Chapter Three

Culminant Retrospect of a Systematic Literature Probe

3.1 Introduction

This retrospect of the reviewed literature describes the current inclinations in PD of Mathematics teachers while integrating ICT in their teaching and learning practices, developing their TPACK, using an ODL platform content delivery and participant interaction. Additionally, this literature probe seeks to understand to what extend ODL as platform for PD can accommodate Mathematics teachers' individual ZPD and provide guidelines for the implementation of the e-Education policy. AT forms the conceptual framework for this research in order to facilitate the progression between respectively subjective and objective approaches; Mathematics teaching and learning; the teacher and role players within the DBE; technological and the societal influences; and to capture the implicit and the explicit knowledge of all role players (Crawford & Hasan, 2006).

The qualitative analysis of the systematic literature review (§ 2.5), managed with Atlas.ti™ as an inductive process of coding (Table 2.4), conceptualised four overarching themes (Figure 3.1). Four themes emerged from the analysis: (i) governance, (ii) school environment, (iii) ODL, and (iv) PD (Figure 2.4). The following sections discuss and interpret the literature relating to the themes, followed by a concatenation of the literature findings according to the principles of AT.

3.2 Governance

Governance is a process whereby the DBE bestows authority on school managers in order to adhere to policy through implementation and modification of rules stipulated within policy documents (The World Bank Group, 2002). The school as organisation should have means to ensure that these policy specifications are pursued as schools are held accountable for the governance of the organisation and outcomes of policy (Kruger, 2004:42). Governance in the South African school context comprises attaining, developing, and augmenting rules, and the direction and implementation of policy within the organisation (Kruger, 2004:46). Since January 1997 all members and structures within South African schools (DBE, district education officials, school managers, teachers, parents and the governing body) have had a responsibility to ensure that the e-Education White Paper be implemented. Therefore systems should be in place to comply with the policy stipulations of the DBE (Mnanganyi, 1995).

Figure 3.1: Network view of the Four Overarching Themes from the Inductive Analysis

3.2.1 Theme 1 of Literature Analysis: Governance

The theme of governance (Figure 2.4) is discussed according to its six categories: (i) objects of governance, (ii) subjects of governance, (iii) tools of governance, (iv) community of governance, and (v) division of labour of governance (Figure 3.2).

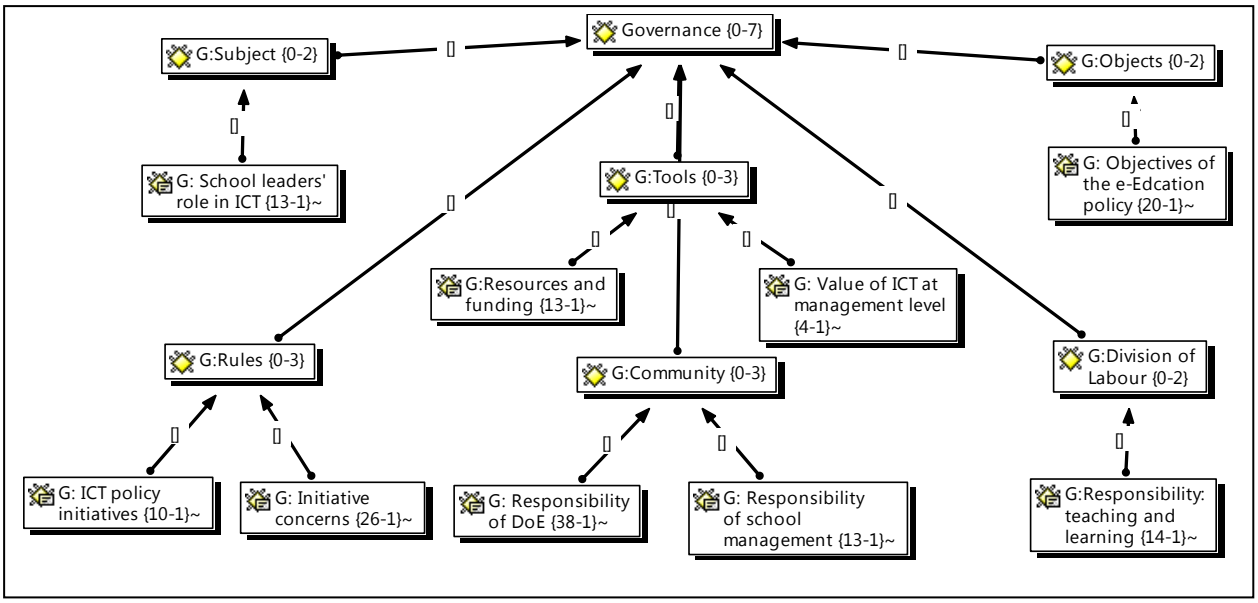

Figure 3.2: Governance as a Theme from the Literature Analysis

3.2.1.1 Objects of Governance

The *objects* of governance comprised one code, the objectives of the e-Education White Paper. In 2004 the DoE launched its first White Paper on e-Education policy (Department of Education, 2004b) as part of the initiative to espouse ICT into in all spheres of education (administrative, management and teaching and learning). This policy developed a set of principles, as a course of action, to deal with inequities within the system, to address the changing climate in education, and to enhance the governance of the organisation (Department of Education, 2004b:16). The vision of the White Paper on e-Education (Department of Education, 2004b) is that all South African citizens have access to lifelong learning, education and training opportunities, which will ultimately contribute towards improving the quality of life. The DBE strived for ICT development to improve the standard of teaching and learning, accommodate diverse learners, and diminish teaching and learning barriers (Department of Education, 2004b:17). Fundamentally the object of the e-Education policy was to ensure that learners attain knowledge and skills to operate in an ICT environment by 2013. The e-Education policy stipulated a three phase ICT integration plan:

- *Phase I (2004-2007)* of the e-Education policy strove to prepare the education systems ready for the ICT integration process
- *Phase II (2007-2010)* of the e-Education policy aimed to achieve system wide integration of ICTs into teaching and learning and in all spheres of education in terms of planning, teaching,

collaborating, communicating, monitoring and budgeting

- *Phase III (2010-2013)* intended to integrate and embed ICTs in order for schools to function effectively with less time spent on planning and more time spent on preparing learners to use ICT while developing their 21st century skills (Department of Education, 2004b:22-23).

The ICT policy implementation aspired to:

- develop an ICT pre-service and in-service continuous programme for PD competencies for educators (school managers, teachers, and administrators)
- provide technology resources for each General Education and Training (GET) and Further Education and Training (FET) organisation
- appoint ICT education subject-specialist at provincial and district level
- train district level and ICT subject-specialist support
- motivate organisations and teachers to integrate ICT in the overall function of the organisation
- ensure that the benefits of e-learning are utilised
- monitor and manage the implementation of the e-Education policy (Department of Education, 2004b:23-36).

The WCED has achieved many of the objectives of the e-Education policy, and it has ICT systems in place to apply intervention strategies to achieve the fundamental objective of the policy. To assess all the mentioned obligations of the DBE is quite a challenge. Table 3.1 provides a synopsis of the status of the WCED for ICT integration. In spite of wide-spread successes, no specialised PD training is available for Mathematics teachers within the WCED (Western Cape Education Department, 2011).

Table 3.1 Western Cape Education Department ICT Readiness

e-Education Policy Aims	Status of Implementation in WCED
ICT pre-service and in-service PD training	• Twenty eight thousand teachers received basic ICT skills training (Western Cape Education Department, 2011)
Supply technology resources in GET and FET	• Khanya initiative in 2012, 85% of schools in province have fully equipped ICT laboratories; 11% in the process (Western Cape Education Department, 2011)
Appoint ICT education subject-specialist at district	• No ICT subject-specialist at district level
Train district level subject-specialist support	• No training for ICT subject-specialists at district level • Twenty schools in province to improve Mathematics and Science (Western Cape Education Department, 2011)
Organisations and teachers integrate ICT	• Disadvantaged schools struggle to integrate ICT (Bladergroen et al., 2012)
e-Learning utilized	• Virtual Private Network (VPN) connects twenty focus schools for Mathematics and Science (Vodacom, 2012)
Implementation of the e-Education policy	• Phase I and Phase II implemented in most schools (Department of Education, 2007:39-41)

To develop Mathematics teachers to become competent with technological innovations, it is vital that the DBE—specifically for this study, the WCED—should reform the context of the organisation, adapt

the initiatives to implement the policy (Hardy, 2008) to develop PD activities in order to deal with the diverse context and challenges within the organisation (Attwell & Hughes, 2010:43). The WCED should develop a PD strategy to address diversity and challenges within the province. But such diversity "will emerge only if educators, researchers and communities are empowered to develop localised or novel responses to socio-technical change—including developing new approaches to curriculum, to assessment, to the workforce and governance, as well as to pedagogy" (Attwell & Hughes, 2010:43). In order to develop new methods, teachers should embrace TPACK to deepen their teaching and learning experiences across the curriculum and ensure that the outcomes for the subject (Mathematics) are met (Mishra & Koehler, 2006:1026). From secondary data analyses of the SITES 2006 data (Cassim, 2010:134), only 31% of the 604 Mathematics teachers in South Africa who participated were confident to use ICT in their pedagogical practices. The data analysis zoomed in on four areas: insufficient confidence, shortage of time, limited access to resources and inadequate PD (Cassim, 2010:134; Mofokeng & Mji, 2009:1614). Insufficient resources and PD are two of the areas which should be addressed at organisational level to meet the objectives of the e-Education policy(Leendertz *et al.*, 2013). The WCED has adequate resources (Table 3.1) and therefore PD as an organisational challenge should be dealt with if the WCED aims to conduct PD with ODL in order to achieve the aims of the e-Education policy (Department of Education, 2004b).

3.2.1.2 Subject of Governance

The *subject* of governance comprised one code: *school leaders' role in ICT* (Figure 3.2). The school leader is responsible to implement all policies (Munro, 2011:111-112). For ICT integration in schools to be successful, the school leader and the SMT should initiate the ICT skills development of the Mathematics teachers and not solely depend on the DBE and the PDE to initiate PD activities. For ICT PD of Mathematics to be effective the SMT should be the agents to drive the process of policy implementation (Education Labour Relations Council, 2003:A53).

The Policy Handbook for Educators (Education Labour Relations Council, 2003:A48-A53) stipulates seven roles for educators and guides the educator in the South African schools context: leader, administrator and manager; learning mediator, interpreter of learning programmes and materials; community, citizenship and pastoral role; scholar, researcher and lifelong learner; assessor; and subject specialist. Each of the seven roles is sub-divided into practical competence, foundational competence, and reflexive competence. The roles which apply to the community of governance relate to (i) leadership, (ii) administration, and (iii) managing of the implementation of ICT into all aspects of the organisation. Adapted from the Education Labour Relations Council (2003:A48-A53), ICT policy implementation emphasises the competencies of the school manager on the three levels of competencies:

- practical competence as leader, administrator and manager is to assess and work in collaboration with professional services and resources to promote learning with ICT
- foundational competence imperative for a school manager is to be knowledgeable of professional

and communal services and PD strategies for using their expertise and apply a variety of methods to the organisation of integrated ICT programmes and collaborative teaching

- reflexive competence where school managers are able to reflect on PD strategies for ICT integration within the organisation, make choices regarding to PD teachers within the organisation, and adapt the PD strategies to suit the context of the organisation (Education Labour Relations Council, 2003:A50).

Most of policy implementation occurs at school level, which indicates that the school manager should go beyond just managing ICT implementation at the organisation (Hadjithoma & Karagiorgi, 2009). He/she should create PD initiatives which support the changes in the curriculum within the context of the organisation (Daly *et al.*, 2009:28; Department of Education, 2004b:24; Hartsell *et al.*, 2009:1). The attributes of a functional learning community comprise shared beliefs, values and vision, cooperative and supportive leadership, a school culture and climate for learning and a community of practice. The learning community work together and focus on learners acquiring the knowledge and skills of Mathematics.

Elements of successful ICT PD of Mathematics teachers at school level can be summarised as effective management of a learning culture, by which the school leader and the SMT influence how the school functions as a learning organisation (Daly *et al.*, 2009:30). This includes: (i) how the school as an organisation creates a positive school culture and climate for ICT PD; (ii) how the school leader works in partnership with the SMT to bring about change in ICT practices; (iii) which types of school-based structures are put in place to assist ICT PD; and (iv) how the school manager supports onsite ICT PD and growth of the SPI of Mathematics teachers (Da Ponte, 2010:1).

A positive school culture and climate is vital in the PD process (Loucks-Horsley *et al.*, 2010:94). The school culture and climate are entwined—the one's function depends on the other. School climate is the summation of values, cultures, safety practices, and organisational structures within a school which enable it to function and respond in a particular ways (Peterson & Deal, 1998:28). The school climate has many dimensions: physical, social, and academic. Physical dimensions of the climate include: (i) the exterior presentation of the school; (ii) the size of school; (iii) the teacher: learner ratio; (iv) the classroom organisation; (v) the availability of resources for teaching and learning; and (vi) the general school safety. The social dimensions include; (i) the interpersonal relationship between the school leader, SMT, teachers and learners; (ii) the quality of teaching and learning, and (iii) the teacher and learner achievement expectations. The academic dimensions of the climate include the assessment practices at school (Loukas, 2007:1). It is difficult to divide the school culture and climate from each other as the two function as a unit.

The school leader, supported by the SMT, establishes a school's culture, norms, beliefs, values, traditions, and policies (Hinde, 2004:2; Nanavati & McCulloch, 2003:3; Peterson & Deal, 1998:28). Culture influences all the facets of the school: (i) how the SMT governs the school as an organisation;

how teachers interact with their colleagues; (ii) how Mathematics teachers approach their teaching and learning; and (iii) to what extent Mathematics teachers accept and adapt to change (Donahoe, 1997:298; Hinde, 2004:2).

There are various strategies a school can apply to create a positive culture for PD of Mathematics teachers. Successful school management is fundamental to change the culture of the organisation (Rodriguez, 2000) in order for Mathematics teachers to become part of their growth process—rather than subjected to it (Daly *et al.*, 2009:30). The SMT deploy: (i) the school ICT strategic plan; (ii) the time estimated for PD; (iii) the use and supplement, if possible, the ICT resources at school; and (iv) the expertise of the teachers, to help design ICT PD in partnership with external stakeholders including the WCED, SACE, CAs, and external service providers (Daly *et al.*, 2009:57; Rodriguez, 2000). Effective school leaders know the competencies of the teachers and how to utilise them best to the advantage of the organisation and to bring about change in the ICT practices of teachers (Daly *et al.*, 2009). This is not a new phenomenon and the SMTs should acknowledge the attributes of each individual teacher, and make use of this expertise in order to compliment the PD initiatives of the DBE and the PDE. The skills of excellent teachers are utilized to empower other staff members as well. These teachers are known as expert teachers who use their creative teaching and learning skills to support other staff members, facilitate the SMT in the PD process, create online groups, and perform exemplary ICT model lessons for their peers and colleagues (Attwell & Hughes, 2010:62).

The organisation of the ICT PD at school affects how well the SMT, teachers, and learners support the learning culture and adhere to the needs of Mathematics teachers. Therefore, it is critical for the school as learning organisation to develop the Mathematics teachers' TPACK—which is just one aspect of the overall culture that supports conditions at schools (Daly *et al.*, 2009:34). When Mathematics teachers are *well-prepared*, *well-versed*, and *thoroughly supported*, then transformation in the curriculum and teaching strategies can take place (Hartsell *et al.*, 2009:1).

Successful management of ICT PD also focuses the social dimension of the school climate. The social dimension of the school climate relates to the interpersonal relationships of teachers with their colleagues. These relationships have an impact on the emotions, attitudes and beliefs, teaching and learning practices, development of the SPI, and self-reflection of teachers within the context of the organisation (Daly *et al.*, 2009:58; Education.com, 2013; Gratch, 2001:134; Loukas, 2007:1). The SMT through versatile, creative, practical, and self-chosen ICT PD strategies positively affect the self-confidence and motivation of Mathematics teachers to accept ICT as a teaching and learning tool (Cogill, 2008; Pachler *et al.*, 2010:78). The school thus creates a positive school climate in order for Mathematics teachers to develop their self-concept, expand their capacity to practice self-reflection (Gratch, 2001:134), support ICT initiative of teachers, and encourage them to develop SPI within the school through collaboration (Hansen & Childs, 1998:14-17). A mindful and supportive SMT (Daly *et al.*, 2009:33-58) can create a culture where teachers become enthusiastic about ICT for teaching and

learning (Crook & Harrison, 2008:26). Such schools are known to be ICT successful (Quek Sai Gearn, 2009).

3.2.1.3 Tools of Governance

The *tools* of governance comprised two codes: (i) resources and funding; and (ii) the value of ICT at management level (Figure 3.2).

The resources and funding relate to the provision of funds and ICT equipment by the DBE. The DBE's investments of financial resources and time aim to improve the ICT knowledge and skills of Mathematics teachers (Resnick, 2005). "The state must fund public schools from public revenue on an equitable basis in order to ensure the proper exercise of the rights of learners to education and the redress of past inequalities in education provision" (Education Labour Relations Council, 2003:E17). The DBE is therefore accountable for the provision of ICT resources, to teachers and learners, for the e-Education policy implementation (Department of Education, 2012b). The White Paper on e-Education's three phase plan stipulated that: (i) eighty per cent of organisations should be able to access to a networked computer facility for teaching and learning; (ii) all organisations should use legal software; (iii) every organisations' ICT facilities should be conducive to facilitate ICT integration into teaching and learning; and (iv) all organisations should have a teacher to manage the facility (Department of Education, 2004b:38). The WCED is the only province in South Africa that is on par with the provision of ICT tools and resources relating to the third generation activity aims to cultivate conceptual tools to comprehend dialogue, various viewpoints, and networks of interactive systems (Engeström, 2001:135).

Phase III implementation: the WCED has insufficient human capital to manage the ICT facilities and provide ICT subject-specialized training (Table 3.1) (Western Cape Education Department, 2011). As the majority of WCED schools have attained the final phase implementation criteria, ODL could be used to augment the shortage in human capital for PD (Van De Westeringh, 2003).

The value of ICT at managerial level assesses how the organisations gain from the use of ICT at their institutions. At system level, through the use of ICT, the DBE can access, collect, analyse, and monitor multifaceted information from school databases. ICT enables schools within the GET and FET bands to access suitable, pertinent, and comprehensive information to successfully govern a school as an organisation. Schools can use ICT to plan, monitor, improve, and evaluate the management of the organisation. School managers can spend less time on monotonous administration tasks and focus on instructional management (Becta, 2002). With the use of ICT, school management can be improved with less financial resources and access more complex information at system and organisational level (Phillips, 2009).

3.2.1.4 Community of Governance

The *community* of governance comprised two codes: (i) responsibility of the DBE, and (ii) the responsibility of school management (Figure 3.2).

Educational leaders at all levels of the system should receive assistance to allow them to manage the use of ICTs, as well as the interrelated transformation processes (Department of Education, 2004b:19). The DBE is firstly and foremost responsible to ensure that the e-Education policy is implemented at all levels of the system. Phase I of the e-Education policy aimed to prepare the education systems for the integration of ICT. However, for Phase I implementation in 2007, an unsatisfactory 22.59% of schools nationally owned ICT infrastructure for teaching and learning, of which 76.55% of schools in WCED were equipped for Phase II implementation, and 85% of schools in the WCED are prepared for Phase III implementation (Western Cape Education Department, 2011; Western Cape Education Department, 2013b).

A Phase II objective was that eighty per cent of district and school managers should receive ICT in-service training to use ICT for managerial and administrative purposes (Department of Education, 2004b:22-23). This objective was achieved and the implementation of Phase III for ICT implementation at administration and management is in place in the Western Cape (Western Cape Education Department, 2011). The DBE's interrelated teacher laptop initiative aimed at the adaption of ICT use of GET and FET band teachers (Cowie *et al.*, 2008; Department of Education, 2004b; Department of Education, 2012b:19). By 2011 all teachers should have been equipped with a laptop for teaching and learning purposes, but has not yet materialised (Mahlong, 2012). As the DBE has not yet delivered on their commitment to the provision of resources, as well as time for Phase III ICT implementation, various PDEs should, from their positions, address the ICT discrepancies.

Provincial managers and subject advisors should be trained in ICT integration to offer support particularly to teachers. District officials should build partnerships with school leaders and teachers to support them in their PD initiatives (Department of Education, 2004a:38). An on-demand training programmes proposes to be a realistic method to provide PD to teachers within the education districts. The current commitments and intervention strategies from the education district do not provide PD of this calibre. A shortage of district level leadership and support affects the ICT integration process as other pathways need to be explored to achieve the Phase III e-Education White Paper objectives (Department of Education, 2004b:38; Ross *et al.*, 1999; Scrimshaw, 2004).

Derived from the above, PD for ICT integration becomes the responsibility of the school management (Education Labour Relations Council, 2003:A48-A53). Even though policy support exists for PD to some extent with PD programmes like *WebQuest* and *IntelTeach* (SchoolNet SA, 2012), the SMT has to initiate ICT PD (Daly *et al.*, 2009:57). The school as organisation, should determine the strategies

for policy implementation, develop a strategic plan, and organise ICT learning communities to share ICT best practices (Loucks-Horsley *et al.*, 2010:72).

3.2.1.5 Rules of Governance

The *rules* of the governance comprised two codes: (i) ICT policy initiatives; and (ii) initiatives concerns (Figure 3.2).

In 2002 the Presidential International Advisory Council on Information Society and Development (PIAC on ISAD) was established to advise government on the development of ICTs in various sectors—education, health, small, medium and micro enterprises. The e-Education policy was supported by the New Partnership for Africa's Development (NEPAD) which aimed to use ICTs to reduce the level of poverty globally. The South African Institute for Distance Education (SAIDE) in collaboration with the SCOPE (Finnish development support) and SchoolNet SA developed eleven teaching and learning modules for initiating ICTs into the school curriculum. SchoolNet additionally supplied mentor-based ICT training for teachers, and the INTEL *Teach to the Future* PD programme for ICT integration. Other initiatives were the establishment of an education portal (Thutong), and the Telkom foundation which equipped 1300 schools with computers and Internet access for teaching and learning (Department of Education, 2004b). At provincial level the Gauteng Department of Education (Gauteng Online) and the WCED (Khanya) launched ICT integration programmes at schools across these provinces. Khanya completed their projects with an overall success rate of 96% of schools equipped or in the process of receiving ICT resources and training (Table 3.1) (Western Cape Education Department, 2011). However, the Gauteng Online project was recently cancelled due to failure to provide many schools in the province with adequate resources and training (Timse, 2013).

The sustainability of these policy initiatives is a concern as they focus on the presence of ICT at the institutions, and do not support the aims of the three phase plan of the e-Education policy (Blignaut & Howie, 2009:662). A concern is that Mathematics teachers do not have the contextual knowledge, appropriate skills and professional support to make a concept shift and change their teaching and learning practices (Hartsell *et al.*, 2009:63). The current ICT PD initiatives do not relate to what actually occurs within classrooms, and they are not adequate to change teaching and learning of Mathematics in schools. Teachers' insufficient confidence is not necessarily due to shortage of PD, but can be ascribed to how PD is organised, assessed, and the amount of pressure teachers experience at school (Schibeci *et al.*, 2008). The majority of former or current PD programmes do not focus on specific contexts or the individual needs of Mathematics teachers. Daly *et al.* (2009:51) advocate that the context of PD development programmes needs to change and role players should work together to supply teachers TPACK.

3.2.1.6 Division of Labour in Governance

The *division of labour* of governance resulted in one code: the responsibility of DBE to teaching and learning (Figure 3.2). All sectors (national, provincial, school) have a responsibility concerning the implementation of Phase III of the e-Education policy and ICT PD of Mathematics teachers. Within a large organisation, as the DBE, the labour is divided on two levels—vertically and horizontally. Vertically, the DBE developed the ICT strategic plan and ICT integration strategies, which the provincial departments have to implement with the assistance of the district officials. Horizontally, the DBE should have financial and human resource structures in place to develop ICT competencies of teachers, supply ICT resources, and provide teaching and learning support (Robertson, 2008:821). Table 3.2 provides an overview of the ICT implementation requirements at national, provincial, and school levels for ICT integration into the teaching and learning.

Table 3.2 Requirements for ICT Integration at National, Provincial and School Level *

Department	Requirements for ICT Integration
National	• Develop a national framework for competencies for administrators, school managers and teachers • Access to ICT infrastructure : administrators, school managers and teachers in GET and FET band • Access to an educational network and Internet: administrators, school managers and teachers in GET and FET band • Access the skills levy for in-service ICT training programmes • Restructure educational institutions to use ICTs as a tool for improve academic performance • Incorporate ICT development plans with ICT PD for management, teachers and learners
Provincial	• Restructure educational institutions to use ICTs as tool to improve academic performance • Access to ICT infrastructure : administrators, school managers and teachers in GET and FET band • Access to an educational network and Internet: administrators, school managers and teachers in GET and FET band • Incorporate ICT development plans with ICT PD for management, teachers and learners • Plan and budget for the appointment of Education specialists in ICT at provincial and district levels • Train district-level ICT and subject specialists in order to provide CPTD and technical support • Offer ICT PD for management, teachers and learners
School	• Restructure school programmes to use ICT as a tool to improve academic performance • Incorporate ICT development plans with school development programme • Support curriculum through engagement with ICT, software, electronic content, online resources, teacher collaboration • Work in partnership with community to ensure shared knowledge about ICTs • Provide extended opportunities for learning and development through ICTs • Offer ICT PD for management, teachers and learners

* (Adapted from Department of Education (2004b:25-33))

Each of the education sectors had certain requirements they had to meet to create a system which were geared towards Phase III implementation of the e-Education policy (Table 3.2). At national level, many schools up till have no access to ICT infrastructure, educational networks, or the Internet (Isaacs, 2005). The DBE did not supply the PDE and schools with sufficient funds to purchase and sustain their ICT resources. There are very few service providers available to ICT PD for teachers. The DBE also does not have ICT PD plans for administrators, school managers and teachers (Day &

Sachs, 2004:187). At provincial and district level, institutions: (i) are not restructured to become ICT savvy; (ii) do not have access to ICT infrastructure; (iii) are not able to access the educational portal or the Internet; (iv) do not have sufficient ICT development plans for administrators, school managers, teachers and learners; and (v) do not have adequate ICT education specialist or subject-specialised training. Many schools: (i) do not restructure their academic programmes to incorporate with ICT developmental plans; (ii) do not integrate ICT in their teaching and learning practices; (iii) seldom support curriculum engagement with ICT; (iv) rarely provide extended opportunities for learning and development through ICT; and (v) do not offer ICT PD development for their teachers (Day & Sachs, 2004:180). The DBE developed a strategic plan which the PDE had to implement, but unfortunately, owing to financial constraints and shortage of human capital, the DBE could not supply the human resources and the support for ICT integration (Lotriet *et al.*, 2010).

The DBE, and PDE have not met certain of the requirements for Phase III implementation, and therefore alternative measures should be put in place to achieve the e-Education Phase III objectives. The WCED which has the least inequities when compared to some other provinces (Table 3.1), are able to move towards Phase III implementation, particularly for the PD of Mathematics teachers for subject-specialized training through an ODL mode of service delivery.

The following sections provide a systematic description of how the above categories of the theme of governance appropriates to the interrelated elements of the activity system.

3.2.2 Governance as Activity System

Chapter One (§1.3.1.5) provided a description of the structure and functions of the third generation activity system. An activity system includes: (i) six interrelated elements known as: objects, subjects, tools, rules, community, and division of labour, (ii) three-way interaction, and (iii) four levels of contradictions (Hashim & Jones, 2007). The governance activity system is an analytical tool to understand the learning conditions of Mathematics teachers in their surroundings. The following section discusses how: (i) the mediated interaction between the subject, object, and community function towards achieving the outcome of the activity (Engeström, 1987), (ii) the categories (objects, subjects, tools, rules, community, and division of labour) conceptualised as elements of Governance structure an activity system (Kuutti, 1996) (Figure 3.3 next page). Figure 3.4 illustrates the primary and secondary contradictions in the activity system (Barab & Plucker, 2002:172; Engeström & Sannino, 2010:7).

The object of the governance activity system is the objectives of the e-Education policy, and the outcome is to develop guidelines for the professional development of Mathematics teachers in the pedagogical use of ICT (Phase III of the e-Education policy) in ODL. The school leaders use a variety of tools (resources and funds, human capital, and ICT at managerial level) in their endeavour to achieve the object. The community comprises DBE, PDE, and SMT as role-players.

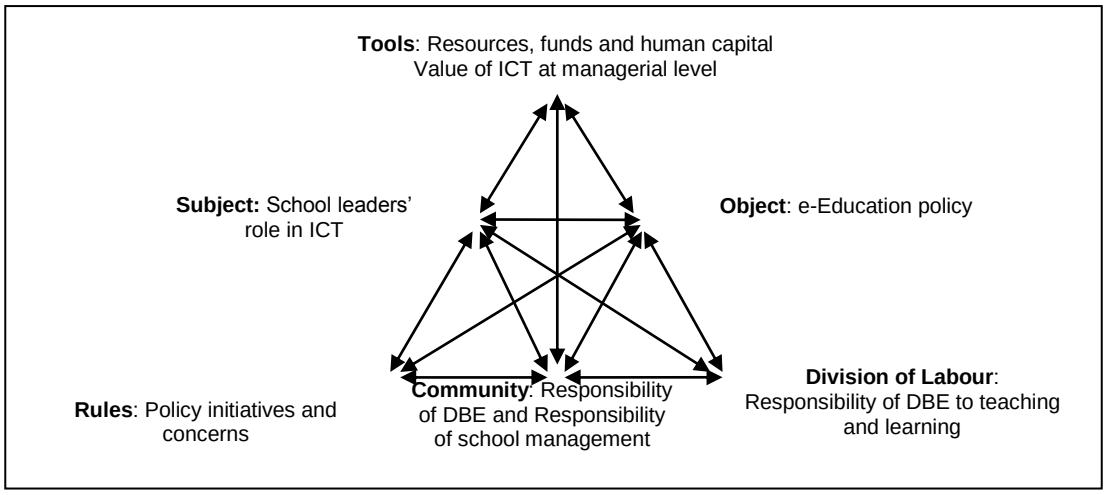

Figure 3.3: Governance Activity System (Adapted from Engeström (1987))

The DBE's liaison with the community is mediated by explicit and implicit rules: (i) policy initiatives (Khanya, Gauteng Online, and SchoolNet (§ 3.2.1.5), and (ii) concerns (insufficient support for ICT implementation). To achieve the objectives of the e-Education policy the DBE, the PDE, and school leaders should work as a team. This management is achieved by dividing the labour (responsibility of DBE to teaching and learning) amongst the DBE, PDE, SMT (community), which consequently mediates the relation between the DBE, PDE, SMT and the object (Figure 3.3). The six interrelated elements of Governance Activity System interactively and individually contribute to achieve the object of the activity.

Figure 3.4 (next page) illustrates the mediated relationship between the subject and object of the Governance activity system as well as the interrelations among the various elements of the activity system. The figure also clarifies the primary contradictions within each code of the activity system. The dashed arrows indicate the secondary contradictions between the elements of the activity system. The split in the dashed arrow indicates the movement of the tension, predicaments, and interventions amongst the elements of the activity system.

For the governance activity system to function efficiently a stronger, emphasis must be on the role of the school as initiator to enable ICT PD of Mathematics teachers through ODL as method of service delivery. The governance activity system has a significant level of influence over the school environment, ODL, and PD (Robertson, 2008:822). A large number of the schools are not yet ready for Phase III ICT implementation at all levels of the education as projected by the e-Education policy (Department of Education, 2004b:23).

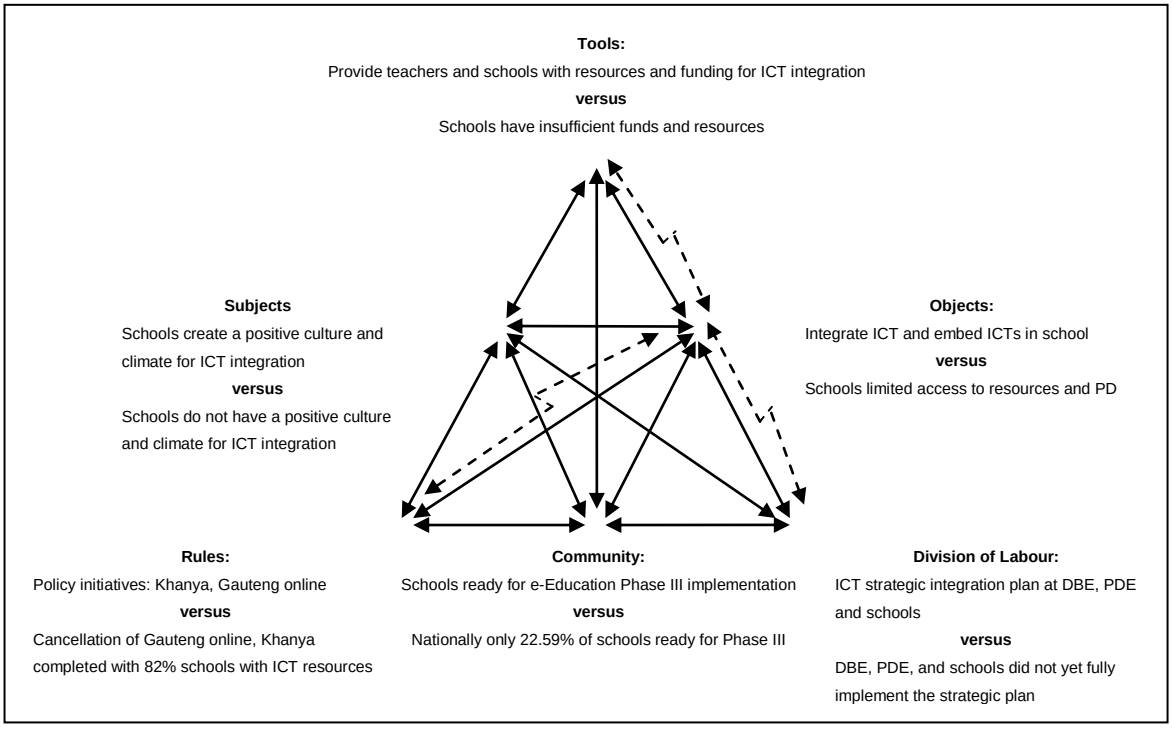

Figure 3.4: Mediated Relationship between the Subject and Object, and Interrelations among the Elements of Governance Activity System

3.3 School Environment

School environment is the aspect that connects a large number of activities within the institution. Many times these aspects are not visible, yet everyone within the organisation experiences its authority. The school environment is the place where not just teaching occurs, but teaching in co-operation with curriculum materials, technology equipment and tools to transfer knowledge, skills, values and attitudes to learners (Uyangor & Gör, 2010:213). Good social interaction and a positive attitude are important attributes to create a school environment favourable to embrace change, motivate educational achievement, and establish positive psychosocial climate and culture (Education Development Center, 2003:121; Lim & Khine, 2006; Uyangor & Gör, 2010:214). Such a school environment encourages a collaborative teaching and learning environment, promotes PD initiatives, and review the PD activities at school (Silins *et al.*, 2002:1).

3.3.1 Theme 2 of Literature Analysis: School Environment

The following sections discuss the theme *School Environment* conceptualised from the inductive analysis with Atlas.ti™ (Figure 2.4). The theme of school environment is discussed in the following sections according to its six categories, (i) objects of school environment, (ii) subjects of school

environment, (iii) tools of school environment, (iv) communities of school environment, (v) rules of school environment, (vi) and division of labour of school environment (Figure 3.1).

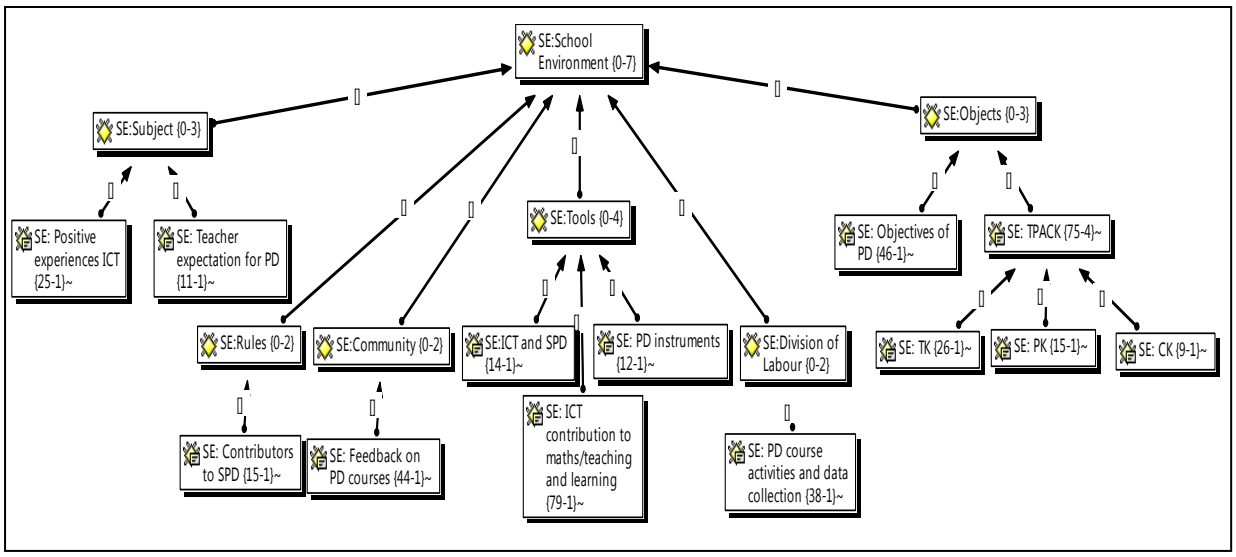

Figure 3.5: School Environment as Theme from Literature Analysis

3.3.1.1 Object of School Environment

The *objects* of school environment comprised two codes: (i) objectives of PD, and (ii) TPACK (Figure 3.5).

There are multiple aims why Mathematics teachers should develop their pedagogical practices with ICT. Teachers should: (i) adhere to the minimum qualification requirements (Department of Education, 2011), (ii) accumulate the 150 PD points on their professional portfolio within their subject specialisation (Department of Education, 2010), (iii) develop the skills to implement the policies; (iv) and improve the quality of teaching and learning of Mathematics (Resnick, 2005:1). Furthermore, the DBE aims to: (i) institute a future ICT education model, (ii) make use of authentic pedagogy, (iii) create a teaching and learning community, and (iv) enhance the professionalism of Mathematics teachers (Prestrige, 2007:2).

In 2011 the DoE introduced a new policy which stipulated the minimum qualification for teachers in South Africa. This policy specified that all teachers should have a minimum National Qualification Framework (NQF) level eight which can be a Higher Diploma in Education, an Advanced Certificate in Education, or a Bachelor's degree in Education (Department of Education, 2011). The DBE is accountable for the PD of administrative staff, school managers and teachers appointed under their jurisdiction. CPTD forms an integral part of education enhancement within any education organisation as policies are continuously adapted and changed to address the global developments and the economic climate of a country.

In South Africa, SACE should manage and provide opportunities for in-service and pre-service training of teachers whereby they can accumulate 150 PD points. SACE assists teachers to: (i) manage and direct their PD to attain the knowledge and skills for their profession, (ii) guarantee that external service providers meet the standards of SACE (Department of Education, 2010), and (iii) develop teachers' knowledge and skills to address the outcomes of the National Curriculum Statement (NCS) (Department of Education, 2006) and the White Paper on e-Education (Department of Education, 2004b). Currently, the DBE and SACE do not supply adequate CPTD for teachers to master the knowledge and skills to adhere to policy specification (Mofokeng & Mji, 2009:1613) which creates barriers that affect ICT integration into the teaching and learning process (Becta, 2008). Eight factors should be taken into consideration when the DBE in partnership with SACE design PD for Mathematics teachers: (i) the NCS, (ii) the White Paper on e-Education policy; (ii) the developmental requirements of teachers; (iii) the curriculum needs of learners; (v) the organisational culture and professional learning communities; (vi) the curriculum, teaching strategies, assessment, and school environment; (vii) the school management; and (viii) the ICT resources and tools at school (Loucks-Horsley *et al.*, 2010:81).

ICT integration PD is to equip Mathematics teachers with the theoretical ideas and supply them with some practical experience as regards the current trends in the curriculum—working with mathematical explorations and investigations (Li, 2005:2). PD provides Mathematics teachers with the opportunity to: (i) reflect on their current practices with ICT; (ii) assess whether their classroom practices are applicable to achieve the outcomes of the Mathematics curriculum, and (iii) evaluate if the PD activities align with the critical and developmental outcomes of the NCS (Da Ponte, 2010:147; Department of Education, 2002a). Fundamentally, PD should prepare teachers to: (i) utilize technology, (ii) teach Mathematics using the technological tools, (iii) accommodate their individual ZPD (Vygotsky, 1978a), and (iv) develop their TPACK (Leendertz *et al.*, 2013:5; Li, 2005:3).

TPACK is essential for ICT integration in Mathematics classrooms. For Mathematics teachers to become skilled to use ICT as an integral part of teaching and learning of Mathematics, they should develop their TPACK. The important dimensions of effective teaching are content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK), and technology knowledge (TK) (Shulman, 2004). CK consists of the organisation of knowledge in the thought processes of teachers. Mathematics teachers should have extensive CK of Mathematics to be able to teach the subject successfully (Ball *et al.*, 2008:395; Mishra & Koehler, 2006:1026). PK is when teachers have the expertise to select the appropriate method to teach the content to the learners. PCK is a combination of subject and pedagogical knowledge (Shulman, 2004:188). Teachers apply PCK when they build on the learners' prior knowledge and adapt their teaching strategies to teach the mathematical content to learners. The central dimension where all these technologies will meet is known as TPACK which is not merely a basis of technology, pedagogy and content, but the foundation for effective integration of ICT in teaching and learning (Mishra & Koehler, 2006:1029). ICT PD of Mathematics teachers for Phase III implementation must be geared towards developing TPACK. With the inclusion of the

development of TPACK in PD of Mathematics teachers, the outcomes of Mathematics education can be achieved, and even exceeded (Li, 2005:12; Loveless et al., 2006:7).

3.3.1.2 Subject of School Environment

The subject of school environment comprised two codes: (i) Mathematics teachers' expectations of PD and (ii) Mathematics teachers' experiences with ICT (Figure 3.5).

The following section relates Mathematics teachers' expectations for PD. Mathematics ICT PD should take place in a teaching and learning environment where the PD activities include content specific tasks for Mathematics teaching (Mofokeng & Mji, 2009:1613). Mathematics teachers deem it vital to form part of the planning, and to have a platform available where they can exchange ideas, solve problems, and deal with ambiguities in the process of classroom transformation (Angeli & Valanides, 2008:166). The more Mathematics teachers collaborate their ICT innovations with their colleagues locally or globally via social media sites like Twitter™, the more they create innovative teaching and learning experiences, and the more they expose their learners to higher-order tasks (Hartsell *et al.*, 2009:54; Schibeci *et al.*, 2008:324). The more Mathematics teachers are exposed to new forms of learning (Swan *et al.*, 2002:169), the more they gain insight as to *why* and *how* ICT is used in Mathematics classrooms, accomplish the appropriate use of ICT for their pedagogical practices in their classroom, and change their attitude with regard to the value of ICT for teaching and learning of Mathematics (Li, 2005:12-13). As teachers' attitudes towards ICT change, they become more confident and skilled to use ICT teaching mathematical concepts and problem solving (Drent & Meelissen, 2007:195; Hartsell *et al.*, 2009:57; Uyangor & Gör, 2010:215). With an increase in confidence they become more enthusiastic, interested, motivated and committed to embrace ICT subject-specialized PD in their teaching and learning environment (Attwell & Hughes, 2010:44; Uyangor & Gör, 2010:213).

Individual Mathematics teachers who participated in various ICT PD activities could vouch how it changed their attitude towards ICT for the teaching and learning of Mathematics. At the outset of the PD activities, the work involved a huge amount of effort, many hours of research, and much commitment, but the outcome was satisfactory. Many even viewed computers as overvalued typewriters before they engaged in PD and became dependent on the computer to do certain tasks for them (Da Ponte *et al.*, 2002:13). The Mathematics teachers acknowledged that their TPACK had increased significantly and they learned useful skills which they could apply when teaching a variety of mathematical concepts (Da Ponte, 2010:152; Li, 2005:6). Many Mathematics teachers are hesitant and fear the Internet, but through engagement they can navigate on the Web and even edit a webpage (Li, 2005:12). Another Mathematics teacher admitted that teaching Mathematics with ICT is fun and that learners embraced this method of teaching and learning (Li, 2005:6-8).

3.3.1.3 Tools of School Environment

The *tools* of school environment comprised three codes: (i) ICT contribution to Mathematics, (ii) ICT and SPD, and (iii) PD instruments (Figure 3.5).

This section confers ICT's contribution to Mathematics teaching and learning. One of the critical outcomes of the NCS was that learners should use electronic and other technology confidently and effectively to solve mathematical problems. "ICT in the Mathematics class is a must. This is the only way to make mathematics approachable and attractive to our pupils in the future" (Da Ponte *et al.*, 2002:14). ICTs in Mathematics teaching and learning have numerous dimensions and may be seen as: (i) supplementary tools to support learners' learning; (ii) auxiliary mechanisms for Mathematics teachers to search for and produce teaching materials, stimulate their learners' creativity, develop learners' 21st century skills, and manage their assessment of learners; and (iii) supporting device for collaboration with peers. The Internet assists in the holistic development of the teachers and their individual, social, cultural, communal, recreational, and professional features (Da Ponte *et al.*, 2002:2).

One of the aims of the White Paper on e-Education was to foster a sense of personal identity so that teachers can be aware of their abilities and shortcomings which should be addressed in the PD process (Department of Education, 2004b:10). The holistic growth of Mathematics teachers to become ICT competent starts with the development of their social professional identity (SPI) (Da Ponte, 2010:2). An identity can be defined as the self-motivated conception of who you are as a person (Rynänen, 2001:98), which is formed during an activity and socialisation in a group (Leont'ev, 1978). (Berger & Luckmann, 1966:3) consider the development of a professional identity as the emancipation process by which you grow and advance through secondary socialisation (Da Ponte, 2010:2).

Da Ponte (2010:145) states that teachers develop a professional identity when they adopt the essential functions, rules and principles of the teaching profession (Da Ponte *et al.*, 2002:2). Professional identity is one facet of the social identity. The social identity is deeply ingrained bonds the external and internal contributors and ensures they function as a unit. "A social identity can be regarded as belonging to a certain world, and can only be understood, in subjective terms, together with that world" (Da Ponte, 2010:146). Mode of communication (language), cultural heritage, social stance, political and religious beliefs, and the role the teacher adopts in the social division of labour are all contributing factors to the formation of a social identity. The social identity of the Mathematics teachers are constantly constructed and reconstructed as they interact with their peers within the school environment. This requires a connection between inherited identities and desired identities. During the interaction the Mathematics teacher, as a member of the group, assumes two roles: the one acknowledged as a member of the group and the other as a participant of the group. When these two roles are combined, it strengthens the social identity (Rynänen, 2001:98). Therefore constructive communication is central to the social professional development (SPD) of Mathematics teachers to

change their pedagogical beliefs and practices (Day, 1999). Vygotsky (1978b) believes that social interaction can facilitate cognitive growth and knowledge acquisition. This relates to the zone of proximal development (ZPD) (§1.3.1.2) which refers to the distance between the actual level of development and the potential level of development which teachers can accomplish if they are supported within their social context (Attwell & Hughes, 2010:20; Low, 2013; Vygotsky, 1978a:80).

The Internet is a multifaceted media application which allows Mathematics teachers to have personal experiences. Firstly, the Internet has a massive compilation of resources with information about educational events, the latest news on educational developments, curriculum related documents, research papers, Mathematics lesson plans, Mathematical software, and more. Secondly, the Internet is a platform where Mathematics teachers can publish their own initiatives of resources (lesson plans, PowerPoint presentations, video clips etc.) applicable to Mathematics teaching and learning and make it available to the broader public to access and use within their classrooms. Thirdly, and more applicable to PD and the ZPD, the Internet creates the medium where Mathematics teachers virtually interact through Cyberspace with colleagues and peers This vast array of technologies which can be used as computer-mediated communication (CMC) all add to the development of the social identity of Mathematics teachers (Chute *et al.*, 1999:4).

If a school motivates peer learning within a school environment it is to ensure that a sense of identity is established. During PD activities Mathematics teachers with versatile skills, diverse PD requirements, and varied learning styles come together and interact within their groups where they share experiences, best practices and ideas (Da Ponte, 2010:8). Novice Mathematics teachers obtain the opportunity to learn from expert Mathematics teachers in a relaxed atmosphere with no hierarchical separation between experts and novices. Mathematics teachers within their school environment are united by a common goal: PD for the pedagogical use of ICT for the effective teaching and learning of Mathematics. Within their groups they converse on aspects related to PD, they come to an agreement on what constitutes the nature of their work, and plan pathways to future PD activities (Attwell & Hughes, 2010:103). Grove *et al.* (2004) believe that teachers form their identities during these activities and it is not necessary to conduct these activities in a technology rich environment. Enochsson and Rizza (2009) disagree when they advocate that teachers should develop their identities in an environment where they can embrace the new technologies. ICT training in a technology-enabled environment ensures that the training within the school environment is valued and logical (Da Ponte, 2010:2) and the ZPD can be addressed as well (Attwell & Hughes, 2010:20).

For Mathematics teachers to develop their SPI the external and internal contributors must be present: the school should establish a community of practice conducive for ICT integration; the organisation should focus their PD on the ZPD of each teacher; teachers should adhere to the roles and responsibilities of a teacher as stipulated within the policy (Education Labour Relations Council, 2003:A49-50); teachers should interact with their peers and expert teachers regarding ICT use for teaching and learning; teachers should accept ICT as an integral part of Mathematics teaching and

learning; and teachers should adopt a positive attitude towards the latest ICT trends and innovations (Attwell & Hughes, 2010:103; Da Ponte, 2010:2; Rynänen, 2001:98).

The *CPTD Management System* aims to assist teachers to systematise and direct their PD to achieve utmost advantage and acknowledgment from the process (Department of Education, 2010:14). The role players should first enquire from the participating teachers their developmental requirements, then select the appropriate PD tools to develop the SPI of Mathematics teachers (Loucks-Horsley *et al.*, 2010:81). Multiple methods can be used in this assessment process—however; it depends who initiates the PD. If the DBE, in collaboration with the provincial offices, wants to develop a PD programme for ICT integration, they should make a holistic analysis of the PD needs of Mathematics teachers within the province (Lessing & De Witt, 2007). Research indicates that a generic PD programme for ICT implementation and integration is not the solution as the individual needs of Mathematics teachers are not taken into consideration (Daly *et al.*, 2009:82); consequently SPD will not occur, and the ZPD will not be addressed (Vygotsky, 1978a).

In order to determine the PD needs of Mathematics teachers, a PD instrument to make a needs analysis. A survey to conduct a needs analysis is one method by which the DBE can determine the PD needs of Mathematics teachers. In South Africa after SITES 2006 (Mofokeng & Mji, 2009:1613) an instrument was distributed to 35 schools in the Gauteng province, to 58 Mathematics and Science teachers to assess whether they used ICT in their teaching and their preferred structure of PD. Teachers had to indicate whether they had (a) attended (b) not attended or (c) wished to attend training involving different aspects of computer usage. Only 41% of the participants had attended introductory courses; twenty percent participated in ICT integrated courses; and 59% aspired to attend ICT integrated courses (Mofokeng & Mji, 2009:1613). However, the instrument did not make a holistic analysis of individual needs for PD of these teachers and it represented a small sample of the Mathematics teachers in the province.

Khanya in the WCED (Western Cape Education Department, 2011), WebQuest and IntelTeach (SchoolNet, 2008) and VPN (Vodacom, 2012) were ICT training projects launched by the DBE and PDEs. These projects completed their cycle due to either completion or shortage of funds (Western Cape Education Department, 2011), however a question arises: did the DBE through the participants do a reflection of the successes and shortcomings of these initiatives? When PD instruments are used it is imperative to assess whether the PD activities were successful and aligned with the aims of PD. Mathematics teachers could write a journal or an autobiography (Li, 2005:221), complete a survey after each phase of the course (Hartsell *et al.*, 2009:56), or participate in online discussion groups during the course (Li, 2005:221) in order to obtain information to assess and evaluate their ICT PD projects. This information would enable the DBE, provincial offices and the school to address the barriers emphasized during the reflection.

3.3.1.4 Community of School Environment

The *community* of school environment comprised one code: feedback on PD courses (Figure 3.5). Mathematics teachers are central to the development process; therefore it is valuable for the DBE, the PDE and school to get feedback from the Mathematics teachers on the PD courses. Some Mathematics teachers were excited and positive about the PD courses they attended and others felt despondent and negative. Many Mathematics teachers started the PD course with a negative attitude, but during the course they changed their pre-conceived ideas (Li, 2005:6).

The positive feedback from the Mathematics teachers related to: (i) the dynamics that were strong during combined group work sessions that made it a major contribution towards their PD; (ii) the commitment in their groups that made them comfortable to share in the process their SPI developed; (iii) teachers' commitment to become a member of the group they when they conquered their self-consciousness (Da Ponte, 2010:152); and (iv) the effective development of PD within their existing school environment with their own ICT equipment (Swan *et al.*, 2002:173). From these observations it becomes evident that Mathematics teachers prefer to engage in group activities for PD. However, it is important that mutual respect exists among the members in the school environment to promote and encourage creativity and collaboration (Loveless *et al.*, 2006:5).

Mathematics teachers negative to PD courses maintained that: (i) there was too much focus on basic computer skills training and too little emphasis on the application of skills for the teaching and learning of Mathematics (Attwell & Hughes, 2010:55; Daly *et al.*, 2009:19); (ii) there was an abundance of once-off and external programmes for PD, (iii) most of the courses were generic and did not address the specific context of their schools (Daly *et al.*, 2009); (iv) many of the Mathematics teachers became despondent because of the tactless opinions of people (service providers) outside the teaching profession (Attwell & Hughes, 2010:59); (v) many of the ICT technologies were underutilized during the PD courses; (vi) many of the participants did not have access to these technologies for PD (Broadley, 2011:7); and (vii) countless PD presentations were disorganised and fragmented (Younie, 2006:395). From the above reflections, many of the negative experiences were caused by organisation and presentation of PD activities.

The Mathematics teachers who were negative at the outset of the PD changed their opinions due to the following reasons: (i) they overcame the obstacles like time constrains and curriculum uncertainties; (ii) they learned that the experiences they gained outweigh the obstacles (Da Ponte *et al.*, 2002:11-16); (iii) they mastered the educational software such as the Geometer's Sketchpad (GSP) and Modellus2 (Da Ponte *et al.*, 2002:5-6); and (iv) when they changed their opinion of what constitutes a teaching and learning environment (Hartsell *et al.*, 2009:54).

Many of these opinions also related to the type of and context of the PD courses these Mathematics teachers attended. Therefore, it is important when the role players design PD activities for

Mathematics teachers certain contextual characteristics, content requirements, and organisational aspects must be kept in mind (Chute *et al.*, 1999:66-67; Daly *et al.*, 2009:69).

3.3.1.5 Rules of School Environment

The *rules* relate to one code: contributors to SPI (Figure 3.5). There are certain aspects within the school environment which contribute towards the formation of the SPI. Within the school environment the school management must create opportunities for Mathematics teachers to develop their SPI. The School Management Team (SMT) should motivate their staff to establish an online network group to share their expertise and insecurities as it is an important element of the teachers' SPI (Da Ponte *et al.*, 2002:111). When teachers interact and engage in a professional setting with their peers they can make a paradigm shift as they observe how others present lessons, communicate their fears and uncertainties, and share their views on best practices (Hartsell *et al.*, 2009:62). Mathematics teachers feel empowered as these activities give a sense of cooperative endeavour, and they start to feel secure in their environment (Li, 2005:229). For a school community to operate as a unit, it should create a shared repertoire of ideas, obligations and memoirs (Attwell & Hughes, 2010:18). Mathematics teachers in South African tend to conduct their work in more isolated settings and when they do communicate in an online network group their discussions are rather superficial (Van der Merwe *et al.*, 2011).

3.3.1.6 Division of Labour in School Environment

The *division of labour* comprised one code: PD course structures and activities (Figure 3.5). Versatile course structures and activities were used for PD of Mathematics teachers over short (two weeks) and long (one year) periods. Each of the courses had a particular focus. The courses which extended over a long period were contextualised, Mathematics teachers could engage in hands-on activities, and at the end they could reflect on what they had learned (Da Ponte, 2010:4). The short courses focused on equipping teachers to utilise the software applications for Mathematics teaching and learning (Hartsell *et al.*, 2009:56-57). From the feedback of PD activities (§ 3.3.1.4) certain suggestions are made when a school designs PD activities, consequently the tasks executed by each member within the school environment and the structure of the courses and activities link closely to these recommendations.

The following section provides a systematic description of how the above categories of the theme of school environment adopts to the interrelated elements of the activity system.

3.3.2 School Environment as Activity System

Figure 3.6 displays the *School Environment activity system* with the interactive object, subject, tools, rules, community, and division of labour as elements of the school environment activity system.

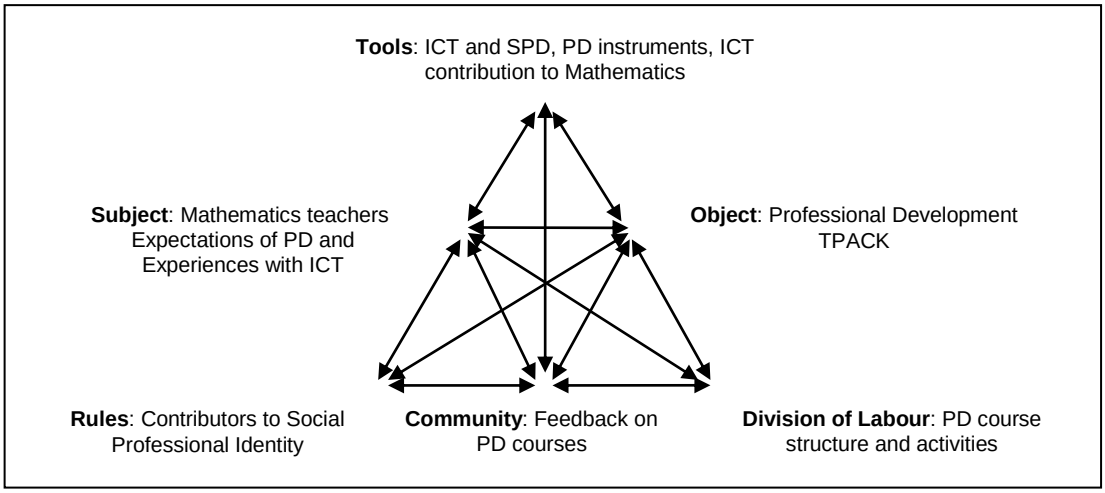

Figure 3.6: School Environment as Activity System (Adapted from Engeström (1987))

This section discusses how: (i) the mediated interaction between the subject, object, and community function towards achieving the outcome of the activity (Engeström, 1987), and (ii) the categories (objects, subjects, tools, rules, community, and division of labour) conceptualised as elements of *School Environment* structure an activity system (Figure 3.6) (Kuutti, 1996). Figure 3.7 illustrates the primary and secondary contradictions in the activity system (Barab & Plucker, 2002:172; Engeström & Sannino, 2010:7).

The object of the school environment activity system is to achieve the objectives of PD, and to develop guidelines for the professional development of Mathematics teachers (Phase III of the e-Education policy) in ODL. The Mathematics teachers' expectations and experiences (subject) use and assess a variety of tools (ICT contribution to Mathematics, ICT and SPD, and PD instruments) to achieve the object. The community comprises feedback of PD courses. The feedback of the PD courses is mediated by explicit and implicit rules: contributors to SPI. To achieve the objectives of PD and TPACK of Mathematics teachers, the DBE, the PDE, and school leaders should listen to Mathematics teachers' expectation and experiences. The DBE, PDE, and schools should evaluate the division of labour (PD course structure and activities) and acknowledge the feedback on PD courses (community). They should use the constructive advice which mediates the relation between the Mathematics teachers' expectations and experiences and the objectives of PD and TPACK of Mathematics teachers (Figure 3.6). The six interrelated elements of school environment interactively and individually contribute to achieve the object of the activity.

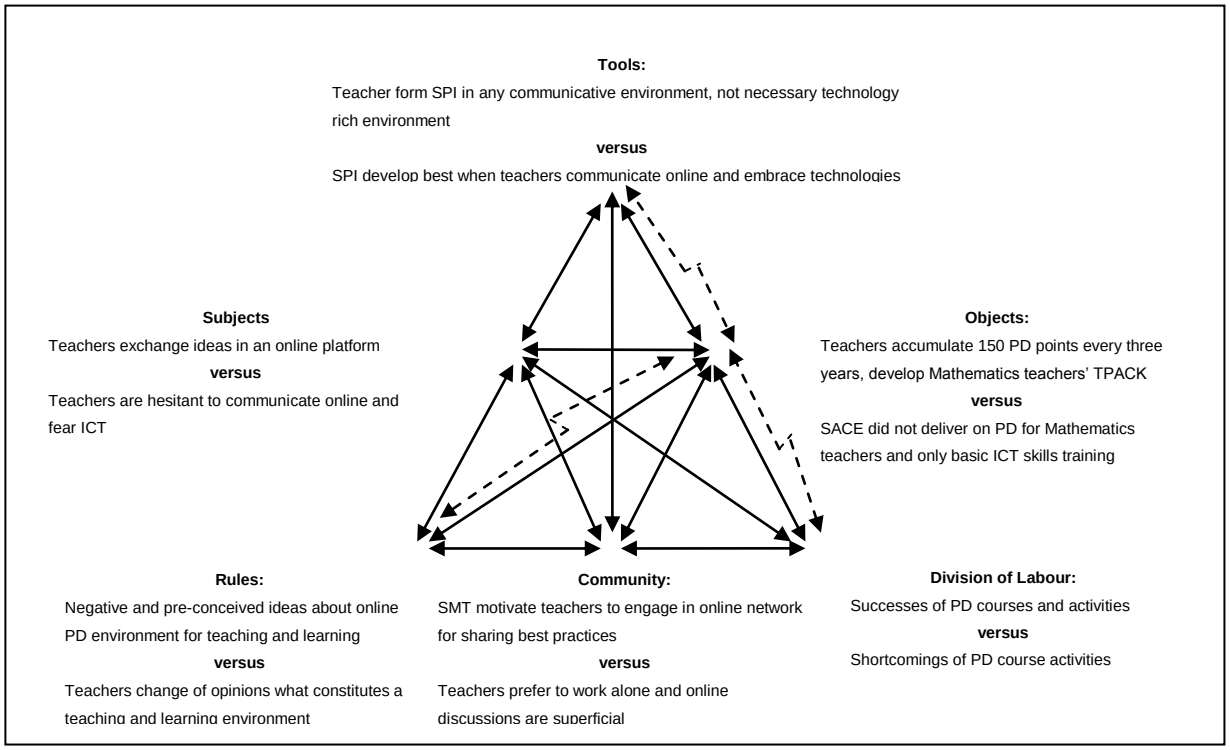

Figure 3.7: Mediated Relationship between the Subject and Object, and Interrelations among the Elements of School Environment Activity System

Figure 3.7 illustrates the mediated relationship between the subject and object of the School Environment activity system as well as the interrelations among the various elements of the activity system. The figure also elucidates the primary contradictions within each code of the activity system. The split dashed arrows indicate the movement of the secondary contradictions (tensions, predicaments, and interventions) between the elements of the activity system.

3.4 Open Distance Learning

Open distance learning is a method of learning with the freedom of time and flexible opportunities to develop and master knowledge and skills. Distance education, also known as distance learning, is when the bulk of teaching is conducted with the teacher and learner geographically removed from each other (Picciano, 2000). The *open* refers to open access, and autonomy to choose what, when, and where to learn (Bollinger & Martindale, 2004:61). Openness in distance learning is seen as the accommodating organisational structures, delivering methods of PD, and communicating mediums used to support learning (United Nations Education Scientific and Cultural Organisation, 2003). ODL and DL in the South African context is a flexible PD service offered by HEIs, to practising teachers, across geographical distances and socio-economic barriers (Kanuka & Conrad, 2003a). With the use of on-line synchronous learning technologies teachers and learners are *face-to-face* in a virtual space rather than physical space (Attwell & Hughes, 2010:81). Over the last decade, in South Africa, forty per cent of university enrolments have related to DL students, which outweigh the 28% of full time students. In 2009, 25% of graduates qualified through ODL. DHET promotes PD in a network of

distance education providers to coherently attain the outcomes of the e-Education policy and create a network of distance education providers (Department of Education, 2012a). ODL is the preferred mode of development for the future. The DBE wants to encourage service providers to offer distance education programmes for the PD of teachers in the GET and FET band (Department of Education, 2012a:71-72).

3.4.1 Theme 3 of Literature Analysis: Open Distance Learning

The following section discusses the theme *Open Distance Learning* conceptualised from the inductive analysis with Atlas.ti™ (Figure 2.4). The theme of ODL is discussed in the following sections according to its six categories: (i) objects of open distance learning, (ii) subjects of open distance learning, (iii) tools of open distance learning, (iv) community of open distance learning, (v) rules of open and distance learning, and (vi) division of labour of open distance learning (Figure 3.6).

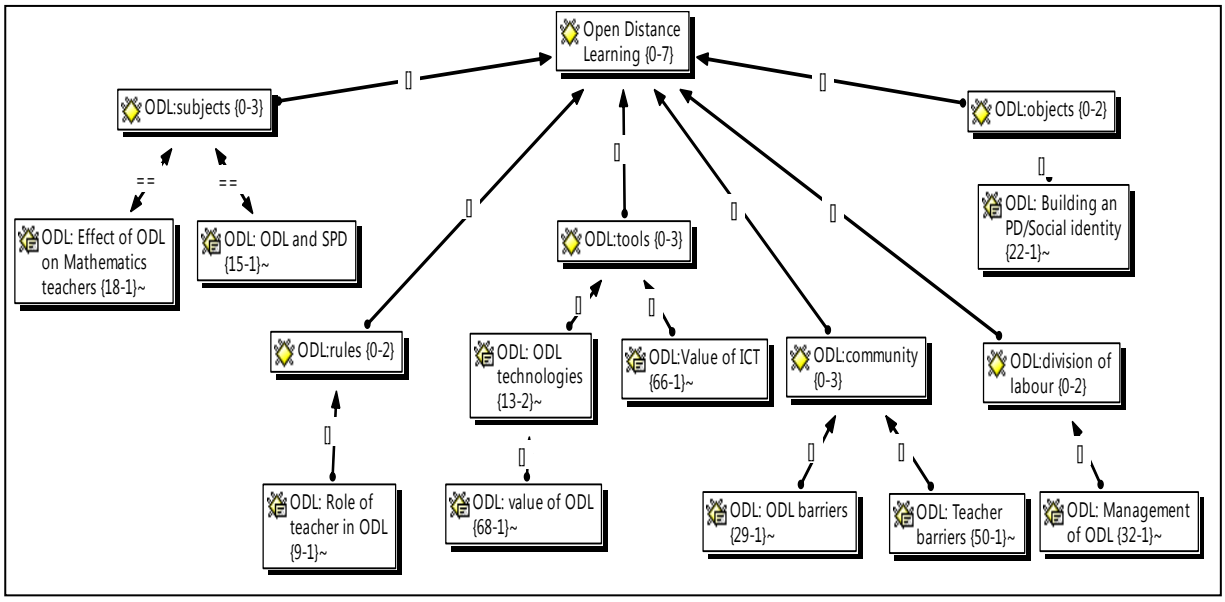

Figure 3.8: Open Distance Learning as Theme from Literature Analysis

3.4.1.1 Objects of Open Distance Learning

The object of ODL comprised one code: building a SPI (Figure 3.8). Building a professional identity is a process which should not be enforced on the Mathematics teachers. The roles and responsibilities of an educator are stipulated within the code of conduct which all educators should adhere to while dealing with professional concerns (Education Labour Relations Council, 2003:C24). These features deal with external contributors to the professional identity. More essential are the internal contributors to developing a professional identity is for Mathematics teachers to have a positive attitude towards PD and self-commit to develop and improve their Mathematical knowledge and skills (Da Ponte, 2010:145). The external and internal contributors coherently contribute towards building a professional identity. The school environment aims to structure a learning environment which instil a

positive attitude towards the use of ICT for the teaching and learning of Mathematics (Da Ponte, 2010:149). In order for PD to be effective the DBE, the WCED, and the school should create a school environment which provide Mathematics teachers with a positive experience during PD and motivate teachers to take ownership of their learning (Da Ponte *et al.*, 2002:2; Daly *et al.*, 2009:27; SchoolNet SA, 2012). Swan *et al.* (2002:4) advocate seven factors within the school environment which have an influence on the failure or achievement of PD training programmes. The school should in advance: (i) assess the local equipment and software; (ii) develop teacher-initiated PD programmes; (iii) evaluate the programme situation; (iv) consider the local culture; (v) appraise the attitudes and beliefs of Mathematics teachers; (vi) require continuous support for PD from the school; and (vii) contemplate a learner-focused PD programme (Swan *et al.*, 2002:8-11). Mathematics teachers should have free access to ICT equipment and technical support to prevent demotivation and shortage of confidence (Attwell & Hughes, 2010:62). Teachers will become positive towards PD and their own learning only when the PDE addresses these factors. To develop a positive attitude towards ICT as tool for teaching and learning, the PDE, and the school should motivate teachers to use educational software, produce online lesson content, and create Mathematics web pages which they can utilize during their PD process (Da Ponte *et al.*, 2002:2; Daly *et al.*, 2009:31).

PD through ODL unlocks the *zone of transitional development* for Mathematics teachers' learning with ICT to address the gap between the actual developmental level of an individual and the potential developmental level (Attwell & Hughes, 2010:20). Mathematics teachers' existing knowledge, skills and prior experiences are used as a base of scaffolding to accumulate new knowledge, but within their potential (Attwell & Hughes, 2010:21; Bozhovich, 2009:52). ODL as mode of PD within an organisation is a feasible method to provide Mathematics teachers with PD activities as: (i) it allows PD activities to concentrate on their individual ZPD; (ii) it can accommodate teachers with versatile ZPD; and (iii) it can develop the social professional identity of Mathematics teachers (Da Ponte, 2010:146). Within an organisation the ODL platform allows for Mathematics teachers with different ZPD and versatile learning styles to develop their TPACK based on their individual PD needs (Daly *et al.*, 2009:9).

On an intrinsic level in asynchronous discussions Mathematics teachers can reflect on their thoughts and beliefs in order to improve their attitudes towards PD. Da Ponte (2010:152) indicates in his study with Mathematics teachers on an ODL platform, that teachers acknowledged that it was an exhilarating experience to be able to connect and share with their peers. Mathematics teachers become less self-consciousness of their individual shortcomings, and more sociable, which make the learning and the enhancement of their SPI possible (Da Ponte, 2010:152). On a cognitive level Mathematics teachers can: (i) share their competencies with their peers in a virtual environment where distance and time constraints is not an issue; (ii) explore the possibilities of the ICT with the assistance of their peers and experts from different organisations; (iii) cultivate new perspectives on the use of ICT in Mathematics teaching and learning; (iv) can grasp how different CK connect; and (v) develop their TPACK essential to realise the objectives of the e-Education policy within and outside their

organisation (Da Ponte, 2010:154; Leendertz *et al.*, 2013:5). Most importantly, for PD to take place, the school should provide sufficient onsite support and opportunities to enable Mathematics teachers to feel confident to access the online environments (Chute *et al.*, 1999:38). Research indicates that Mathematics teachers' attitudes are in place; however, the existing context of the schools globally and in South Africa is not conducive to provide PD of this magnitude (Da Ponte, 2010:158).

3.4.1.2 Subject of Open Distance Learning

The subject of open distance learning comprised two codes: (i) ODL and SPD, and (ii) the effect of ODL on teachers/Mathematics teachers (Figure 3.8).

PD of Mathematics teachers in an ODL environment involve more than mere development of pedagogical competencies, but any PD activities should focus on the holistic development which includes aspects that relate to individual and social development (Day, 1999). Therefore the PD of Mathematics teachers are a multifaceted process in their professional, cultural and social context to improve the quality of their work within their classrooms and at school. Only when teachers are developed as an entire being will the process reach maximum result within the school and education community (Da Ponte, 2010:146) and progress are made to reach the objectives of the e-Education policy.

Mathematics teachers, who engaged in PD in an online environment through written communication, reflected on their classroom practices (Da Ponte, 2010:152; Department of Education, 2004b:20), improved their teaching and learning, resolved uncertainties regarding Mathematics teaching, shared information with their peers, and focussed on the objectives of the subject. The Mathematics teachers realised that they are participants the teaching and learning process, but were concerned about the teaching community, the hard work needed to raise the standard of classroom teaching, and the commitment of some of their colleagues (Da Ponte, 2010:152-153).

In an online environment Mathematics teachers are required to depend on their written communication skills. This compels them to reflect on their classroom practices and share their thoughts and PK (Da Ponte, 2010:154). When Mathematics teachers engage in online discussion they assume professional values and attitudes. The professional values and attitudes focus on the importance of self-discovery and exploration with various ICT tools and the essential role of collaboration and discussion of Mathematics teachers with their peers. During these processes Mathematics teachers develop their professional identity (Da Ponte *et al.*, 2002:112).

3.4.1.3 Tools of Open Distance Learning

The *tools* of open distance learning comprised three codes: (i) value of ICT (ii) ODL tools, and (iii) the value of ODL (Figure 3.8).

ICT affords prospects for Mathematics teachers to prepare their teaching and learning strategies, deliver the Mathematics content to their learners, assess the initiatives of their learners, cater for learners with versatile learning styles, and communicate information and practices with other Mathematics teachers (Da Ponte, 2010:145). ODL tools and technologies are available to implement PD in an online environment. The PD needs of the organisation determine which ODL technologies to use to achieve the outcomes of the PD. Being predetermined, the development of the SPI of the Mathematics teachers is central in the PD process and the ODL technologies used should promote the development of constructivist strategies (Da Ponte, 2010:147; Driscoll, 1994). Virtual learning environments (VLEs) link the knowledge resources with Mathematics teachers, their organisations, and the existing knowledge accessible within the virtual environment (Agostini *et al.*, 2011:56) to sustain the development of social networks for learning (Fischer, 1995). Through the use of Weblogs, ePortfolios, and social networks, the organisation enhances the e-learning, augments knowledge management, and develops communities of practice (Razavi & Iverson, 2006). With the introduction of web-based learner management systems (LMSs) like Moodle, Totara, Learnanywhere, WebCT, Blackboard and eClass it has become easy for teachers to create e-Learning environments (Pearson & Trinidad, 2004:1). Currently only higher education institutions in South Africa make use of a LMS (Mlitwa, 2006).

As Mathematics teachers best develop their SPI within a social context ,an asynchronous discussion forum is a method to engage teachers in group discussion and to enhance their SPI (Da Ponte, 2010:146). Personal Learning Environments (PLEs) improve social networking, collaborative learning, and develop e-learning tools (Wilson, 2006). PowerPoint or Hyperstudio presentations can be used in ODL spaces used for to augment online threaded discussions. Virtual spaces allow Mathematics teachers to interact and communicate to develop their Mathematical competencies (Razavi & Iverson, 2006). PLEs are boundary objects which assist the change within the ZPD between the knowledge in a traditional face to face PD course and the knowledge needed for the effective integration of ICT at school (Attwell & Hughes, 2010:22). PLEs include a collection of Web 2.0 technologies which are used for working, learning, reflecting and collaborating with other Mathematics teachers and peers within and outside their organisation (Attwell & Hughes, 2010:37). PLEs use social software for informal learning which is learner-centred, problem-based and motivated by individual needs. With the use of PLEs it is possible to accommodate Mathematics teachers with different ZPDs, and shift the focus from integrated learning platforms such as VLEs or course management systems (Attwell & Hughes, 2010:37). Additionally, Mathematics teachers within the organisation can use PLEs to device their own PD plans (Attwell & Hughes, 2010:56).

3.4.1.4 Community of Open Distance Learning

The *community* of open distance learning comprised two codes: (i) ODL barriers, and (ii) teacher barriers in ODL (Figure 3.8).

Many participants experienced communication to be one of the profound barriers in ODL. In ODL most of the communication occurs by means of email and Mathematics teachers with diverse needs, interests and with different levels of knowledge and skills, form part of one group. Many online PD initiatives do not focus on evaluating the transformation of the TPACK of teachers in an online forum (Daly *et al.*, 2009:36). Broadley (2011); Da Ponte (2010:152-153) conducted PD activities with Mathematics teachers using ODL as platform and realised that during group discussions the participants do not focus on curriculum development and classroom dynamics which is the central aim when creating these platforms of communication. Mathematics teachers feel that the distance causes estrangement between the members of a group and some human contact is vital for PD. Organisations identified the following barriers to ODL: (i) insufficient skills of service providers to conduct PD online, (ii) shortage of time to execute e-Learning, (iii) the inadequate knowledge of the possibility of online learning, and (iv) quality of online resources (Attwell & Hughes, 2010:33). Even though online forums are becoming a mode of communication for PD, instructors find them difficult to manage (Daly *et al.*, 2009:37). For e-Learning to be successful, teachers should have frequent access to reliable infrastructure (Department of Education, 2004b), and therefore organisations should address the barriers within their organisations. The inequities regarding the provision of resources and access to the World Wide Web (WWW) make it challenging for DE providers and other institutions in South Africa to optimally utilise this mode of service delivery (Department of Education, 2012a:56).

In summary, this section relates to teacher barriers in ODL. The internal barriers relate to the individual (Mathematics teachers). During online PD Mathematics teachers feel separated from their subject community and often find it hard to express their thoughts in writing. Many teachers are apprehensive towards ICT due to their level of skills, and experience difficulties to complete assignments (Da Ponte, 2010:159). Mathematics teachers do not use the online tools to enhance their teaching and learning practices as they are suspicious of the use of ICT for Mathematics teaching and learning (Da Ponte *et al.*, 2002:94). They are often reluctant to participate in critical discussions on best practices (Prestrige, 2007:255). The discussions in the forum promote collegiality, but cannot ensure that it encourages learning (Daly *et al.*, 2009:35).

3.4.1.5 Rules of Open Distance Learning

The *rules* of open distance learning comprised one code: role of teacher in ODL (Figure 3.8). Mathematics teachers are central role players in PD and commence and motivate the participation in ODL PD (Prestrige, 2007:254). The roles of the teachers change as they execute tasks, participate in online discussions, and evaluate their peers within their group (Van De Westeringh, 2003:6).

Mathematics teachers should: (i) have a comprehensive and profound understanding of the subject, (ii) use versatile methods to transfer the knowledge to their learners, and (iii) provide constructive feedback to their group. Mathematics teachers in an online environment should have the: (i) expertise to continuously update their skills; (ii) PK and adapt to a changing environment; (iii) deep understanding of ICT; and (iv) ability to collaborate and function in an online learning community (Van De Westeringh, 2003:7).

3.4.1.6 Division of labour in Open Distance Learning

The *division of labour* in open distance learning comprised one code: the management of ODL (Figure 3.8). ICT PD in an online platform should focus on the transformation of Mathematics teachers' TPACK, which is currently not being developed within the existing context of PD (Daly *et al.*, 2009:19). PD in an online environment should take place in three segments: (i) developmental, which focuses on how Mathematics teachers acquaint themselves with the diverse technological resources; (ii) experimental, which concentrates on how Mathematics teachers expand their Mathematics CK through technology, and (iii) instructional which guides Mathematics teachers to apply the TPACK to develop instructional material (Da Ponte *et al.*, 2002:97). The majority of present PD activities motivate collegiality, but are not created according to the three segments, with no long term goals in mind, and do not support the PD process of Mathematics to accumulate knowledge and skills for teaching and learning (Daly *et al.*, 2009:35). Even though many of the constraints are not within the power of the school, the school can supply Mathematics teachers with access to ODL and technology to accelerate the process of ICT integration in schools.

For a school to function in an ODL platform the school should: (i) produce a suitable and shared range of ideas, commitments and management initiatives, and (ii) select the appropriate resources to build the professional identity of the Mathematics teachers within the school. ODL is an established method of in-service training for practising teachers in South Africa, but a new mode for PD training for teachers in the United Kingdom (Daly *et al.*, 2009:15), and especially in South African school context. Abundant ICT PD initiatives through ODL are implemented across many countries with great success (Daly *et al.*, 2009:35). However, these ODL PD initiatives conducted in countries like Western Australia, Hong Kong, (Pearson & Trinidad, 2004), Portugal, and Brazil (Da Ponte *et al.*, 2002:146) have not yet reached the South African educational institutions across the nine educational districts.

The subsequent sections provide a systematic description of how the above categories of the theme of open and distance learning adapt to the interrelated elements of the activity system.

3.4.2 Open Distance Learning as Activity System

Figure 3.9 displays the *Open Distance Learning* activity *system* with the interactive object, subject, tools, rules, community, and division of labour as the elements of ODL.

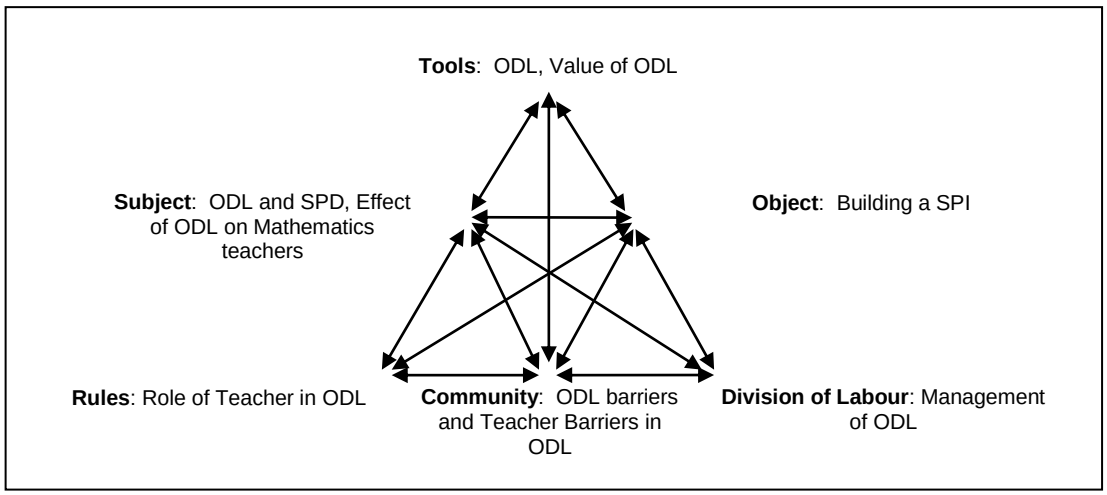

Figure 3.9: Open Distance Learning Activity System (Adapted from Engeström (1987))

The following section discusses (i) how mediated interaction between subject, object, and community function towards achieving the outcome of the activity (Engeström, 1987), and (ii) how the categories (objects, subjects, tools, rules, community, and division of labour) conceptualised as elements structure an activity system (Figure 3.9) (Kuutti, 1996). Figure 3.10 illustrates the primary and secondary contradictions in the activity system (Barab & Plucker, 2002:172; Engeström & Sannino, 2010:7).

The object of an ODL activity system develops Mathematics teachers' SPI with the outcome to develop guidelines for the professional development of Mathematics teachers in the pedagogical use of ICT (Phase III of the e-Education policy) in ODL. The subject (ODL and SPD, effect on ODL on Mathematics teachers) requires knowledge of the various ICT and ODL tools (value of ICT, ODL tools, and the value of ODL) to achieve the object. The community comprises management of ODL. The management of ODL is supported by implicit rules: the role of the teacher in ODL. To build a SPI, the DBE, PDE, and school leaders should address the ODL barriers and the teachers' barriers in ODL. Building a SPI of Mathematics teachers is achieved by managing ODL (division of labour) through addressing the ODL and teacher barriers (community), which consequently mediates the relation between the subject (ODL and SPD, and effect of ODL on Mathematics teachers) and the object (Figure 3.7). The six interrelated elements of school environment interactively and individually contribute to achieve the object of the activity.

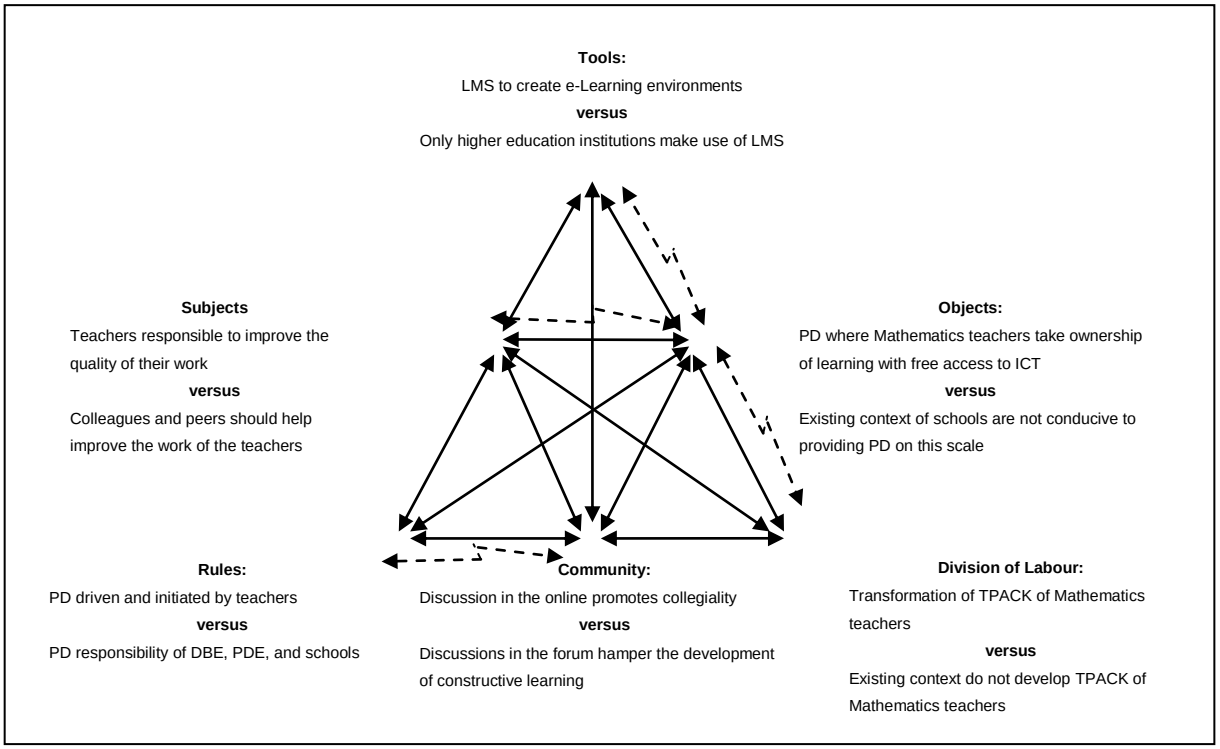

Figure 3.10: Mediated Relationship between the Subject and Object, and Interrelations among the Elements of Open and Distance Learning Activity System

Figure 3.10 illustrates the mediated relationship between the subject and object of the ODL activity system as well as the interrelations among the various elements of the activity system. The figure also elucidates the primary contradictions within each code of the activity system. The split dashed arrows indicate the secondary contradictions (tensions, predicaments, and interventions) between the elements of the activity system. Secondary contradictions identified in this activity system were between the (i) community and the rules (currently Mathematics teachers do not use online tools to develop their PCK even though they are expected to function in an online environment), (ii) object and the subject (collaboration and discussion in an online environment and the importance of self-discovery and exploration), and (iii) tools and objects (schools access to VLEs and PLEs versus the context of schools in South Africa regarding access to VLEs, and PLEs).

Within the activity system, the operations and conditions can hamper the development of the SPI of Mathematics teachers. The actions within this activity system can either contribute or obstruct the activity in the ODL activity system. Additionally the DBE, PDE, and school should address the needs which are fundamental for all the interrelated aspects of the activity system to function as a unit of analysis and to achieve the aim of the activity system.

3.5 Professional Development

PD is a means to support teachers in their workplace, and understand their context, roles and responsibilities better. It is an on-going process throughout teachers' careers (Attwell & Hughes, 2010:80) to upgrade their knowledge, skills and competencies especially those who are not proficient to deliver the curriculum achieve the outcomes of policy (Hartsell *et al.*, 2009:53).

3.5.1 Theme 4 of Literature Analysis: Professional Development

The following section discusses the theme *Professional Development* as conceptualised from the inductive analysis with Atlas.ti™ (Figure 2.4). The theme of professional development is discussed in according to six categories: (i) objects of professional development, (ii) subjects of professional development, (iii) tools of professional development, (iv) community of professional development, (v) rules of professional development, and (vi) division of labour of professional development (Figure 3.11) (next page).

3.5.1.1 Objects of Professional Development

The *object* of the professional development comprised two codes: (i) PD characteristics and (ii) PD through ODL (Figure 3.11).

This section discusses the typical and distinctive features of PD. PD is a complex process in which the teachers are occupied as their professional, cultural and social context with their colleagues and peers (Da Ponte, 2010:146). Included within PD is also the provision of resources, tools and opportunities to facilitate the teaching and learning process (Daly *et al.*, 2009:64-65). PD is a key strategy in education reform (Loucks-Horsley *et al.*, 2010:68) for quality Mathematics teaching and learning (Hartsell *et al.*, 2009:53). The PD of teachers include all the learning experiences of a teacher—natural and planned—whereby teachers gain knowledge and skills to support the quality of their work with their learners and the with other participants in educational institutions (Day, 1999:107). ICT PD is the development of Mathematics teachers in order to use computer-based tools (Prestrige, 2007:252) for teaching and learning. PD of Mathematics teachers for ICT integration in the curriculum is a multifaceted process to: (i) develop Mathematics teachers' TPACK; (ii) improve their critical reflective skills (Daly *et al.*, 2009:18); (iii) develop their SPI (Da Ponte, 2010:146) and (iv) achieve the outcomes of the e-Education policy (Department of Education, 2004b).

PD through ODL contributes towards achieving the aims of e-Education policy. PD is a complex process (Daly *et al.*, 2009:18) and many issues must be taken into consideration when the DBE and the PDE plan and development PD courses. The DBE and the PDE should use the professional standards to plan and evaluate CPTD (Ofsted, 2010:6).

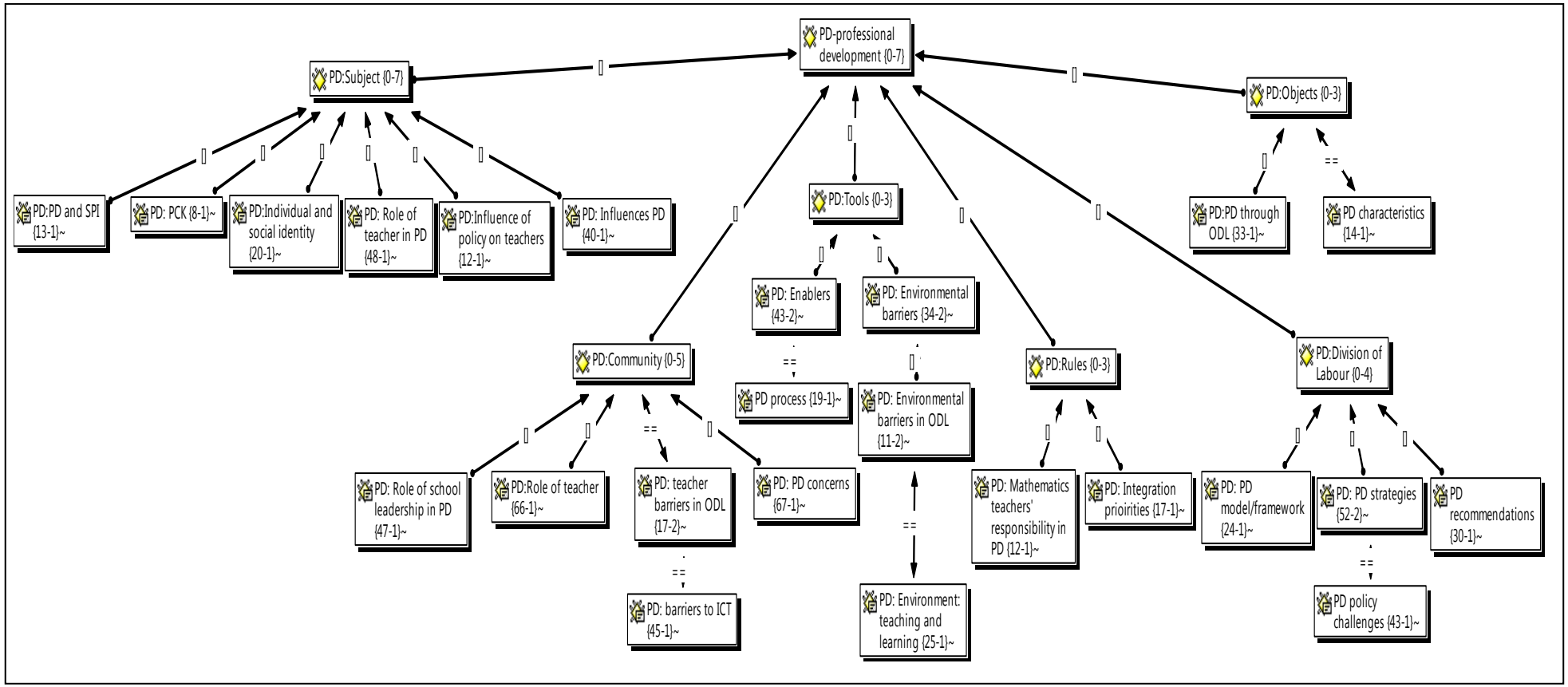

Figure 3.11: Professional Development as Theme from Literature Analysis

PD in an ODL platform ICT PD considers the restructuring from a upgrading of skills orientation to the establishment of *transformative outcomes of ICT PD* (Prestrige, 2007:252). A skills development programme aligned with the CPTD management system should be developed for all teachers in the GET and FET bands (Department of Education, 2010).

The DBE expects Mathematics teachers to be prepared in order to embrace ICT for teaching and learning (Da Ponte *et al.*, 2002:107). Even though the DBE has good intentions with the introduction and integration of ICT in the pedagogy, the inadequate planning of ICT integration strategies makes the current ICT initiatives fail admirably (Mofokeng & Mji, 2009:1613). Mathematics teachers are expected to accept the indistinguishable value of ICT and adopt it for teaching and learning without any strategic planning and assessing from the DBE (Daly *et al.*, 2009:24). The absence of an ICT action plan for ICT integration allows for Mathematics teachers to have an overload of work, a shortage of time for collaboration and reflection which encourage individualism, and hamper the development of the SPI (Daly *et al.*, 2009:82). Through its own negligence the DBE is confronted with a system which is under strain regarding the provision of resources. Therefore the DBE encourage DL providers to offer programmes for PD of teachers and lecturers in the GET and FET band (Department of Education, 2012a:56-57).

Section 3.4.1.1 provides a detailed description of the benefits for Mathematics teachers in developing their SPI when PD takes place in an ODL platform. When Mathematics teachers engage in PD through ODL, it is possible for them to accomplish certain of the roles described in the Norms and Standards of Educators which include: (i) mediator of learning; (ii)interpreter and designer of learning programmes and material; (iii) leader; (iv)administrators and managers; (v) scholars; (vi)researchers and lifelong learners; (vii)assessor; and (viii) learning area or phase specialists (Department of Education, 2002a:11; Education Labour Relations Council, 2003:A48-53).

3.5.1.2 Subjects of Professional Development

The *subjects* of professional development comprised six codes: (i) PD and SPI, (ii) PCK, (iii) individual and SPI, (iv) the role of teacher in PD, (v) influence of policy on teachers, and (vi) influence of PD on teachers (Figure 3.11).

This segment discusses PD and SPI. During PD Mathematics teachers are involved professionally, socially and culturally. Professionally—to adhere to the roles and responsibilities of the teaching profession. Socially—to interact and communicate with their colleagues and peers. Culturally—to develop their personal and professional identity. The personal development of the Mathematics teacher includes the improvement of cognitive knowledge and social skills. Firstly Mathematics teachers develop their PCK to bestow learners with the knowledge, skills, attitudes and values. Secondly they improve their relations with their colleagues, peers and learners. Thirdly they promote their learners' development; and fourthly they accept the norms of interaction with learners and

colleagues. The professional identity is when they accept the standards, principles, roles and responsibility of the *teaching profession* (Da Ponte, 2010:146). The personal development, goes hand-in-hand with the professional identity (Attwell & Hughes, 2010:19). Mathematics teachers' professional identity evolves during socialisation when they engage with their peers and colleagues within their environment (Da Ponte *et al.*, 2002:112). Mathematics teachers are by nature fluent in numbers, but written communication may not come with the same fluency. When they communicate with their peers, they reflect on their current classroom practices within their school environment (Da Ponte, 2010:146). Human beings make sense from the patterns in their social encounters that take place over a period of time within their immediate context, current situation, and recent productions. Symbolic social interaction, also known as social constructivism, uses communication to delineate meaning and expand conceptual delimitation (Kanuka & Anderson, 1998:59). Through socialisation and written reflection Mathematics teachers: (i) create and connect ideas; (ii) share experiences and information (Anderson, 2002:129); (iii) accept positive criticism from their peers; (iv) defend their ideas own ideas, views and opinions; (v) develop lessons; and (vi) discuss at distance with their colleagues and online participants (Aceto *et al.*, 2010:6; Da Ponte, 2010:5; Loveless, 2011:306). Within the school environment the teachers interact and connect with their inner self, as a person and as a professional, which allow them to grow personally and professionally (Haberman, 2004:52).

When Mathematics teachers develop professionally they start to be part of a *community of practice* where they learn, construct meaning from their experiences, and gain PCK (Attwell & Hughes, 2010:19). PCK, specifies the interface between subject and pedagogical knowledge, also referred to as specialized content knowledge (Loucks-Horsley *et al.*, 2010:15). PCK becomes evident when teachers have the ability to build on their learners' prior knowledge and adapt their teaching strategies to best facilitate the new content to learners (Koehler, 2012). Mathematics teachers consequently then have the expertise to select the appropriate methods of teaching the content to learners (Daly *et al.*, 2009:38). For ICT to bring value to teaching it cannot be regarded as context-free as it should be linked to the pedagogy and content (Daly *et al.*, 2009; Mishra & Koehler, 2006:1026). When teachers familiarise themselves with ICT for teaching they development their TPACK which requires them to: (i) understand the representation of concepts with technology; (ii) use technologies in constructive ways to teach content; (iii) utilize technologies to teach difficult concepts; (iv) redress the learning problems of learners; (v) built on prior knowledge of learners; and (vi) construct new philosophies (Mishra & Koehler, 2006:1029). In order for Mathematics teachers to be proficient in ICT integration, the PD within their school context should promote the development of TPACK. When PD is directly linked to these experiences Mathematics teachers start to make a paradigm shift, develop TPACK (Attwell & Hughes, 2010:28) and become aware of the value of communication to develop their SPI (Cofflied, 2000:8; Zakaria & Daud, 2009:225). Therefore, socialisation is critical in PD of TPACK (Gratch, 2001:121). ODL is a platform—for socialisation with their colleagues and peers, and the formation and reformation of an SPI (Da Ponte, 2010:2), for teachers to become part of the *community of practice*, and uphold their professional culture (Attwell & Hughes, 2010:19).

Before any form of PD can take place, Mathematics teachers should assess their levels of professional knowledge and their TPACK (Daly *et al.*, 2009:27). As soon as teachers have awareness of their professional shortcomings, they are able to take proactive approaches to change their TPACK. When they are familiar with their TPACK limitations and needs, effective learning can take place in three phases: (i) an awareness of their PD, (ii) conscious engagement and reflection of their own learning; (ii) authentic collaboration which will lead to change in teaching practices (Daly *et al.*, 2009:30). Therefore, Mathematics teachers should develop an individual ICT PD plan to suit their needs and shortcomings. When Mathematics teachers have the freedom to attend PD based on their individual needs they will: (i) embrace ICT integration as the new mode of teaching and learning Mathematics; (ii) be open to revise their PD activities; (iii) become part of a community of practice where they collaborate and share ideas; (iv) accept classroom visits from experts and CAs; and (v) change their attitude and beliefs regarding PD (Daly *et al.*, 2009:82; Rodriguez, 2000:34). When Mathematics teachers change their attitudes and beliefs regarding ICT, their ICT skills develop and consequently their confidence will increase (Daly *et al.*, 2009:83).

Mathematics teachers are first and foremost the key initiators in change and the crucial element in PD (Broadley, 2011; Schibeci *et al.*, 2008:313). Their portfolios include teacher, mentor, helper, stimulator developer and supporter of teaching and learning programmes (Hartsell *et al.*, 2009:56). A Mathematics teacher performs his or her tasks and identifies with the role and responsibilities of the teaching profession (Da Ponte, 2010:4; Education Labour Relations Council, 2003:A49-50; SchoolNet South Africa & SCOPE, 2012). Accepting their roles and responsibilities requires teachers to regard ICT as an integral component to administer and deliver the curriculum (Department of Education, 2004b:15). Mathematics teachers should step outside the non-ICT culture that exists in schools and embrace the challenge and success of ICTs inside and outside of GET and FET institutions. Embracing the challenges requires Mathematics teachers to critically analyse and evaluate the ICT resources and its benefits, and converse with their colleagues to expand and assess their viewpoint on the benefits of ICTs (Department of Education, 2004b:16; Younie, 2006:15). Teachers must adopt critical analysis and evaluation as a continuous activity within their workplace (Broadley, 2011:9). When teachers make the paradigm shift from a product-directed method to a problem-centred approach, support mechanisms should be in place that allow them to communicate with colleagues and peers inside as well as outside their school. Additionally, they should have access to subject-specialised information, on current educational and pedagogical views, and on models of good Mathematics practices elsewhere (Van De Westeringh, 2003).

Owing to inadequate planning from the DBE for the integration of ICT in teaching and learning, the initiatives tend to collapse as Mathematics teachers avoid the use of ICT for teaching and learning (Mofokeng & Mji, 2009:1613). Teachers are expected to implement policy, they are motivated to believe that they should adopt ICT without any reservations, and in the process they forget to reflect on what is best to ensure quality teaching and learning (Cordingley *et al.*, 2007). The DBE wants a quick return on investment, but will not spend enough time to develop PD programmes, and does not

support the ICT PD for content-specific knowledge. Mathematics teachers are expected to implement policy without qualms (Zakaria & Daud, 2009:226). The DBE has a lot of stipulations built within the policy and teachers are expected to transform teaching and learning (Department of Education, 2002a:3), but the support structures to support teachers in these endeavours are virtually non-existent. Therefore it becomes critical that the policy makers should reassess the nature of PD of Mathematics teachers (Daly *et al.*, 2009:81).

This section relates to the influence of PD. Mathematics teachers who participate in PD: (i) develop PCK and TPACK, (ii) adopt new teaching and learning strategies, (iii) take ownership of their own learning, (iv) become motivated to learn, (v) acquire confidence and (vi) transform their attitudes towards Mathematics (Daly *et al.*, 2009:31-34).

3.5.1.3 Tools of Professional Development

The theme *tools* of the professional development comprised three codes: (i) PD enablers, (ii) environmental barriers, and (iii) ODL barriers (Figure 3.11).

The following discussion relates to PD enablers. PD enablers within the context of this analysis focus on issues which motivate teachers or make it possible for Mathematics teachers to participate in PD activities. The success of PD programmes depends on the structure of the PD course, the course content, and the tasks (activities) which the participants have to complete (Da Ponte, 2010:149). Mathematics teachers participate in PD over a longer period where they continually reflect in their groups and their TPACK increase significantly (Hartsell *et al.*, 2009:60). Mathematics teachers, just like learners, have diverse learning styles and when PD activities accommodate Mathematics teachers with different learning abilities, there will be steadfast progression in all the participants. PD should be part of the whole school development strategy, schools should address PD activities from a bottom-up approach, teachers should work in collaborative groups during PD activities, and have access to subject-specialists to support them during PD activities (Broadley, 2011:187; Daly *et al.*, 2009:54; Swan *et al.*, 2002:171). PD has significant outcomes when Mathematics teachers' individual needs are catered for, and when there are opportunities for them to explore with the resources at their disposal (Attwell & Hughes, 2010:28; Daly *et al.*, 2009:59).

Certain factors in every institution obstruct or delay PD processes. They are environmental barriers which the organisation can control and rectify. The organisation has no control over unexpected technical glitches, e.g. faulty computers, broken servers, malfunctioning networks, and challenges relating to communication through interactive tools. With careful planning some of these unexpected glitches can be resolved (Da Ponte *et al.*, 2002:101). Many schools have insufficient ICT resources and equipment and even though Mathematics teachers attend the training sessions, they are unable to implement what have they learnt during PD in their classrooms (Hartsell *et al.*, 2009:54; Mofokeng & Mji, 2009:1612). The insufficient PD by the DBE, PDE and school is a major environmental barrier

for the integration of ICT (Mofokeng & Mji, 2009:1614). Very few schools have: (i) an ICT policy which stipulate the PD initiatives, (ii) an ICT implementation plan in place, (iii) a time-frame on their roster for teachers to utilise the computer laboratory, and (iv) access to policy guidelines which stipulate the forthcoming ICT PD (Daly *et al.*, 2009:20).

Using a distance learning platform for PD could make Mathematics teachers aware of how to conduct Mathematical investigations, enable them to collaborate with other Mathematics teachers outside their existing context, make new teachers become part of the teaching community, and facilitate them to work closely with their colleagues at school and outside as well (Da Ponte, 2010:149). In any developmental programme and context there are many challenges which affect the successes of PD, particularly in an online environment. There are barriers related to the intrinsic of nature and extrinsic nature of ODL. The extrinsic barriers are: (i) shortage of provision of resources, (ii) minimal distribution and management of funds, (iii) scarcity of PD programmes, (iv) insufficient time for organisation support, and (v) inadequate knowledge of members within the organisation (Attwell & Hughes, 2010:33). The intrinsic barriers in an ODL platform are: (i) insufficient opportunities to participate in critical discussions (Prestrige, 2007:6) and (ii) prospects of face to face discussion with their peers and colleagues (Da Ponte, 2010:152). The DBE should address the extrinsic barriers and the intrinsic barriers can be dealt with when developing the PD programme in an ODL platform.

Because of insufficient funds to supply all institutions with adequate resources and funds to build an integrated system, it becomes a challenge to bridge the digital divide which requires greater investment in the education sector (Department of Education, 2004b:33). However, the majority of schools within the WCED have broadband access and ICT resources which can support PD therefore the extrinsic barriers are less of an issue in the WCED (Western Cape Education Department, 2011). As DL is a relative new mode of PD for teachers in the GET and FET band in South Africa (Department of Education, 2012a:71-72) the reflection of PD through ODL from other system can assist the DBE to address the barriers experienced beforehand. The DBE should commit to the e-Education policy and PD of teachers and start with an analysis of the PD needs of teachers within the provinces.

3.5.1.4 Community of Professional Development

The *community* of PD comprised four codes: (i) role of the school leadership in PD (ii) role of teacher, (iii) teacher barriers in ODL, and (iv) PD concerns (Figure 3.11).

School leadership plays an integral role in the PD of Mathematics teachers. School leaders influence the confidence and enthusiasm of Mathematics teachers to use ICT creatively. A secondary analysis from the South African SITES 2006 data confirmed that the focal point of school leaders in ICT integrations should be to listen to the teachers' views, assess their teaching and learning approaches and pay attention to their inter-personal relationships (Daly *et al.*, 2009:30-32; Munro, 2011:112). The

school leader should structure the organisation of the school to be information producing organisations through *knowledge generating processes*: (i) reviewing professional working knowledge, (ii) supervising the procedure of generating new professional knowledge, (iii) authenticating the professional knowledge generated, (iv) distributing the generated professional knowledge (Daly *et al.*, 2009:32).

This section relates to the role of teacher. The DBE, PDE, and the SMT can play their part to supply teachers with resources, create a stimulating teaching and learning context, and expose teachers to quality PD. However, the teacher is the most important role player to ensure quality teaching and learning central to effecting change in teaching and learning (Hartsell *et al.*, 2009). Mathematics teachers must view themselves as advocates of policy, whose role is to create a thought-provoking environment for learners to accumulate knowledge, develop their critical thinking skills, and acknowledge their efforts (Da Ponte *et al.*, 2002:95). Mathematics teachers should plan their teaching and learning strategies in advance, reveal adequate PCK, and embrace transformation. Only then can changes in the curriculum and teaching methods take place. For successful ICT integration in teaching and learning, Mathematics teachers should experiment with ICT to gain utmost from its potential (Hartsell *et al.*, 2009:53-54) and have sufficient TPACK to deliver the prescribed curriculum (Daly *et al.*, 2009; Mofokeng & Mji, 2009:1611). Mathematics teachers should acknowledge their shortcomings and communicate with their peers to assist them to bridge the gaps in their knowledge. They should: (i) participate in discussions on teaching and learning strategies; (ii) observe their peers in their teaching and learning endeavours; (iii) evaluate their own practices and those of their peers; (iv) expose them to constructive criticism; (v) plan, propose, investigate, develop, and evaluate teaching and learning materials; (vi) accept the possibility of failure during the implementation process of new strategies; and (vii) agree that *change is a process* and does not happen overnight (Daly *et al.*, 2009:28).

This section discusses teacher barriers in ODL. Mathematics teachers, who participate in PD activities online, acknowledge that they struggle to: (i) share their views in an online environment, (ii) express their opinions in words, (iii) accept new methods of communication and professional collaboration, (iv) use the computer due to their poor skills and apprehension of computers, (v) keep track of the discussions in the forums (Da Ponte, 2010:152-155).

The use of ODL as mode of service delivery for PD raises some concerns. During PD in a distance education setting, several Mathematics teachers expressed anxiety concerning the use of computers even though they acknowledged it as an integral part of PD process. Mathematics teachers were anxious whether they would be able to complete their tasks within the given timeframe allocated to them. Even the instructors raised some concerns: (i) which sections of the PD programme were successful, and (ii) which parts of the PD programme were unsatisfactory (Da Ponte *et al.*, 2002:149,153). Many PD programmes still focus on skills development and not on advancing the Mathematics teachers' TPACK (Daly *et al.*, 2009:16; Hardy, 2008:110). Mathematics teachers

participate in PD programmes, but the contextual factors at schools hinder the integration of the knowledge and skills acquired during PD activities (Daly *et al.*, 2009:23).

3.5.1.5 Rules of Professional Development

The *rules* of professional development comprised two codes: (i) Mathematics teachers' responsibility in PD, and (ii) ICT integration priorities (Figure 3.11).

Mathematics teachers are central to change in education and policy issues should not overshadow the importance of their individual professional needs (Broadley, 2011:9). Mathematics teachers drive PD and should initiate participation in PD activities (Daly *et al.*, 2009:30; Prestrige, 2007:4). However, the reality is that many teachers require certain structures to be in place or else they will not participate in PD (Rodriguez, 2000). Therefore, for progression and skills development Mathematics teachers have to adhere to the policy specifications of SACE; the 150 PD points which they have to accumulate (Department of Education, 2010:16), and ICT strategic plan developed by the DBE, the PDE and the SMT.

Even though policy stipulates that all teachers should have a certain level of qualification and attain the PD points within a given time-frame, raising the standard of Mathematics education is a national priority for the DBE (Mahlong, 2012). The DBE, PDE and schools should develop of Mathematics teachers to use the resources at their disposal to achieve the outcomes of Phase III of the White Paper on e-Education and raise the standard of Mathematics education in South Africa (Department of Education, 2004b:33). In several studies Mathematics teachers indicated their need for their TPACK PD (Attwell & Hughes, 2010:46; Mofokeng & Mji, 2009:1613; Zakaria & Daud, 2009:229).

3.5.1.6 Division of Labour in Professional Development

The *division of labour* in professional development comprised three codes: (i) PD models or frameworks, (ii) PD strategies and (iii) PD recommendations (Figure 3.11). Table 3.3 provides an overview of the PD models and frameworks used in various contexts globally (next page).

The SMT can utilise the extended list of PD frameworks and models. These frameworks and models show a combination of face-to-face and online PD strategies tried, tested, and evaluated in different contexts. A PD evaluation framework guides the school to determine whether the PD model can apply within the context of the school. Each school and teacher is unique and models for ICT CPD need to be able to address major individual differences between teachers' needs and motivation levels (Daly *et al.*, 2009:82).

A strategy to PD indicates a plan or an approach which the school has to follow during PD activities. Schools should make use of a combination of face-to-face instructions and online interactions as

many teachers do not feel comfortable in online learning and need the human contact (Li, 2005:231). During a group interview at the School of Continuing Education the Mathematics lecturers also displayed their technophobia and the need for peer interaction during PD (Addendum 3.1 and attached article for Edmedia). PD should fit in with Mathematics teachers' development of their professional knowledge and social identity (Da Ponte *et al.*, 2002:113). Mathematics teachers have to better utilise the Internet, especially for informal interactions, written reflections, and peer collaboration (Da Ponte, 2010:154). Additionally the DBE should conduct future studies to examine the successes and shortcomings of PD to improve the TPACK of Mathematics teachers (Hartsell *et al.*, 2009:62). During the systematic literature analysis of this research numerous PD models and frameworks were used and identified as effective within various contexts, but none have yet been used or evaluated in the South African context (Addendum 2.9).

Some of the fundamental recommendations made for future PD is for PD to focus on contextualised learning where ICT is integrated as part of the course within the appropriate context and teachers practice these skills in their classrooms (Li, 2005:230). However, none of these models were developed with the South African school context in mind, particularly the use of educational technologies and the integration across the curriculum (Swan *et al.*, 2002:1) (Table 3.3 next pages). New models of PD are needed, which include a focus on the development of local cultures of interest to be sustainable. In order for the DBE and school to ensure the development of SPI of Mathematics teachers, many contextual and demographical aspects should be considered. When the schools select a PD model it should: (i) suit the needs of the school, (ii) adhere to the PD requirements of Mathematics teachers, (iii) address the development of their SPI (Da Ponte, 2010:6), and (iv) ensure that they enhance Mathematics teachers' TPACK (Daly *et al.*, 2009:69).

The strategies within these different frameworks and models are available for institutions to use and consider, as well as the recommendations for future PD of Mathematics teachers in an ODL platform. Within the South African school context the PD of Mathematics teachers in an ODL platform is a new phenomenon (Van der Merwe *et al.*, 2011). Currently there are no PD models and frameworks in an ODL platform to suit the context of schools within South Africa. The DBE, PDE, and schools should analyse the local context and needs of Mathematics teachers and develop a new model for PD.

The subsequent section provides a systematic description of how the above categories of the theme of professional development adjust to the interrelated elements of the activity system.

Table 3.3 Professional Development Models and Frameworks

Framework or Model	Aim	Activity	School Managers' Role	Mathematics Teachers' Role
Guskey's Influential Framework Based on five levels: • Teachers' reaction • Teachers' learning • Organisational support and change • Teachers' use of new knowledge and skills • Teachers' learning outcomes	To focus on individual, perceptive, and qualitative areas of engagement	• Principled: reflect on educational values and responsibilities • Theoretical: deal with conceptual issues • Evidence-based: examine practice-based research • Situated: comprehend their professional learning	• Support and adapt to change	• Teachers differentiate between technologies for learning • Teachers apply critical thinking about their practice • Teachers acquire a deep understanding as how ICT assist learning • Teachers cross-examine their ICT practices to see if they are valuable experiences for the future • Teachers identify their learning as individual and context specific (Guskey, 2002)
High Collaborative-based Model • Captures features of a COP • Reflects on school as a COP	Design ICT PD to ensure high collaboration	• Envision • Plan • Enact	• Include teachers in ICT vision share • Develop ICT PD integration plan in collaboration with teachers	• Teachers determine PD based on individual needs • Teachers assist with PD ICT integration plan (Daly *et al.*, 2009:74-79)
Low Collaborative-based Model • ICT school development plan according to policy guidelines	To fulfil an ICT vision determined by policy or HOD	• Low level of collaboration	• SMT and ICT coordinator determine ICT PD needs • SMT develops ICT PD according to policy guidelines • SMT designs ICT PD to external demands	• Teachers no insight to ICT PD • Teachers rarely collaborate (Daly *et al.*, 2009:74-79)
Low Collaborative External Players model • Ethos of school and relationship with external service providers determine low or high collaborative ICT PD		• High or low level of collaboration • External stakeholders have slight impact on PD • School ICT curriculum set	• SMT approach determines whether ICT PD in either low or high collaborative • SMT provides little support • SMT provides limited and inconsistent PD	• Teachers collaborate to develop ICT PD • Teachers determine ICT PD based on individual needs • Teachers receive no classroom support to experiment, reflect with their peers, and entrench new practices (Daly *et al.*, 2009:74-79)
High Collaborative External Players Model • Flexible and differentiated	To have a ICT PD approach to address teachers' individual needs and adapt ICT PD to suit	• PD based on context of school • School visits • Online access to PD activities	• SMT supports ICT PD • SMT arranges school support visits	• Teachers engage in collaborative ICT PD • Teachers have time to engage

Framework or Model	Aim	Activity	School Managers' Role	Mathematics Teachers' Role
approach to ICT PD • Ethos of school fundamental in PD • Collaboration with external providers essential • Adapt to school context	context of school	• Time for PD activities	• SMT supplies Internet access for online training, support and collaboration • SMT provides time for follow-up sessions	in follow-up activities • Teachers access to continuous collaborative activities in online forums • Teachers access to subject-specialised training and support online and onsite • Teachers attend structured courses online or off-site and receive accreditation
Vogel (2010) proposes a PD framework: • Technology-centred • pedagogy-centred • Learner-centred • institution-centred • Centralised-local • Extrinsic-intrinsic motivation • Formal -informal • Situated-generalised • Support-development ethos	To provide ICT collaborative PD training focussing on problem solving for all staff and additional subject-specialised and software training	• Compulsory formal PD sessions for all teachers • Compulsory subject-specialised session in small groups • Optional after school sessions • Optional software training sessions • Optional software briefing in staff meetings	• SMT provides ICT PD through external and internal service providers • SMT offers collaborative PD • SMT supplies foremost contextualised PD • SMT provides problem-centred PD • SMT offers PD teacher-generated activities	• Teachers attend PD collaborative training online • Teachers have access to generic and subject-specialised PD • Teachers have optional training for software use (Attwell & Hughes, 2010:57)
A case study based on: • A structured, rapid problem-based group activity to introduce teachers to Web 2.0	Focus to bridge the gap from knowledge and skills to practice in the classroom	• Preliminary stage: a needs-analysis questionnaire • Stage 1: a presentation to introduce teachers to a technology • Stage 2: in groups they then brainstorm how these might use it in their own contexts, write down concise ideas • Stage 3: look at posted ideas, and use of technologies. Prioritise them • Stage 4: summary of the priorities, proposes, and an action plan	• SMT supplies access to Web 2.0 technologies • SMT supports collaborative group sessions • SMT implements action plan	• Teachers complete a questionnaire to determine the needs • Teachers participate in group sessions • Teachers collaborate and brainstorm about technologies • Teachers prioritise in groups which Web 2.0 technologies they will utilise • Teachers summarise the action plan (Attwell & Hughes, 2010:58)

3.5.2 Professional Development as Activity System

Figure 3.12 displays the *Professional Development activity system* with the interactive object, subject, tools, rules, community, and division of labour as elements of PD.

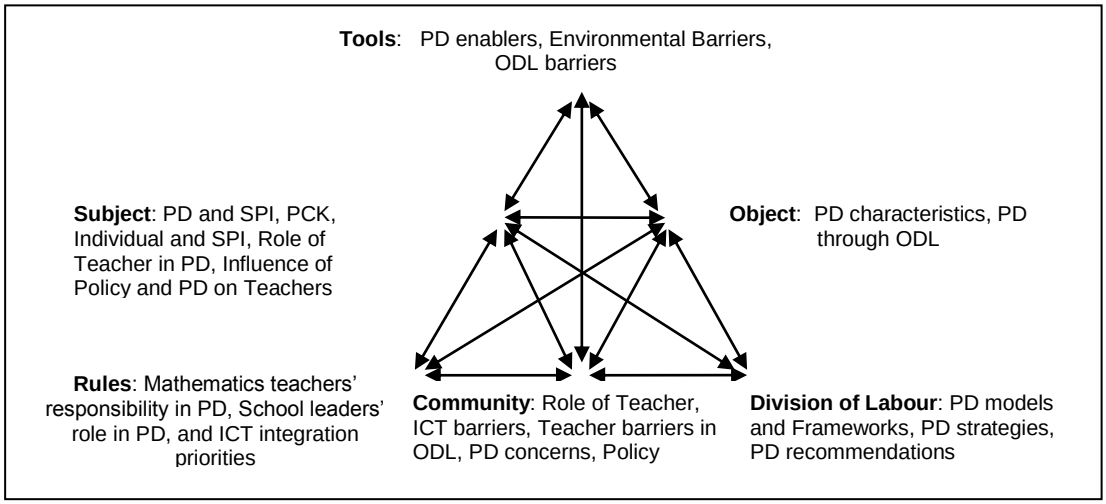

Figure 3.12: Professional Development Activity System (Adapted from (Engeström, 1987)

The following section discusses how: (i) the mediated interaction between the subject, object, and community function towards achieving the outcome of the activity (Engeström, 1987), and (ii) the categories (objects, subjects, tools, rules, community, and division of labour) conceptualised as interactive elements of professional development to construct an activity system (Figure 3.12) (Kuutti, 1996). Figure 3.13 illustrates the primary and secondary contradictions in the activity system (Figure 3.13) (Barab & Plucker, 2002:172; Engeström & Sannino, 2010:7).

The object of the PD activity system is to accomplish PD through ODL, and the outcome is to develop guidelines for the professional development of Mathematics teachers in the pedagogical use of ICT (Phase III of the e-Education policy) in ODL. The subject (influence of policy on Mathematics teachers in PD and the development of the SPI in PD and PCK), is affected by a variety of tools (PD enablers, environmental barriers and ODL barriers) which hinder the process of achieving the object. The community comprises the role of school leadership in PD, the role of Mathematics teachers, the barriers they experience in ODL, and the PD concerns in an ODL platform. The Mathematics teachers' connection with the community is mediated by explicit and implicit rules (Mathematics teachers' responsibility in PD, and ICT integration priorities). To achieve the PD through ODL the Mathematics teachers in collaboration with the DBE, PDE and school should activate the PD enablers and address the environmental and ODL barriers. This execution is achieved through assessing the division of the labour (PD models and frameworks, PD strategies, and PD recommendations) and addressing the role of the teacher, the ICT barriers, the barriers Mathematics teachers experience in ODL, and the PD concerns (community), which consequently mediate the relation between the

Mathematics teachers and the object (Figure 3.9). The six interrelated elements of professional development interactively and individually contribute to achieve the object of the activity.

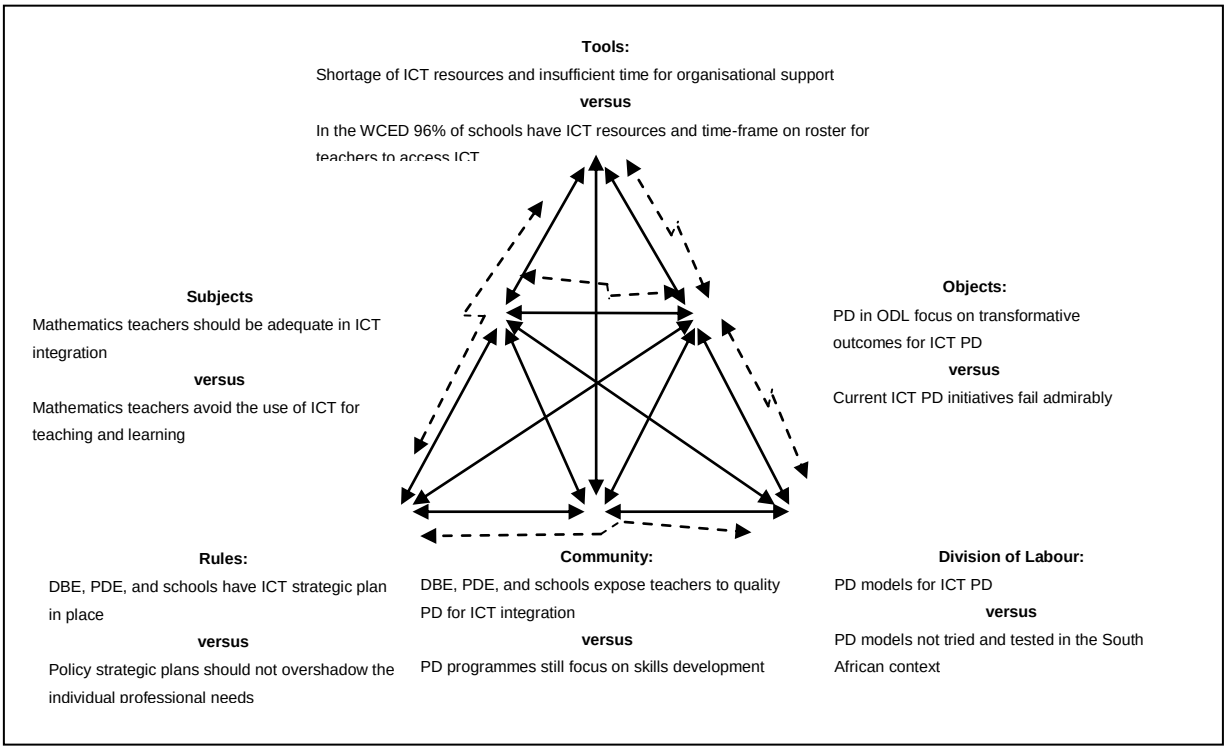

Figure 3.13: Mediated Relationship between the Subject and Object, and Interrelations among the Elements of Professional Development Activity System

Figure 3.13 illustrates the mediated relationship between the subject and object of the Professional Development activity system as well as the interrelations among the various elements of the activity system. The figure also clarifies the primary contradictions within each code of the activity system. The split dashed arrows indicate the movement of the secondary contradictions (tensions, predicaments, and interventions) between the elements of the activity system. There are secondary contradictions between all the elements of Professional Development activity system. These contradictions include the quality of PD, PD models, and the current provision of resources and PD programmes.

3.6. Activity Systems on Two Planes of Cultural-historical Analysis

Engeström's third generation activity theory (§1.3.1.5) conceptualises this research according to the two planes of cultural-historical analysis, i.e. the organisational plane and personal plane with four interactive activity systems (governance, school environment, open distance learning; and professional development) which combine to form an object-oriented activity with a central object—guidelines for the professional development of Mathematics teachers in the pedagogical use of ICT in

open distance learning aligned with the stipulation of the White Paper on e-Education (Department of Education, 2004b).

3.6.1 Organisational Plane of Cultural-Historical Analysis

Within the organisational plane of cultural-historical analysis the outcome is to develop the capacity to meet the present and future educational requirements of a specific group or individual with access to political, physical, financial and human resources (Robertson, 2008:821).

The required outcome of the organisation plane of cultural-historical analysis is to obtain a functional organisation, create a sustainable school environment, and access the applicable platform to address the outcomes of Phase III of the e-Education policy and of this object-directed activity—guidelines to the professional development of Mathematics teachers in the pedagogical use of ICT in ODL (Department of Education, 2004b). Embedded in this organisational plane of cultural-historical analysis, three of the four activity systems relate to aspects of the organisation. Governance activity system, School Environment activity system, and ODL activity system encompass the organisational plane of social cultural analysis. The organisational plane of cultural-historical analysis should be viewed as a unified system with on-going activity to produce the outcomes to the object-directed activity (Robertson, 2008:821) (Figure 3.14). Each of the three activity systems has its own object which it aims to achieve. While the Governance activity system aims to achieve the objectives of the White Paper on e-Education (Figure 3.3), the School Environment activity system aims to attain the objectives of PD and TPACK (Figure 3.6), and the Open Distance Learning activity system aims to create the platform for Mathematics teachers to build a SPI (Figure 3.9). Through expansive learning the three systems aim to achieve the central object of this object-directed activity: guidelines for the professional development of Mathematics teachers in the pedagogical use of ICT in ODL.

3.6.2 Personal Plane of Cultural-Historical Analysis

The outcome of the personal plane of cultural-historical analysis is to meet the current and future requirements of the e-Education policy and the objects of this object-directed activity (*guidelines for PD of Mathematics teachers for the pedagogical use of ICT in ODL*). Only the PD activity system directs the personal plane of cultural-historical analysis. The personal plane of cultural-historical analysis focusses on all the aspects within the *PD activity system* which relate to the PD of Mathematics teachers in an ODL platform (Figure 3.14). The required outcome of the PD activity system is to address all the integrating activity aspects of PD (Figure 3.12).

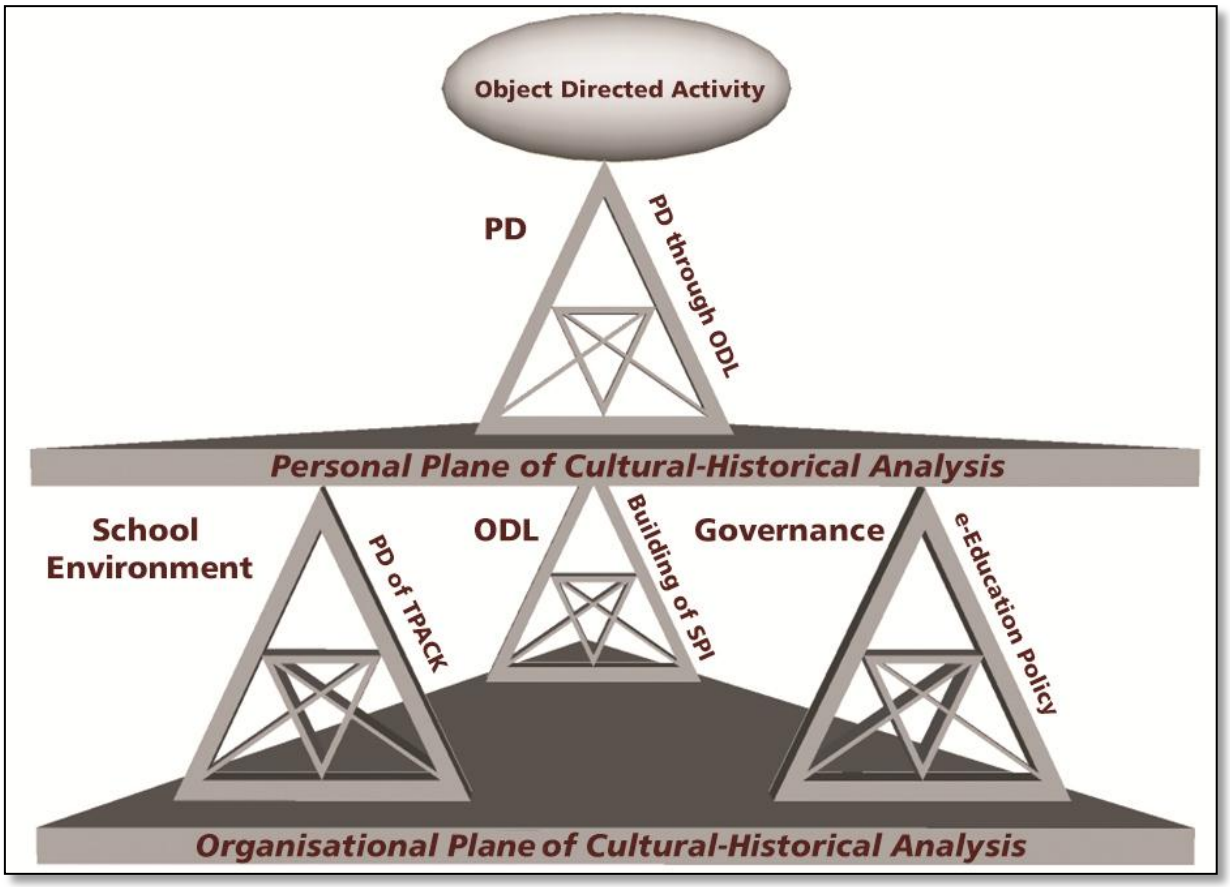

Figure 3.14: Four Conceptual Activity Systems on Two Planes of Cultural-Historical Analysis

Figure 3.14 illustrates the four conceptual activity systems on two planes of cultural-historical analysis. The four activity systems coherently form the conceptual activity systems of this research which aimed towards radical exploration of the existing research regarding the PD of Mathematics teachers in the pedagogical use of ICT in ODL.

3.7 Summary of the Chapter

This chapter discussed the literature probe conceptualised from four themes: governance, school environment, ODL and PD. This chapter also gives a description of how each theme formulates an activity system and how the codes are structured within the interrelated elements of AT. Chapter Four discusses Phase II of the fully mixed sequential equal status multi-mode design and methodology of this study.