect exploratory, descriptive and explanatory data from the Mathematics teachers through retrospective and prospective enquiry. The questionnaire comprised seven parts, formulated according to stringent processes. The first two parts of the questionnaire focused on acquiring demographical information from the Mathematics teachers. Parts C, D, E, and F comprised the constructs of the inductive analysis according to the four themes of the qualitative analysis by means of a five-point Likert scale. Part G of the questionnaire presented four PD models adapted for the South Africa context. The researcher considered five key elements and applied the eight stages of planning a sample strategy. The sample included Mathematics teachers in the WCED representative from the eight EMDCs, the five quintiles, various locations, variation in learner numbers, and with versatile medium of instruction. Before the distribution of the questionnaire to Mathematics teachers in the WCED, the researcher validated the questionnaire in the North-West Province with Mathematics lecturers from the North-West University and Mathematics teachers adhering to the same characteristics as the intended sample. The final sample constituted 179 schools and 300 Mathematics teachers in the WCED. The Ethics Committee of the North-West University granted ethical clearance for the study. The researcher obtained permission to distribute the questionnaire from the office of the Superintendent-General of Education of the WCED, the school principals and the Mathematics teachers for distribution during the first quarter of 2013. The statistical procedures during the analyses of the findings measured the credibility of the research.

6.2.5 Chapter Five: Modelling Quantitative Measurements and Results

Chapter Five modelled the quantitative measures and results. Through the analyses, the research identified the structures in the WCED and identified the elements in the WCED which contradicted each other. Three types of analyses followed: descriptive statistics, factor analysis and hierarchical linear modelling. Descriptive statistics with frequencies and percentages signified the biographical information organised as frequencies, means and standard deviation. The principal axis factor analysis with Oblimin rotation performed clustered the items of the questionnaire as theoretically interpretable. A Cronbach Alpha tested the reliability extracted factors from Parts C, D, E, and F of the questionnaire. The eleven factors extracted were concatenated into a fifth activity system, known as TAS. The hierarchical linear models determined the significant differences and associations between the biographical information and the elements of TAS. Effect sizes were calculated to determine practically significance. Medium and large significant differences were reported.

6.3 Synopsis of the Adjustable and Radical Exploration Phases of the Research

Phase I (adjustable exploration phase) of this complex research (Figure 1.6), through a culminant retrospect of a systematic literature probe, in the context of participation, explored what was known knowledge and skills about the phenomenon (PD of Mathematics teachers for the pedagogical use of ICT in ODL) (§ 1.3.1.6). During this process four activity systems were conceptualised on two planes of cultural-historical analysis (Figure 3.14) (§ 3.6). Phase II of the radical exploration phase of the research, in the context of transformation (Figure 1.6), constructed knowledge and conceptualised a fifth activity system (TAS).

The following sections summarise the findings relating to the research question from: (i) the adjustable exploration phase, and (ii) the radical exploration phase of the research.

6.3.1 Synopsis of the Findings of the Adjustable Exploration Phase of the Research

Each of the four activity systems identified aspects which directly impact on the research question. The governance activity system highlighted the inability of the DBE and PDE to adhere to the objectives of the e-Education policy. The WCED was the only provincial education department on par towards Phase III implementation of the e-Education policy. The analysis identified the school manager as the role player in ICT integration in schools. School managers create a school culture and climate in order for the school to function as a learning organisation. The SMT should develop an ICT strategic plan and utilise the competencies of the expert Mathematics teachers to support the novice or less skilled teachers. The school manager should also focus on the social dimensions of the school climate. Good interpersonal relationships of teachers with their colleagues promote the development of the SPI of Mathematics teachers. Even though the DBE is accountable for the provision of funds and resources, many schools do not have access to quality resources. The school should supply and upgrade its ICT resources. Various ICT implementations were initiated by the DBE and the PDE, but the sustainability thereof was of major concern. Alternative measures are required to address the inequities of ICT implementation. To achieve the objectives of the e-Education policy the DBE, the PDE, and school leaders should work as a team. However, a stronger emphasis must be on the role of the school as initiator for ICT implementation.

Mathematics teachers are expected to develop their professional competencies to implement policy and improve the quality of Mathematics teaching and learning in South African schools. PD should prepare teachers to use ICT during their teaching and learning practices. However, the current PD initiatives do not provide training of this magnitude. Mathematics teachers are clear regarding their expectations for PD: Mathematics teachers want to participate in PD based on their individual requests within their subject groups. In general, in various context Mathematics teachers have a positive attitude towards PD. Mathematics teachers acknowledge the many dimensions of ICT for Mathematics teaching and learning, how ICT could assist them to develop and advance through secondary socialisation, and allow them to have access vast array of resources and documents to explore and grow their competencies. For Mathematics teachers to develop, certain external and internal contributors must be present—a community of practice and adhering to the role and responsibilities of the teaching profession. The DBE, PDE and schools should perform a needs assessment of the PD requirements of Mathematics teachers considering certain contextual characteristics, content requirements, and organisational aspects.

Mathematics teachers should develop their SPI, and while PD through ODL proposes to address the development of their SPI and the ZPD. Mathematics teachers assume professional values and attitudes when they engage in online discussion. VLEs and PLEs can sustain the social networking with colleagues and peers where they develop their SPI. PLEs assist the change within the ZPD between the knowledge in a traditional face to face PD course and the knowledge required for the effective integration of ICT. Even though ODL has profound barriers like distance and communication, these can be addressed during the planning of the PD course. ODL can accelerate ICT integration in schools as distance and human capital are major stumbling blocks for PD of Mathematics teachers in the pedagogical use of ICT. PD in an ODL platform contemplates the restructuring from an upgrading of skills orientation to the establishment of transformative outcomes of ICT PD. First, Mathematics teachers should assess their levels of competency, become part of a subject network group, change their attitudes, and accept criticism as they are central to the success of the whole PD process. The DBE, PDE, schools and Mathematics teachers collaboratively can develop a PD model to suit the South African school context and the requirements of Mathematics teachers.

6.3.2 Synopsis of the Findings of the Radical Exploration Phase of the Research

The following section summarises the findings from the descriptive (§ 5.2) and inferential statistics (§ 5.3) the culmination of TAS (§ 5.3.6), and the hierarchical linear modelling (§ 5.4).

The descriptive statistics indicated an appropriate dispersion of male and female participants with a good balance in age variation. The majority of the Mathematics teachers had between 0-9 years of experience teaching Mathematics, mostly in grades 8 and 9. Most of the Mathematics teachers spoke and taught in Afrikaans. Mathematics teachers' (93%) qualifications were above the minimum NQF level eight qualifications and 84% held a specialised qualification in Mathematics. Mathematics teachers in all eight EMDCs from different types of schools, and from various quintiles participated in the survey. Only 5% of the schools did not have functional Internet-enabled computers for administration, planning and teaching and learning. Mathematics teachers (51%) regarded themselves as ICT competent, 89% had access to Internet and 81% had access to a personal computer for administration, planning and teaching. Many Mathematics teachers (89%) had not yet attended an online course. Mathematics teachers (81%) mostly used their cellular phones to chat with friends, family and peers, but 68% preferred computers for lesson preparation. Mathematics teachers selected Models 1 and 3 as PD preferred PD models (Table 5.4).

During the exploratory factor analysis the items in Part C clustered into four homogeneous groups. The four factors corresponded with Responsibility of DBE, Responsibility of management, Responsibility to teaching and learning, and Policy initiatives. The twelve items in Part D grouped as two homogeneous groups and resembled TK, and TPACK. Ten variables in Part E clustered into two factors which corresponded with Contributors to SPI and ICT for SPD. The nineteen variables in Part F clustered into three homogeneous groups, which corresponded with teachers' expectations for PD, Building a SPI, and PD models and frameworks. During the exploratory factor analysis the majority of the extracted factors showed a Cronbach Alpha of ≥0.7. The eleven extracted factors conceptualised the fifth activity system (TAS) with the highest mean of 3.26 for Responsibility of DBE, Contributors to SPI and PD models and frameworks.

The hierarchical linear models measured the significant differences between the biographical information in Parts A and B of the questionnaire and the elements of TAS. Female Mathematics teachers viewed the Responsibility of the DBE and management, Responsibility to teaching and learning, Policy initiatives, and Contributors to SPD as more important than their male counterparts. The older age groups regarded the Responsibility of the DBE as more important. There were significant differences between languages (Afrikaans, English and other indigenous languages) and Teacher expectations for PD, Contributors to SPD, Building a SPI, and Responsibility of management with Contributors to SPD. Only teachers' expectations for PD showed significant differences with language of instruction ($p=0.008$). Mathematics teachers with higher levels of qualification showed significant differences with TK. The analysis indicated significant differences between the school quintiles and responsibility of DBE, teachers' expectations for PD, contributors of SPD, TPACK, and building a SPI. English speaking Mathematics teachers were more aware of their SPI and were more positive towards the roles and responsibilities of the teaching profession than Afrikaans speaking Mathematics teachers. Mathematics teachers from former Model C schools scored significantly higher than other schools regarding contributors of SPD and responsibility to teaching and learning. The other items of the biographical information did not furnish significant differences with the elements of TAS.

The subsequent section validates the findings from the adjustable and radical exploration phases of the research by means of SEM.

6.4 Validation of the Adjustable and Radical Exploration Phases through Structural Equation Modelling

The SEM validated the fundamental relation between components of the questionnaire (§ 5.3.6), and to authenticate the expansive learning process (§ 6.7.5). The goodness-of-fit (CFI) statistics give various measures to evaluate model fit. Mueller (1996) suggests that the Chi-square test statistic should be divided by degrees of freedom. Interpretation of the size of this value depended to a large extent on the viewpoint of the investigator, but in practice some interpreted ratios of 3, 4 or even 5 as representing a good model fit (Mueller, 1996). Chi-square test statistic divided by its degrees of freedom (CMIN/DF) value of 2.22, which should be smaller than 5 to indicate a good fit (Mueller, 1996). Comparative Fit Index (CFI) value of 0.74, where values larger than 0.9 are indicative of a good overall fit (Mueller, 1996). Root Mean Square Error of Approximation (RMSEA) value of 0.11 with a 90% confidence interval of 0.10-0.12, which should be smaller than 0.1 for acceptable fit (Blunch, 2008:77). The researcher constructed two SEM models to confirm the processes.

6.4.1 Structural Equation Modelling of Governance, School Environment and Open Distance Learning

SEM with AMOS (Amos Development Company, 2011) tested the relationship between Governance, School Environment, ODL, and PD as hypothesised in Figure 6.1 (Addendum 6.1).

Table 6.1 Standardised Regression Weights and Correlations between Governance, School Environment and Open Distance Learning

Activity System	Standardised Regression Weights	P values
PD←Governance	-0.01	0.959
PD←ODL	-0.62	0.604
PD←Environment	0.82	0.479

$p<0.05$

Although none of these relationships were statistically significant ($p<0.05$) Table 6.1, the standardised regression weights for Governance on PD was -0.01, for School Environment on PD was 0.82, and for ODL on PD was -0.62. The correlation between Governance, SE and ODL were statistically significant and high—it varied between 0.56 and 0.94. The standardised regression coefficients indicated that when correlations between Governance, School Environment and ODL were taken into account, the influence of Governance on PD was non-existing, while school environment had a positive influence on PD and ODL had a negative influence on PD. Figure 6.1 illustrates the SEM of Governance, School Environment and ODL.

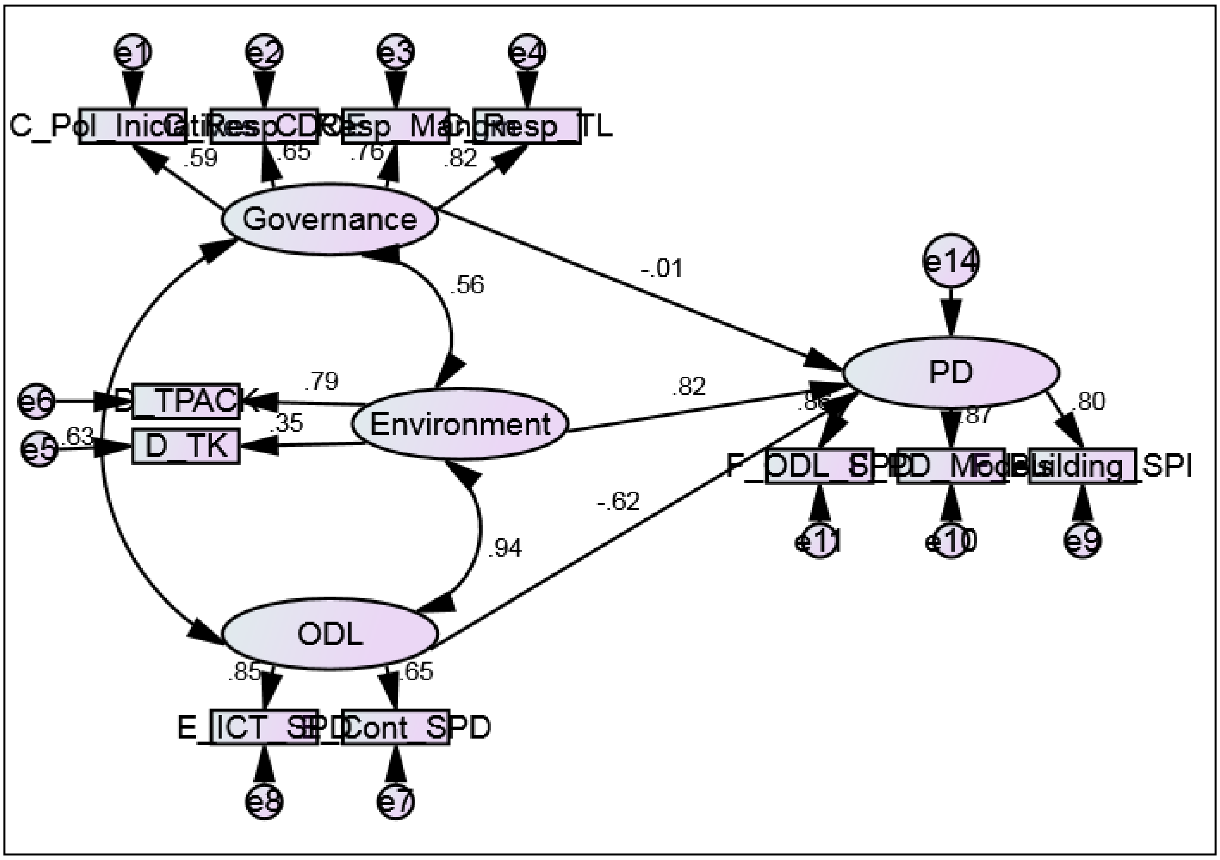

Figure 6.1 Structural Equation Model of Governance, School Environment, Open Distance Learning, and Professional Development with Standardised Regression Weights

The goodness-of-fit (CFI) statistics calculated the proportions of variance accounted for by the model in Figure 6.1. The goodness-of-fit measures for the model comprised:

- Chi-square test statistic divided by its degrees of freedom (CMIN/DF) value of 3.40, which was smaller than 5 which indicated a good fit (Mueller, 1996:90).
- CFI value of 0.88, which was indicative of a acceptable overall fit (Mueller, 1996:90)
- RMSEA value of 0.11 was not smaller than 0.1 which indicated an unacceptable fit (Blunch, 2008:77).

Figure 6.1 presented the SEM with the standardised regression weights of the influence of the four activity system: Governance, School Environment, ODL and PD.

6.4.2 Structural Equation Modelling of Mediation of Governance, School Environment, Open Distance Learning and Professional Development

The SEM in Figure 6.1 confirmed no statistically significant relationships between Governance, School Environment, ODL and PD. The SEM in Figure 6.2 illustrates the mediation effect of School Environment between Governance and, ODL, as well as their relationship with PD as hypothesised in Figure 6.2 (Addendum 6.1).

Table 6.2 Standardised Regression Weights and Correlations of Mediation between Governance, School Environment and Open Distance Learning

Activity System	Standardised Regression Weights	P values
Environment←Governance	0.56	0.001
ODL←Governance	0.16	0.265
ODL←Environment	0.85	0.001
PD←ODL	-0.64	0.499
PD←Environment	0.83	0.395

$p<0.05$

Table 6.2 indicated there were statistically significant relationships between Governance and School Environment (p=0.001) and between School Environment and ODL (p=0.001). Table 6.2 indicates the standardised regression weights for Governance on School Environment was 0.56, Governance on ODL was 0.16, School Environment on ODL was 0.85, ODL on PD was -0.64, and School Environment on PD was 0.83. The standardised regression coefficients indicated that Governance had a positive influence on School Environment, and School Environment had a positive influence on ODL, while ODL had a negative influence on PD. Figure 6.2 illustrates the mediation between Governance, School Environment and ODL. The total standardised effect of Governance on ODL was 0.636, the direct standardised effect of Governance on ODL was 0.163, and the indirect standardised effect of Governance on ODL was 0.473. The ratio of the indirect standardised effect to the total standardised effect (mediation ratio) is an indication of the proportion of the total effect that is mediated, in this case 0.744 (74.4%). Together with the non-significance of the direct regression path, this is an indication of total mediation that will be implemented in the next model.

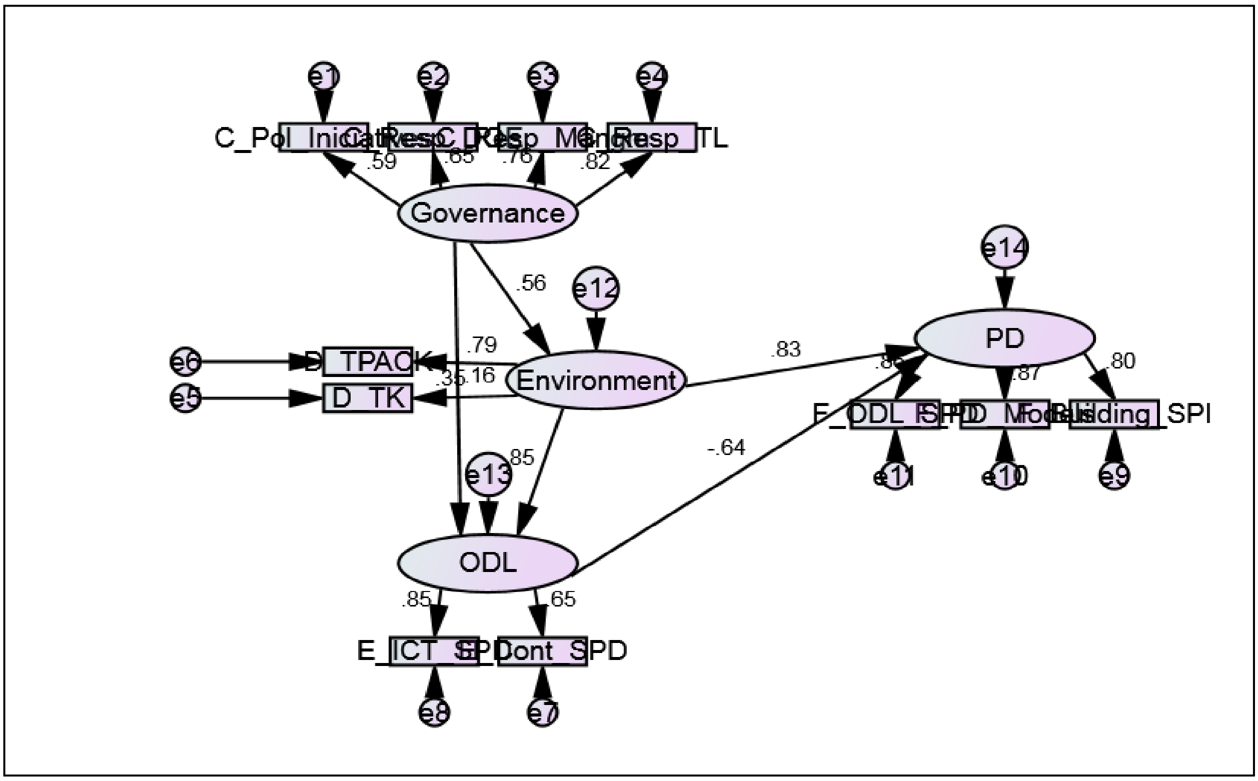

Figure 6.2 Structural Equation Model of Mediation between Governance, School Environment, Open Distance Learning with Standardised Regression Weights

The goodness-of-fit (CFI) statistics calculated the proportions of variance accounted for by the model in Figure 6.2. The goodness-of-fit measures for the model comprised:

- Chi-square test statistic divided by its degrees of freedom (CMIN/DF) value of 3.31, which was smaller than 5 which indicated a good fit (Mueller, 1996:90).
- CFI value of 0.89, which was indicative of a acceptable overall fit (Mueller, 1996:90).
- RMSEA value of 0.11 was not smaller than 0.1 which indicated an unacceptable fit (Blunch, 2008:77).

6.4.3 Structural Equation Modelling of Expansive Learning of Governance, School Environment, Open Distance Learning and Professional Development

The SEM model in Figure 6.3 incorporates the results from the previous SEM model (Figure 6.2) to illustrate the expansive learning cycle from Governance to School Environment, to ODL and subsequently to PD (Addendum 6.1).

Table 6.3 Standardised Regression Weights and Correlations between Governance, School Environment, Open Distance Learning and Professional Development

Activity System	Standardised Regression Weights	P values
Environment←Governance	0.61	*****
Environment←ODL	0.97	*****
PD←ODL	-0.90	0.594
PD←Environment	1.07	0.533

***** p<0.05

Table 6.3 indicates statistically significant relationships between Governance and School Environment ($p<0.05$) and between School Environment and ODL ($p<0.05$). The standardised regression weights for Governance on School Environment were 0.61, for ODL on School Environment was 0.97. Although not statistically significant the standardised regression weights for ODL on PD was -0.90, and for School Environment on PD was 1.07 respectively. The standardised regression coefficients indicated that when correlations between variables were taken into account, Governance had a positive influence on School Environment and ODL, and School Environment had a positive influence on ODL, and PD. However, ODL had a negative influence on PD.

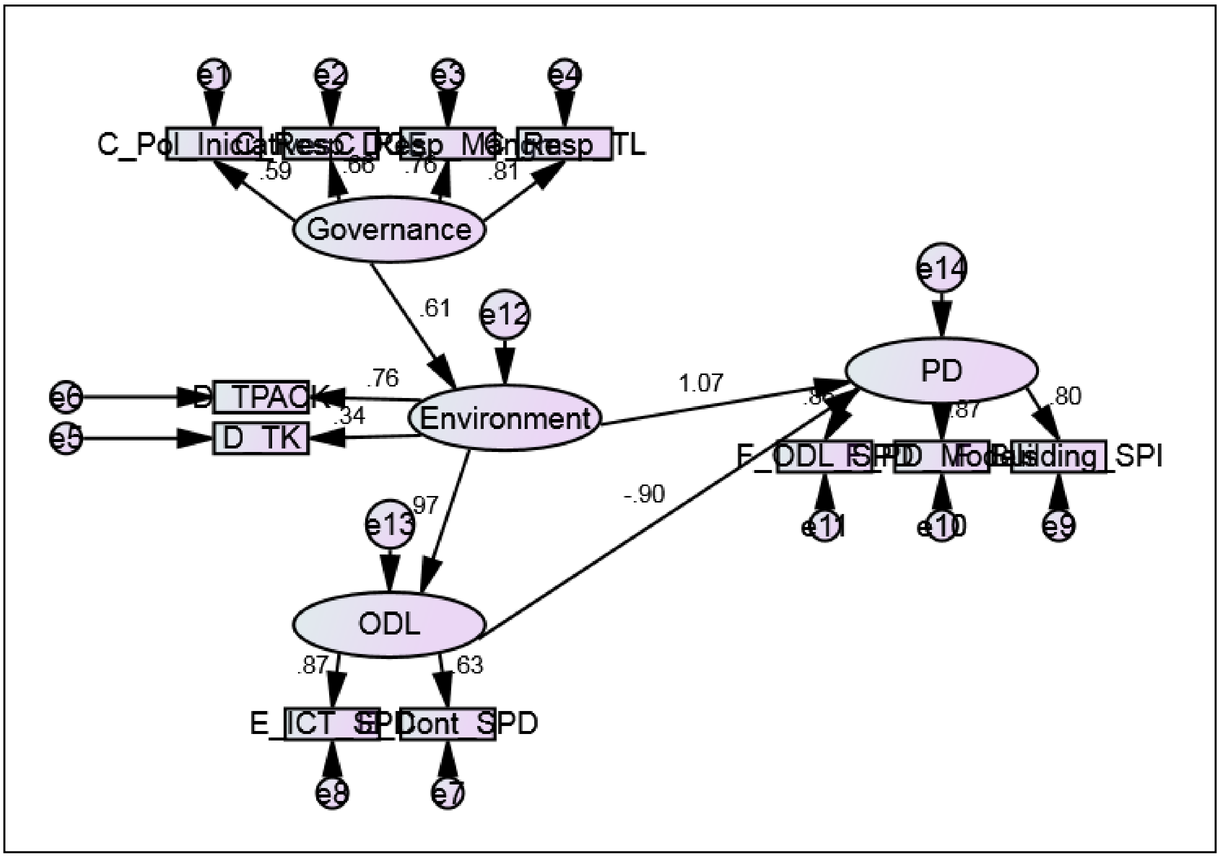

Figure 6.3 Structural Equation Model of Expansive Learning from Governance, School Environment, Open Distance Learning, and Professional Development with Standardised Regression Weights

The goodness-of-fit (CFI) statistics calculated the proportions of variance accounted for by the model in Figure 6.3. The goodness-of-fit measures for the model comprised:

- Chi-square test statistic divided by its degrees of freedom (CMIN/DF) value of 3.40, which was smaller than 5 which indicated a good fit (Mueller, 1996:90).
- CFI value of 0.88 was indicative of a acceptable overall fit (Mueller, 1996:90).
- RMSEA value of 0.11 was not smaller than 0.1 for unacceptable fit (Blunch, 2008:77).

The SEM in Figure 6.3 illustrates the validation of how the four activity systems were supportive towards achieving the object of the research. The SEM in aimed to authenticate the expansive learning process (§ 6.7.5).

6.4.4 Five Activity Systems from the Adjustable and Radical Exploration Phases of the Research Connected Through Boundary Objects

The five activity systems, individually and jointly, were fundamental to ensure the outcome of the object-directed activity of this research. The first four activity systems established the CAS of the research. Figure 3.14 illustrates in the centre on two planes of cultural-historical analysis the first four activity systems as conceptualised during the qualitative analysis (§ 3.6). The fifth activity system (TAS) concatenated the findings of the first four activity systems (§ 5.3.6). Figure 6.4 illustrates the five activity systems (CAS and TAS) from the adjustable and radical exploration phases (next page).

The five activity systems are connected through boundary objects which can be physical artefacts or a collection of information, conversations, policies, awareness, rules, contracts or even people. Each activity system has an object (intended activity) which contributed to the change in learning (Leont'ev, 1978), the one central object (guidelines for the professional development of Mathematics teachers in the pedagogical use of ICT in ODL) drives the PD process (§ 1.3.1.6) (Engeström, 2000:961). Unified the boundary objects supports and aims toward the central object of this research.

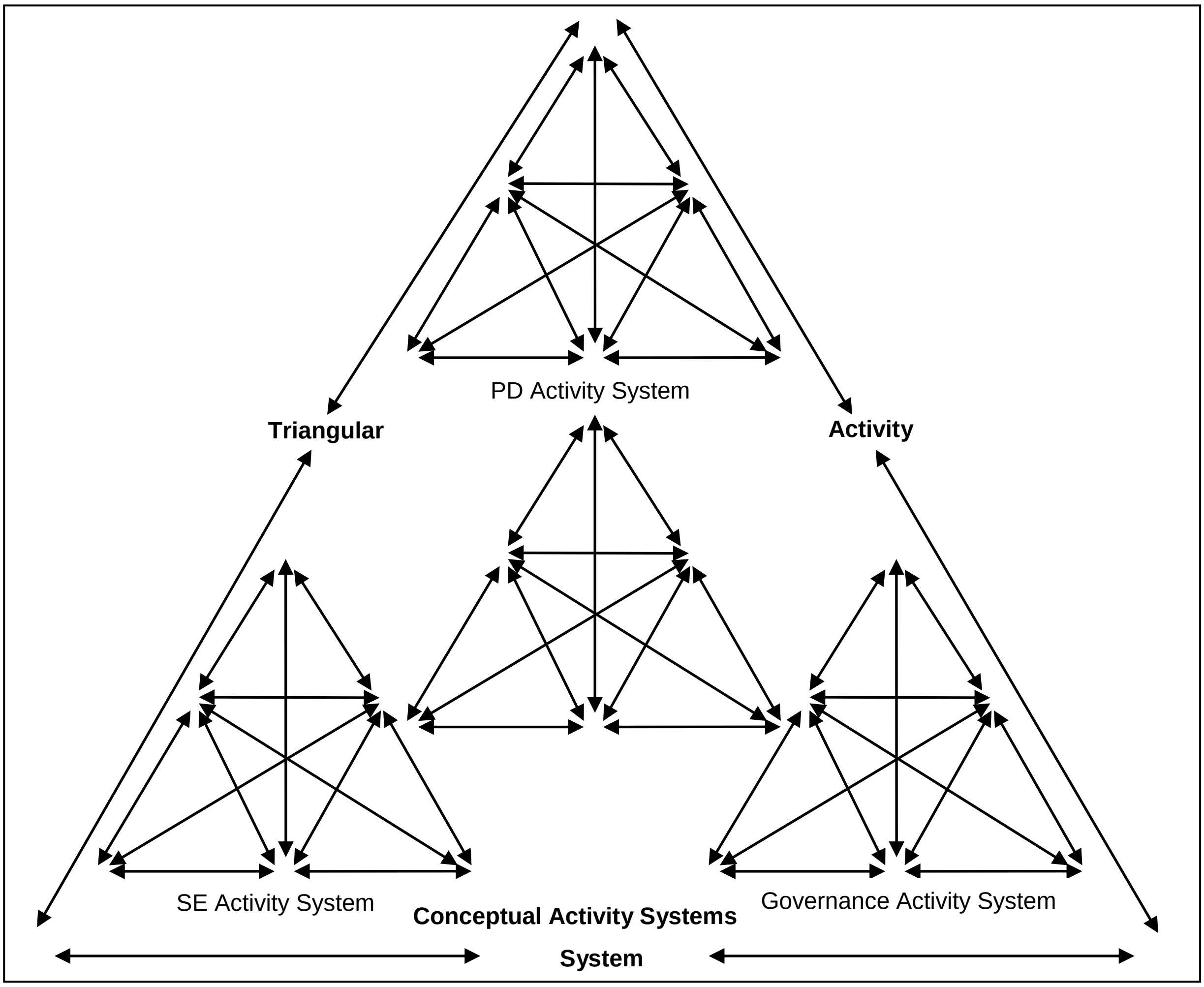

Figure 6.4: Conceptual and Triangular Activity Systems

6.4.5 Expansive Learning through Boundary Crossing in the Five Activity Systems

Expansive or transformative learning expands the communal object by means of innovative tools, models and concepts (Engeström, 2000). This form of learning does not focus on acquiring new knowledge in a hierarchical structure, but develops horizontal knowledge through expanding models and finding alternative methods to solve the objects of the activity (Engeström, 1987). During expansive learning, knowledge is built which was not available at the onset of the activity (Engeström & Sannino, 2010:12). Learning creates knowledge and alters the activity by bridging the boundaries and linking the activity systems, even though they function as individual systems (Engeström, 1987). This study conceptualised five activity systems which were symbiotic and co-dependent, and expansive learning was used for boundary crossing and network building in the context of this study. Bridging the gap between the implementation of Phase III of the e-Education policy required crossing between different organisational and personal levels (Engeström & Sannino, 2010:12). The outcomes of the e-Education policy (Phase III) are replaced with guidelines for the professional development of

Mathematics teachers in the pedagogical use of ICT in ODL. However, more boundary objects required to be crossed: the objectives of PD and TPACK, building a SPI, PD through ODL, and guidelines for the professional development of Mathematics teachers in the pedagogical use of ICT in ODL through six phases. The six phases of this expansive learning cycle comprise:

- **Phase I**: Governance Activity System assessed the existing context at national, provincial, and school level for Phase III of the e-Education policy
- **Phase II**: School Environment Activity System analysed the objectives of PD and the TPACK of Mathematics teachers and made a synopsis of the PD requirements of Mathematics teachers to address the outcomes of this activity system
- **Phase III:** ODL Activity System assessed ODL as a mode to deliver PD to Mathematics teachers
- **Phase IV:** PD Activity System evaluated the existing PD models and frameworks and the recommendations for PD through ODL
- **Phase V:** TAS concatenated findings from Phase I to IV
- **Phase VI:** Developed guidelines for the professional development of Mathematics teachers in the pedagogical use of ICT in ODL.

Figure 6.5 illustrates the phases of expansive learning for *guidelines for the PD of Mathematics teachers in the pedagogical use of ICT in ODL*.

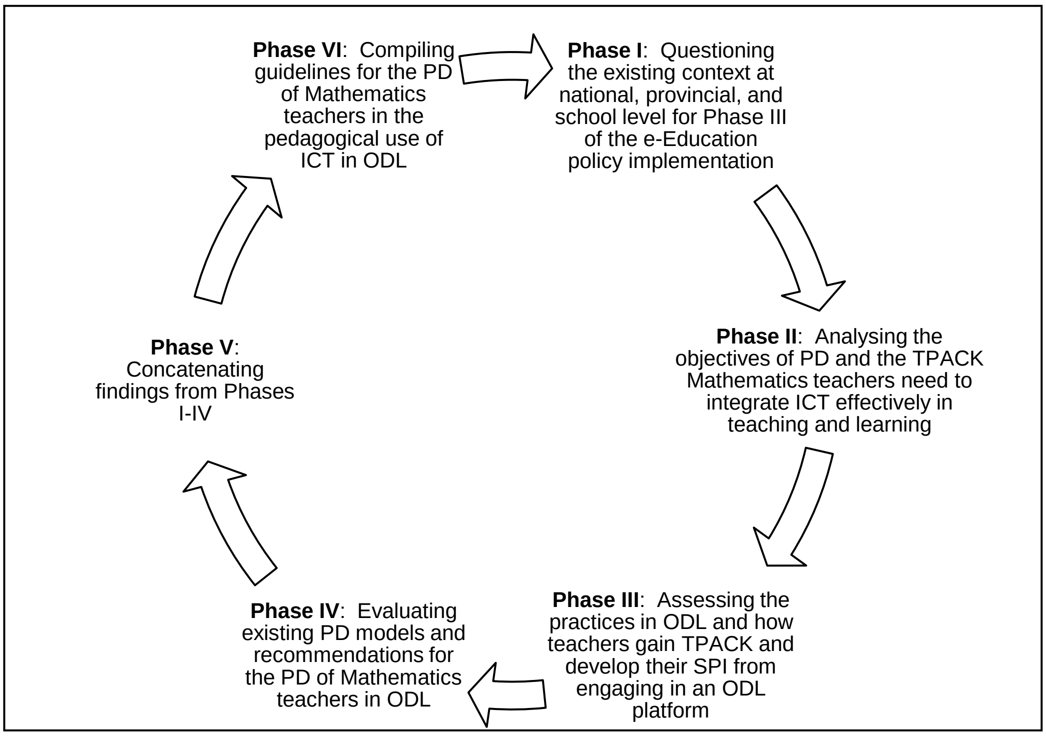

Figure 6.5: Expansive Learning Cycle for Guidelines for the Professional Development of Mathematics Teachers in the Pedagogical use of ICT in ODL

Figure 6.5 illustrates the five activity systems, with the boundary objects of each activity system of the expansive learning process. After crossing all the boundaries from the Phase I to Phase V, linking the objects of each activity system and identifying the contradictions within and between the activity systems, the research could adhere to the object of this activity—guidelines for the PD of Mathematics teachers in the pedagogical use of ICT in ODL.

6.5 Guidelines for the Professional Development of Mathematics Teachers in the Pedagogical Use of Information and Communication Technology in Open Distance Learning

This section provides the proposed guidelines, derived from the radical and adjustable exploration phases of the research, for the professional development of Mathematics teachers in the pedagogical use of ICT in ODL, according to Engeström's third generation activity theory (Engeström, 1987). The interactive elements (Table 6.4 Guidelines for the PD of Mathematics teachers in the pedagogical use of ICT in ODL) form part of the object-directed activity of this research. Specific guidelines are suggested for each element of the activity system.

Table 6.4 Guidelines for the Professional Development of Mathematics Teachers in the Pedagogical Use of ICT in ODL

Elements of Activity System	Guidelines for the PD of Mathematics Teachers in the Pedagogical Use of ICT in ODL According to Third Generation Activity Systems
Objects	• Phase III objectives of the White Paper on e-Education • PD of Mathematics teachers' TPACK • Mathematics teachers building a SPI • PD through ODL
Subject	**DBE should**: • Plan and evaluate PD using professional standards • Raise the standard of existing PD initiatives • Manage and provide in-service and pre-service subject-specific training • Evaluate PD programmes • Develop PD aligned with the CPTD management system **PDE should**: • Plan district ICT initiatives • Evaluate previous ICT initiatives • Create Mathematics network groups • Develop PD programmes **SMT should**: • Make a holistic analysis of the PD requirements of Mathematics teachers • Develop TPACK of Mathematics teachers through ODL • Determine PD strategies • Develop PD based on Mathematics teachers' requirements, therefore a holistic PD programme will not be effective for all schools • Appraise the attitudes of Mathematics teachers • Create a positive school environment • Choose versatile, creative, practical and self-chosen ICT PD strategies • Create a culture for teachers to become enthusiastic • Make teachers part of the planning of PD initiatives • Establish a community of practice • Support PD initiatives of Mathematics teachers to prevent demotivation

Elements of Activity System	Guidelines for the PD of Mathematics Teachers in the Pedagogical Use of ICT in ODL According to Third Generation Activity Systems
	Mathematics teachers should: • Access their professional knowledge • Construct new philosophies • Develop content specific ICT tasks • Create a community of practice where they learn and develop PCK and TPACK • Utilise technologies to teach • Create content specific tasks • Reflect on PD • Create groups which comprise teachers with versatile ICT skills • Interact with their peers and colleagues within their social environment as a member and participant • Develop their SPI through socialisation with their colleagues and peers
Tools	**DBE should**: • Invest in ICT equipment: laptops, and IWBs • Upgrade the ICT equipment and provide the funds and human capital to manage the facilities • Supply schools with a networked computer facility • Reinstate the laptop initiative • Install a generic LMS for all schools **PDE should**: • Access the ICT tools for PD • Provide schools with training to access the ODL technologies • Budget for support staff **SMT should**: • Install reliable infrastructure for ICT integration in classrooms • Manage the networked facilities • Create a technology-enabled environment • Expose Mathematics teachers to VLE, and PLE for ICT integration • Provide training for ODL technologies and quality online resources • Appoint a ICT facilitator to manage the ICT networked facility and to support teachers in their classrooms **Mathematics teachers should**: • Use PLE to network with peers and colleagues • Explore with the ICT tools
Community	**DBE should:** • Set up a panel to make a needs analysis for ICT implementation at national, district and school level **PDE should:** • Develop PD programmes in collaboration with HODs and teachers from all schools in the district • Create a community of practice • Plan share sessions where groups come together face-to-face or online to share initiatives and concerns **SMT should:** • Provide time for teachers to access the ICT facilities • Create a timetable for Mathematics teachers to access the ICT facilities • Generate opportunities for Mathematics teachers to communicate online **Mathematics teachers should:** • Create online network groups to share, access and evaluate ICT practices in the Mathematics classroom • Share their ICT expertise with their colleagues and peers • Plan their ICT teaching and learning in advance • Acknowledge their shortcomings, communicate with their colleagues and peers in their subject group to bridge the gap • Expose themselves to positive criticism

Elements of Activity System	Guidelines for the PD of Mathematics Teachers in the Pedagogical Use of ICT in ODL According to Third Generation Activity Systems
	• Accept change is a process, does not happen overnight, failure is a possibility
Rules	**DBE should:** • Revisit the ICT developmental plans for administrators, school managers, teachers and learners as stipulated in the White Paper of e-Education • Access the previous policy initiatives • Develop PD strategies align with the CPTD management system • Recognise that Mathematics teachers is central to change and policy should not overshadow individual professional needs **PDE should:** • Develop an ICT strategic plan align with the ICT developmental plan of the DBE **SMT should:** • Adhere to the ICT developmental plans • Develop ICT school policy • Ensure that Mathematics teachers do not work in isolated settings **Mathematics teachers should:** • Evaluate their colleagues and peers • Use versatile methods to transfer knowledge • Provide constructive feedback
Division of Labour	**DBE should:** • Plan future ICT initiatives • Develop PD models which suit the South African context • Evaluate PD course structures and allow Mathematics teachers to assess policy initiatives • Allow PDEs to implement their own PD programmes • Support PD programmes from PDE • Evaluate the service providers for PD to make sure the focus is on ICT integration in teaching and learning • Explore the opportunities of online platforms for PD • Provide PDE and schools with guidelines for ICT integration **PDE should:** • Guide teachers to apply TPACK • Make a holistic analysis of PD requirements of Mathematics teachers in the districts • Create short and long courses with service providers • Test Model 1 and 3 chosen by Mathematics teachers in the WCED • Create groups with different levels of qualifications, from different quintiles and independent schools **SMT should:** • Create teaching and learning opportunities for ICT integration • Support ICT initiatives by the DBE and PDE • Collaborate with HODs and subject groups to plan ICT initiatives and PD • Appoint a lead teacher for ICT integration in the Mathematics subject group **Mathematics teachers should:** • Acquaint themselves with versatile technologies • Expand their FITNESS and TPACK • Participate in PD programmes • Evaluate PD initiatives and provide constructive feedback • Adapt PD models to suit their own needs

Table 6.4 outlines the proposed guidelines for the WCED for the PD of Mathematics teachers in the pedagogical use of ICT in ODL. Table 6.4 provides operational guidelines for the DBE, PDE, SMT and Mathematics teachers relating to PD of Mathematics teachers in the pedagogical use of ICT in ODL.

Fundamentally ICT integration and implementation initiatives start with the DBE. Before developing future PD which aligns with the CPTD management system and Phase III of the e-Education policy, the DBE should appoint a DBE panel which comprises national and provincial ICT coordinators. This group should first conduct a need analysis for ICT implementation at national, district, and school level. The panel should revisit the ICT development plans for administrators, school managers, teachers and learners as stipulated in the e-Education policy. This panel should assess the current professional standards and evaluate the existing PD and the overall quality of the service providers. Once all the ground work has been done they can plan future ICT initiatives, develop PD models which suit the South African school context, and supply the PDE and schools with guidelines for PD. The DBE should invest in the provision of ICT equipment and human capital, reinstate the laptop initiative for teachers, and supply schools with a networked computer facility so that they can explore with online platforms for PD. Additionally the DBE should support ICT initiatives from the PDE.

The PDE should have an advisory commission which constitutes the provincial and district ICT coordinators, the Mathematics subject advisors and HODs from schools in the districts. This group should do a need analysis of ICT implementation in the province, evaluate previous ICT PD programmes and plan ICT PD strategies aligned with the ICT development plan and guidelines of the DBE. One of their tasks would be to make sure that schools have access to reliable ICT tools for teaching and learning and PD, and select service providers (online or face-to-face) for short and long PD courses best suited to the context of the schools in the districts. The district coordinators, subject advisors, HODs, and school ICT coordinators create a community of practice where they plan ICT integration share sessions either face-to-face or online. With the completion of each course the commission should evaluate the courses and allow the Mathematics teachers to reflect before they plan their next intervention. PD should be an on-going process and the PDE should budget accordingly.

Once the PDE have completed their planning for ICT integration, the SMT, the Mathematics HOD, the Mathematics teachers and the ICT coordinator of the school should develop an ICT policy for the school with clear PD strategies, ICT tool specifications, and support mechanisms for teachers. The SMT should create a school culture and climate conducive for ICT integration, budget for support staff, plan ICT training sessions for teachers to use VLEs and PLEs, create a subject network group which communicates online and face-to-face, and appoint a lead teacher for ICT integration in the Mathematics subject group. The SMT of the school should apply a PD model which suits the context of their school.

Mathematics teachers are central to their own learning and building their SPI. Mathematics teachers should assess their professional knowledge to construct new philosophies, and create a subject network group where they interact as participants and members within their social environment. Within the subject network group they access PLEs to share ideas and best practices, using versatile methods to transfer knowledge to their learners. Mathematics teachers should acknowledge their shortcomings within their groups to bridge the gap in their FITNESS, PCK, and TPACK. They should create content specific tasks and explore with the ICT tools to deliver their teaching and learning. In their network group they evaluate their own initiatives, as well as those of their colleagues and peers through constructive feedback. Mathematics teachers should participate in PD programmes. At the end of a PD programme they should evaluate the PD programmes, provide constructive feedback, and adapt the PD models to suit their context and requirements.

PD of Mathematics teachers for Phase III implementation of the e-Education policy should be a joint initiative. The mediation between interactive elements is central to achieve the objectives of the e-Education policy (ICTs integrated and used by all role players in education by 2013).

6.6 Future Research

The researcher proposes the questions in Table 6.5 which originated from the contradictions identified in CAS. The research questions originate from the tertiary and external quaternary identified during the qualitative analysis of the research.

Table 6.5 Pertinent Future Research Questions

Conceptual Activity Systems	Pertinent Questions
Governance	• Successful school management is fundamental to change the culture and climate of the school as an organisation. How can the DBE, PDE support schools to create a positive culture and climate for ICT integration? • The DBE and SACE do not supply adequate CPTD for teachers to master the knowledge and skills to adhere to policy specification. How can the current CPTD management system be adapted to make PD more specialised so that teachers can benefit from the process?
School Environment	• What measures should be in place to change Mathematics teachers' opinions on which constitutes a teaching and learning environment? • How will the PDE or schools engage Mathematics teachers in an online environment to develop their SPI? • The abundant once-off and external programmes for PD do not address the context of schools in South Africa and are many times disorganised and fragmented. How do the DBE and PDE go about selecting service providers and programmes for ICT PD?
ODL	• How can the existing context of schools in South African be adapted to provide PD of TPACK in an online environment? • How should ODL in schools be implemented so that Mathematics teachers take ownership of their learning?
Professional Development of Mathematics teachers	• Current PD initiatives do not advocate the use of ICT for Mathematics teaching and learning, how will the DBE steer PD using ODL to focus on transformative outcomes for ICT PD? • Mathematics teachers in South African schools avoid the use of ICT for teaching and learning. How can the adoption of ICT for Mathematics teaching be accelerated in South African classrooms?

6.7 Value of the Research

In addition to the research output of the North-West University, and the TELHE research entity, this study contributes to the scientific community on different levels:

- The research developed, validated and standardised an instrument for PD of Mathematics teachers for the pedagogical use of ICT which can consequently be used to compare the contexts of other South African provinces, as well as by other researchers to explore and describe PD needs in diverse contexts.
- Conducting a systematic literature is a common for the Natural Sciences, but not generally used for Education (§ 2.4.1.1). The process worked well and contributed to rich data, as well as the validity of the study.
- The equal status sequential use of qualitative and quantitative methodologies contributed to a comprehensive spectrum of analysis and addressed the research limitation that the study did not only depend on a single methodology (Burrell & Morgan, 1979:22).
- The activity systems conceptualised during the adjustable and radical exploration phases of the research coherently contributed towards the needs of the successful implementation of the e-Education policy.
- The voices of rural schools are often ignored as people perceive them less knowledgeable. This research confirmed no fundamental differences between rural and urban schools and that they on equal footing contributed to the findings of this study.
- Mathematics teachers at ground level, who mostly follow top-down instructions, had the opportunity to share their perceptions and attitudes towards the integration of ICT in Mathematics teaching and learning.
- Although often criticised, this research confirmed the successes that the Khanya project in the WCED achieved.
- The researcher networked at ground level with many Mathematics teachers, subject advisors, and officials from the WCED—an opportunity probably achieved only once in a life-time.

6.8 Researcher's Reflections of the Research Journey

There were some processes and aspects of my research journey through a complex landscape that compelled me to reflect on them. In the following section, I reflect on the (i) contribution of the methodology, the conceptual framework, (ii) systematic literature study, and (iii) data collection journey.

6.8.1 Fully Mixed Sequential Equal Status Multi-Mode Research Design and Methodology

During my MEd degree I conducted a secondary data analysis using the SITES 2006 South Africa Mathematics teachers' dataset and I felt comfortable working with statistics. I therefore had no previous exposure to conducting research in the interpretivist paradigm or of multi-mode research. However, my research question that emanated from the results of my masters' dissertation steered the research towards a multi-mode research design and methodology. The fully mixed sequential equal multi-mode research design and methodology in this study allowed me to obtain a holistic view of the research phenomenon at hand. Phase I of this research gave a realistic overview of Mathematics teachers' experiences. I used the data from the inductive analysis and developed a questionnaire that dove-tailed with the research question in order to construct knowledge. Developing the questionnaire for Phase II of the research provided the opportunity to develop a questionnaire suited to the South African context which, if adapted, can also be applied in other contexts. The findings from Phase II of the research merged with the findings from Phase I and the WCED have guidelines with real depth which can be applied in a large population. I am convinced that my research would not have been of the same depth had I used a single methodology. For me, using a fully mixed sequential equal multi-mode research design and methodology was about completing the research circle.

6.8.2 Engeström's Activity Theory

Engeström's activity theory functioned as conceptual framework to broaden the scope of this research. I was able to study many processes, identify and analyse activities which were significant to the research. AT can be an intricate framework and I spent many hours reading and analysing research that made use of AT as conceptual framework. My research remained focused as AT guided my thought processes. AT is a versatile framework which applied to both phases of the research: conceptualising the qualitative and quantitative analysis. AT allowed me to select individual parts from the findings and focus to understand the complexity of the individual parts and where these fitted in with the broader unit of analysis. The five activity systems of the research can function as individual systems and as part of a unit of analysis. As the research developed guidelines, the expansive learning process assisted me in the progressive development towards achieving the aim of the research. AT is an appropriate framework when a researcher wants to study organisations and development. For many years scholars did not acknowledge the work of Vygotsky and co-workers to surpass psychology from behaviourism to a post-cognitive approach. Psychologist now realise the importance of transcending psychology from the downside of psychoanalysis and behaviourism to a socio-constructivist approach where each person's human development differs from those of their peers and the ZPD of each person is recognised as unique.

6.8.3 Systematic Literature Review

Conducting a systematic literature review was a stimulating process. I approached librarians from other faculties to assist me to conduct the process as researchers in the Faculty of Education Sciences rarely made use of this method to locate literature for their research. I developed skills which I can now share with my colleagues and peers in the faculty, as well as utilise in the future. I spent many hours searching for documents, recording the process, and evaluating the selected documents, but in the end it was more than just worthwhile. I attained documents adhering to the research phenomenon. The selected documents served two purposes for this research: qualitative analysis and as a structure for my literature review. Initially this process was time consuming, but using this process saved time in the end as I was able to analyse the documents, write a focused literature on the research phenomenon and use some of the constructs for the guidelines.

6.8.4 Data Collection Journey

Travelling across the Western Cape to collect data from the Mathematics teachers made me aware again of the reality of schools. When I was a teacher, I was cognisant of what happened at grass roots level; what teachers had to confront and assimilate every day. I developed empathy and admiration for them all over again. To stay positive and deliver quality teaching to learners who have little respect or discipline must be very frustrating. In many schools I encountered scenarios like that, but the teachers still do their utmost to see that the job gets done. I salute teachers! However, I also came into contact with negative teachers who found it difficult to provide positive feedback and had a negative attitude towards the learners and their PD. This remains a huge problem...

I had the opportunity to visit a few classrooms in some districts. In one school situated in an informal settlement I had the privilege to interact with grade 12 learners. Many of those learners were focused on their future. However, the social inequities across the province made me realise that it would take a lifetime for schools and education in South Africa to be equal. Each teacher can merely do his/her best. One school I visited on a Friday morning had seven teachers absent. Teachers who stay absent from school for no reason do not fulfil or adhere to their roles and the responsibilities of the profession. Strong leadership and management are central to a well-functioning school. This was evident when I visited the schools, even though many schools were located in very poor areas and faced numerous socio-economic challenges. I believe that irrespective of where you teach, as a teacher you can make a positive contribution to the lives of your learners.

My global position system (GPS) became my solitary friend to locate the schools according to the contact details supplied to me by the WCED. There were two schools which I could not locate with the GPS, but I could use my cellular phone to contact those schools. I would not have been able to collect data from 179 schools and personal contact with 300 teachers without support and assistance from and friendly strangers to explain the routes with a friendly smile...

The researcher’s reflections of the research journey culminate in a nutshell: Together, step by step, we should race to raise the standard of transformative Mathematics education in South Africa for future brilliance!