Enhancing Mathematics teachers' Self-Directed Learning through Technology-Supported Cooperative Learning

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DECLARATION

I, **KEABETSWE GORDON SEKANO** declare that **Enhancing Mathematics teachers' Self-Directed Learning through Technology-Supported Cooperative Learning** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references

24-11-2019

SIGNATURE **DATE**

(KG SEKANO)

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To God all the glory, for giving me the strength, health and capacity to do everything as well as could be expected.

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ABSTRACT

Mathematics achievement is always a topic that draws a lot of attention, especially in South Africa. One way in which to support teachers in successfully implementing the curriculum and improving their teaching practice is to assist them in becoming more self-directed. This study aimed to enhance Mathematics teachers' self-directed learning (SDL) through Technology-Supported Cooperative Learning (TSCL) as a professional development (PD) strategy. Cooperative learning (CL) is a strategy that has been connected to the promotion of SDL. SDL is defined by Knowles (1975:18) as a "process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and integrating appropriate learning strategies, and evaluating learning outcomes." In order to answer the research question, an investigation into the body of scholarly knowledge was examined. The themes that were explored were: Mathematics education, SDL, CL and teacher PD.

A purposive sample was used in the empirical study and the participants were Mathematics teachers who attended PD workshops once a week at the Royal Bafokeng Institute (RBI) premises in the Rustenburg area. Framed within the interpretive paradigm, a qualitative approach was followed. A design-based research approach (DBR) was utilised in this study and the process was iterative in that a number of prototypes of the TSCL PD were developed. The first step was to review the literature, followed by doing a needs analysis of the teachers in order to establish what their needs in terms of PD were and also how their SDL could be enhanced. Following Mathematics teachers' needs analysis and the review of the literature, a suitable and appropriate intervention, in the form of the PD, was designed, refined, and improved. In the final stage, the TSCL PD was implemented as an opportunity for teachers to take responsibility for their own professional growth (i.e. become more self-directed).

Data collection using semi-structured interviews and follow-up interviews were scheduled with all the participants. The interviews were audio recorded and transcribed after which they were coded using ATLAS.ti™. Based on the findings of this study, it was evident that teachers need to engage in a PD that is affordable, flexible, intensive and on-going. Findings also indicated that teachers enjoyed the practical PD sessions and found great value in attending these sessions. The results showed that TSCL as a PD strategy fosters lifelong learning, as it provides teachers with an opportunity to improve their teaching methodologies, by working together, exchanging ideas and materials, regardless of their geographic proximity.

KEYWORDS

Mathematics education, Cooperative learning, Self-Directed Learning, Professional development, Technology-supported cooperative learning

OPSOMMING

Om sukses in Wiskunde te behaal, is nog altyd ’n onderwerp wat baie aandag trek, veral in Suid-Afrika. Een manier waarop onderwysers ondersteun kan word om die kurrikulum suksesvol te implementeer en onderwyspraktyk te verbeter, is deur onderwysers meer selfgerig te laat funksioneer. Hierdie studie poog om Wiskunde onderwysers se Selfgerigte leer (SGL) d.m.v. tegnologie-ondersteunde koöperatiewe Leer (TOKL) as ’n professionele ontwikkeling (PO) strategie, te verbeter en te bevorder.

Koöperatiewe leer (KL) is ’n strategie wat verbind word met die bevordering van SGL. Knowles (1975:18) definieer SGL as ’n proses waarin individue die inisiatief neem, met of sonder die hulp van ander, om hul leerbehoeftes te diagnoseer, leerdoelwitte te formuleer, menslike en materiële hulpbronne vir leer te identifiseer, toepaslike leerstrategieë te kies, te integreer en leeruitkomste te evalueer. ’n Ondersoek na die beskikbare akademiese kennis is gedoen, in ’n poging om die navorsingsvraag te beantwoord. Die volgende temas is ontgin: Wiskunde-onderrig, SGL, KL en PO van onderwysers.

’n Doelgerigte steekproef is in die empiriese studie gebruik en die deelnemers was Wiskunde onderwysers wat PO werkswinkels bygewoon het by die Royal Bafokeng Institute (RBI) se lokaal in Rustenburg. Die studie is vanuit ’n interpretivistiese paradigma geloods, met ’n kwantitatiewe benadering wat gevolg is. ’n Ontwerp-gebaseerde benadering (OGB) is gebruik in hierdie studie en die proses was iteratief van aard aangesien ’n aantal prototipes van die TOKL PO ontwikkel is. Die eerste stap was om die literatuur te bestudeer om vas te stel wat die behoeftes in terme van die PO was, en ook hoe die onderwysers se SGL bevorder kon word. Nadat die Wiskunde onderwysers se behoeftes geanaliseer is, asook die literatuur, is ’n toepaslike en geskikte intervensie (in die vorm van die PO) ontwerp, verfyn en verbeter. Gedurende die finale fase is die TOKL PO geïmplementeer om ’n geleentheid te skep vir onderwysers om verantwoordelikheid te neem vir hulle eie professionele groei (m.a.w. hulle word meer selfgerig).

Data-insameling is gedoen deur gebruik te maak van semi-gestruktureerde onderhoude en opvolg onderhoude is met al die deelnemers gedoen. Die onderhoude is d.m.v. oudio-opnames opgeneem en getranskribeer, en is daarna gekodeer deur gebruik te maak van ATLAS.ti™. Gebaseer op die bevindinge van hierdie studie, was dit duidelik dat die onderwysers betrokke moes raak by ’n PO wat bekostigbaar, buigbaar, intensief en deurlopend was. Die bevinding het ook getoon dat onderwysers praktiese PO sessies geniet het, en hulle aansienlik daarby gebaat het om hierdie sessies by te woon. Die resultate het aangetoon dat die TOKL as ’n PO strategie, lewenslange leer kweek, aangesien dit onderwysers ’n geleentheid bied om hulle onderrig-metodologieë te verbeter deur saam te werk en idees en materiaal uit te ruil, ongeag van hulle geografiese nabyheid.

SLEUTELWOORDE

Wiskunde-onderrig, Koöperatiewe leer, Selfgerigte Leer, Professionele Ontwikkeling, Tegnologies-ondersteunde koöperatiewe leer

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ACRONYMS AND ABBREVIATIONS

ANA	Annual National Assessment
C2005	Curriculum 2005
CAPS	Curriculum and Assessment Policy Statements
CBL	computer-based learning
CD	compact disc
CDE	Centre for Development and Enterprise
CL	cooperative learning
DBE	Department of Basic Education
DBR	design-based research
DoE	Department of Education
E-learning	electronic learning
GMMDU	Govan Mbeki Mathematics Development Unit
GP	Gauteng
ICT	information and communications technology
IT	information technology
LMS	learning management system
MGSLG	Matthew Goniwe School of Leadership and Governance
M-learning	mobile learning
MSSI	Mpumalanga Secondary Science Initiative
MST	Mathematics, Science and Technology
NCS	National Curriculum Statement

NEEDU	National Education Evaluation and Development Unit
NSC	National Senior Certificate
NWU	North-West University
OBE	outcomes-Based Education
PC	personal computer
PD	professional development
QACDAS	Qualitative Analysis Computer Data Analysis System
RBI	Royal Bafokeng Institute
RNCS	Revised National Curriculum Statement
CD-ROM	compact disc-read only memory
SACE	South African Council for Educators
SDL	self-directed learning
SGB	school governing body
HOD	Heads of department
SNS	social network sites
TIMSS	Trends in Mathematics and Science Study
TSCL PD	technology-supported cooperative learning professional development
TSCL	Technology-Supported Cooperative Learning

CHAPTER ONE

INTRODUCTION TO THE STUDY

1.1 INTRODUCTION AND THE PROBLEM STATEMENT

Mathematics achievement is always a topic that draws a lot of attention, especially in South Africa. Different reports – for example National Education Evaluation and Development Unit (NEEDU) and the National Report on the Annual National Assessments (Department of Basic Education (DBE), 2012) – reveal that learners perform ineffectively in both Trends in Mathematics and Science Study (TIMSS) (see Reddy *et al.*, 2016) and the Annual National Assessment (ANA). These reports express that, learners in South Africa perform "below acceptable levels in reading, writing and counting" (DBE, 2011a:6; 2012). Evidence in support of this position, can be found in the work of the Centre for Development and Enterprise (CDE) (2013:3), as they also assert that the way in which Mathematics is taught in South Africa, is "amongst the worst in the world as teachers themselves struggle to respond to questions that they are teaching from the curriculum and expecting their learners to answer". From these results, there is a realisation that teachers are responsible for deciding how Mathematics should be taught and learnt. As a result, teachers have a significant impact on the learners' academic performance and achievements.

Fauzan *et al*. (2013:161) reveal that poor quality teachers as well as poor teaching practices are the reason for the crisis in Mathematics education in South Africa. They posit that the causes of poor learner performance in Mathematics might be impacted by different aspects, for example, outdated teaching practices, changes in the curriculum, and teachers' lack of adequate content knowledge of the subject. Teachers still appear to lecture and use traditional teaching methods more frequently than using learner-centred methods, which links directly to the poor quality of Mathematics education (Gitaari *et al.,* 2013:6). In spite of the fact that the teacher may be able to illustrate content effectively, it is possible that teachers themselves lack expertise in teaching Mathematics for understanding (Murphy, 2012:188).

Another factor that may affect the poor performance in Mathematics education [and teachers' lack of self-directed learning (SDL)], is the training that the teachers receive (Rakumako & Laugksch, 2010:139). It has been established that conventional approaches to teacher professional development (PD), such as once-off workshops, usually do not lead to noteworthy changes in teaching methodologies (Murtaza, 2010:214). Research demonstrates that teacher PD activities, such as workshops, seminars and conferences have minimum influence on the continuing PD for teachers (Hendricks, 2004:16; Iheanachor, 2007:19; Murtaza, 2010:124). The problem regarding Mathematics education is so extensive that there are constantly opportunities for more training and re-training of Mathematics teachers, with the hope of improving the results. A concern can then be raised that most teacher PD strategies are not focusing on Mathematics teachers' needs and also not on empowering teachers to take responsibility for their own professional growth (i.e. become more self-directed). It is this setback that possibly supports the poor content delivery and performance of South African learners in Mathematics (Mouton *et al.,* 2013:8).

Wagner (2011:4) recommends that to promote learners' conceptual understanding, it is important that teachers themselves (as learners) firstly need to develop into "self-directed individuals" (Ellis, 2007:55) in order to cope with changes, stay up to date with content knowledge and move towards teaching and learning that foster SDL in their classes. It is important therefore for teachers to learn to teach in ways that help learners think critically and allow for collaboration and communication, so that learners can become familiar with the necessary skills required for the 21st century (Šapkova, 2013:735). One way in which to support teachers in successfully implementing the curriculum and improving their teaching practice is to provide them with an opportunity to participate in a PD strategy that is collaborative, flexible and also addresses their needs (Ertmer & Ottenbreit-Leftwich, 2013:428).

Evidence from previous studies points towards the idea that there is a need for a new model of teacher PD that engage teachers in the development of knowledge and skills so that they are able to teach in a manner that fulfils the requirements of the 21st century (Assareh & Bidokht, 2011; Avalos, 2011; Darling-Hammond, 2017; Garcia, 2012). According to Garcia (2012), a successful PD strategy in the 21st century should allow teachers to use technology to construct knowledge, learn collaboratively and reflect on knowledge learnt. Supported by Assareh and Bidokht (2011:791), technology use in PD creates new possibilities for teachers to engage in their own learning, as well as learning with others, using a wide range of online resources and application software. The partnership for 21st Century skills also stresses the importance of learning with technology tools for an effective contribution in a competitive global economy (Partnership for 21st Century skills, 2009:1).

However, the above mentioned studies provided limited insight into the impacts technology-supported PD had on teachers' own professional growth. This gap in the literature motivated the need to implement Technology-supported cooperative learning (TSCL) as a PD strategy which offers teachers an opportunity to think deeply about issues, communicate, work in groups and solve problems. It is in this vein that this study aims to enhance Mathematics teachers' own professional growth (in terms of SDL development) through TSCL as a PD strategy.

Mentz and Bailey (2019) recommend future research focusing on TSCL to enhance SDL. This study attempts to show that the use of technology in PD, supported by the five basic elements of CL that have been proved by many studies, can enhance Mathematics teachers' SDL. The use of technology in PD is definitely not a new concept. In fact, TSCL PD has been important to education from several years back (see 2.5.4). Technology in PD offers the opportunity for teachers to become more collaborative and extend learning beyond the classroom ((Ekizoglu & Ozcinar, 2010:5889). This example is given by Taylor, Goede and Steyn (2011:28), who confirm that technology for education is presently more important than before as it triggers change in the delivery means, due to its growing power and capabilities. The envisaged PD strategy should, among other things, provide Mathematics teachers with resources and tools to create, organise, manage, and assess their teaching and learning, in order to address poor learner performance in Mathematics. TSCL PD is set to be one of the strategies that provides teachers with an opportunity for lifelong professional learning, a strategy where teachers take an active role and become self-directed learners (Bagheri *et al.,* 2013:15).

1.2 CLARIFICATION OF CONCEPTS

The following are some important concepts used in the study

1.2.1 Mathematics education

Mathematics education centres on engaging learners in critical thinking circumstances that require reasoning, finding, creating and communicating ideas (Nieuwoudt, 1998:77; Plotz, 2007:43; Van de Walle *et al.*, 2014:2). Mathematics education involves that teachers ought to have a good comprehensive knowledge of Mathematics. They should also promote mathematical understanding and manage teaching and learning effectively (Venkat & Spaull, 2015:130).

1.2.2 Self-directed learning

SDL is defined as:

> [A] process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying

> human and material resources for learning, choosing and integrating appropriate learning strategies, and evaluating learning outcomes (Knowles, 1975:18).

For the purpose of this study, SDL was conceptualised as a process, which offers an individual (in the case of this study, the teacher) the opportunity to set goals, plan, evaluate, and implement their own learning (Thornton, 2010:181).

1.2.3 Cooperative learning

CL is defined by Johnson *et al.* (2008:1-14) as an approach that involves a small group of learners, each with different levels of ability, working together as a group to tackle an issue in order to accomplish a common goal. According to Johnson and Johnson (2013:102), CL is based on the following elements: positive interdependence, individual accountability, promotive interaction, the appropriate use of social skills, and group processing.

The concept and process of CL may at times overlap with the concept of collaborative learning. Collaborative learning often refers to unstructured groups working jointly on an activity (McWhaw *et al*., 2003:83). However, both cooperative and collaborative learning are viewed as small group practices that are concerned with encouraging social interaction and team work (Merriam *et al*., 2007:292). The current research however, only focused on CL.

1.2.4 Technology-supported cooperative learning

TSCL exists "when the instructional use of technology is used in combination with the use of CL" (Johnson & Johnson, 1996:787). Both technology and CL facilitate active engagement: CL by encouraging individuals to interact with each other to accomplish the learning task, and technology by expanding communication between individuals, while demanding attention to the task (Johnson & Johnson, 2014).

1.2.5 Teacher professional development

Teacher PD is commonly recognised as a significant approach used to enhance teacher knowledge and skills (Avalos, 2011:10). PD allows teachers to deepen their knowledge while becoming creative and adventurous in their teaching practices (Hirsh, 2009:12). In her research, Murtaza (2010:212) gives proof that PD strategies that are engaging, can help teachers to increase their knowledge as well as improving their teaching practices. Opfer and Pedder (2011:184) note that teachers need PD opportunities, not just in light of the fact that these opportunities promote the acknowledgment of their work as professionals, yet in addition on the grounds that, similar to the case for all professionals in any field, new opportunities for development, learning, and improvement are constantly welcome. It is through PD that teachers get the opportunity to advance their knowledge in their areas of specialisation (Murtaza, 2010:213). As such, it is important that PD strategies meet individual teachers' need, as well as different levels of content knowledge and skills (Desimone, 2009:182). In this dissertation, PD is always referred to in terms of teacher PD.

1.3 RESEARCH QUESTIONS

The main question for this research is how can TSCL PD enhance Mathematics teachers' SDL skills?

In order to answer this research question, the following sub-questions needed to be addressed:

- What does the body of scholarship reveal about teacher PD with specific reference to Mathematics education and Self-directed learning?
- What are Mathematics teachers' needs in terms of TSCL PD and SDL development?
- How do Mathematics teachers experience TSCL PD?

1.4 AIMS OF THE STUDY

The aim of this study was to enhance Mathematics teachers' own professional growth (in terms of SDL development) through TSCL as a PD strategy. In order to achieve this aim, the following sub-aims were identified:

- to determine what the body of scholarship reveals about teacher PD with specific reference to Mathematics education and SDL;
- to identify Mathematics teachers' needs in terms of TSCL PD and SDL development; and
- to investigate Mathematics teachers' experience of TSCL PD.

1.5 RESEARCH DESIGN AND METHODOLOGY

This section includes a discussion on the research process, research design and methodology that guided this study.

1.5.1 Research design

A research design refers to strategies and techniques chosen by a researcher in order to connect different components of the research, so as to find answers to research questions (Nieuwenhuis, 2010:70). Mouton (2013:56) views a research design as an arrangement or outline of how one expects to conduct the research. Affirming these views, Nieuwenhuis (2010:70) mentions, "[a] research design refers to a plan or strategy which moves from an underlying philosophical assumption to specifying the selection of participants, the data gathering techniques to be used and data analysis to be done". In this study, the research design was informed by the interpretivist research paradigm. The following Figure 1.1 is a graphical representation of the research design that guided this study.

1.5.2 Research approach

According to Mertler (2009:248), a research approach is the specific plan for collecting data in a research study. There are three common research approaches, namely: qualitative, quantitative and mixed methods (McMillan & Schumacher, 2010:11). A qualitative research approach was utilised in this study in order to get comprehensive descriptions of the participants (McMillian & Schumacher, 2010:16). As noted by Merriam (2009:13), a qualitative approach is concerned with individuals' opinions, emotions and experiences**.** For that reason, a qualitative approach was deemed suitable for this study as it allowed the researcher to investigate how teachers experienced the TSCL PD and ultimately to what extent SDL development was perhaps visible.

1.5.3 Research paradigm

Central to the entire discipline of educational research is the choice of a suitable research paradigm. A paradigm is a general philosophical orientation about the world and the nature of research that the researcher brings to the study (Botma, Greeff, Mulaudzi, & Wright, 2014:39). The research paradigm provides the lens through which the phenomenon is studied, it delineates the intent of the research, the motivation and expected outcomes (Botma et al., 2014:40). The philosophy of the nature of reality (ontology), how it can be discovered (epistemology) and the practices used to study a phenomenon (methodology) are interdependent and form a coherent research paradigm (Johnson & Christensen, 2012:31).

The study follows an interpretivist worldview, as the intention is about understanding the social realities and how people interpret their own world. Interpretivists believe that people decide how to act in a situation according to their interpretation of that situation (Brink *et al.,* 2012:25). The ontological position taken by the researcher was that peoples' experiences are real and should therefore be taken seriously. From the interpretivists' point of view, knowledge is constructed and based on observable phenomena, but always includes subjective beliefs, values and reasons (Botma *et al.,* 2010:40). Knowledge for this study was constructed by interacting and working through epistemological questions, listening to information that participants reveal, and documenting experiences shared by the participants

(Botma *et al*., 2010:45). The methods associated with data gathering in interpretivism relates to interviewing and observations (Brink *et al.,* 2012:26).

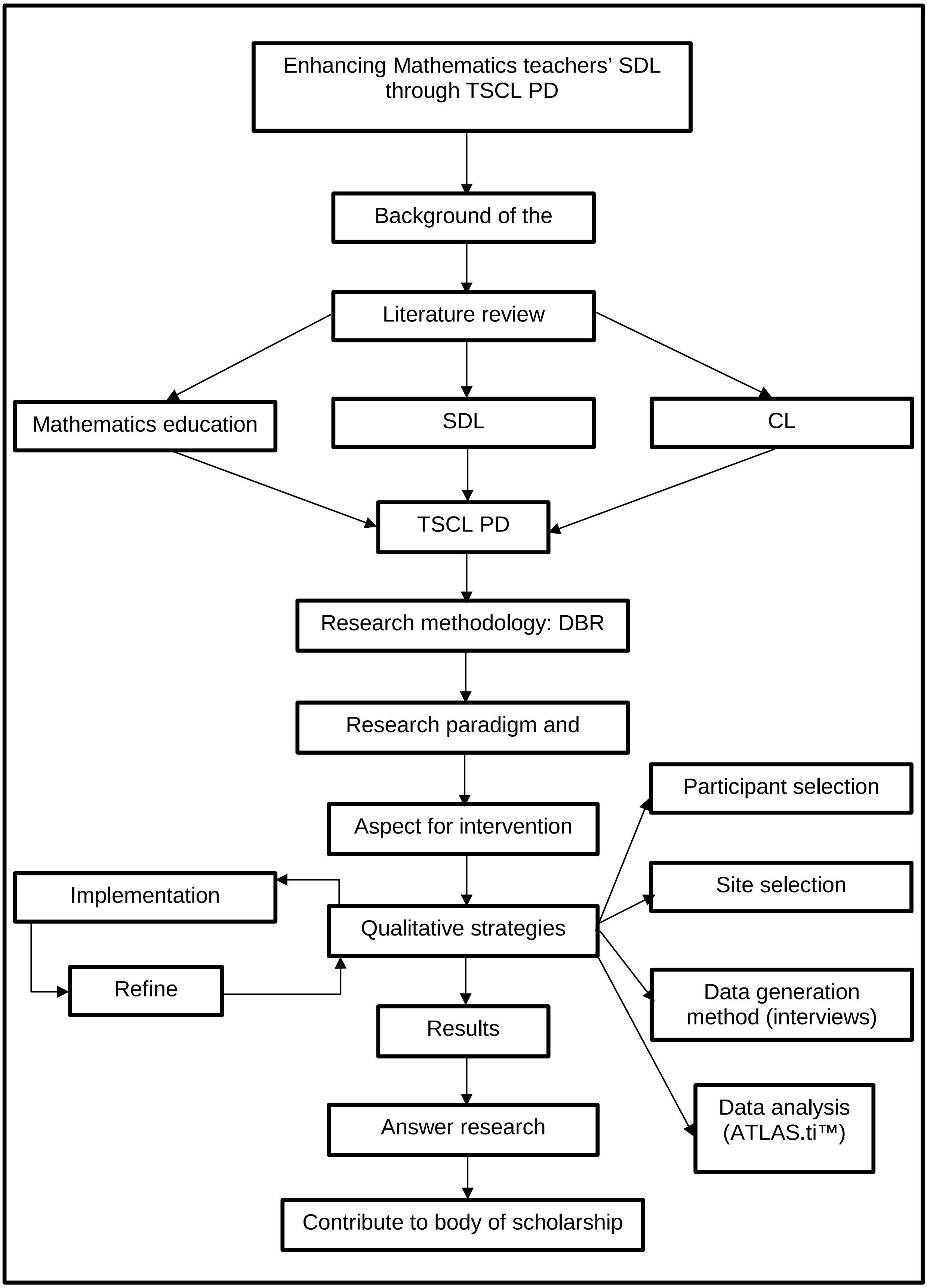

Figure 1-1: Research design and methodology for this study
Source: Author's own compilation

1.5.4 Research methodology: design-based research

Anderson and Shattuck (2012:16) define design-based research (DBR) as an approach "designed by and for educators that seeks to increase the impact, transfer, and translation of education research into improved practice". DBR in education refers to a creative and promising methodology wherein the iterative progression of answers for complex issues gives the background for scientific investigation (McKenney & Reeves, 2014:131). Researchers who work with DBR not only endeavour to take care of real-world issues, but they also seek to unfold new information and knowledge (McKenney & Reeves, 2014:133). DBR can incorporate both qualitative and quantitative methods. In this study, DBR is used within a qualitative study.

There are a few accepted best practices to be considered when conducting DBR. Initially, results in DBR depend on the design procedure, extensive problem analysis, and the design solution that results from the procedure and problem analysis (McKenney & Reeves, 2012:77). It is also significant that research be incorporated with the design cycles, which necessitates that not all design decisions be made in advance. This gives a clear opportunity for the information to be revised during the iterations. Flexibility is a very important component during DBR, which encourages changes and improvements during implementation so as to bring about a more grounded solution. In this study, the design cycle started by recognising the problem, at that point developing solutions informed by literature and existing design principles. This was followed by implementing the solutions in practice through iterative cycles, and reflecting on the principles to enhance solution implementation (McKenney & Reeves, 2012:79). An illustration of the process of DBR according to Amiel and Reeves (2008:32) is presented in Figure 1.2 below.

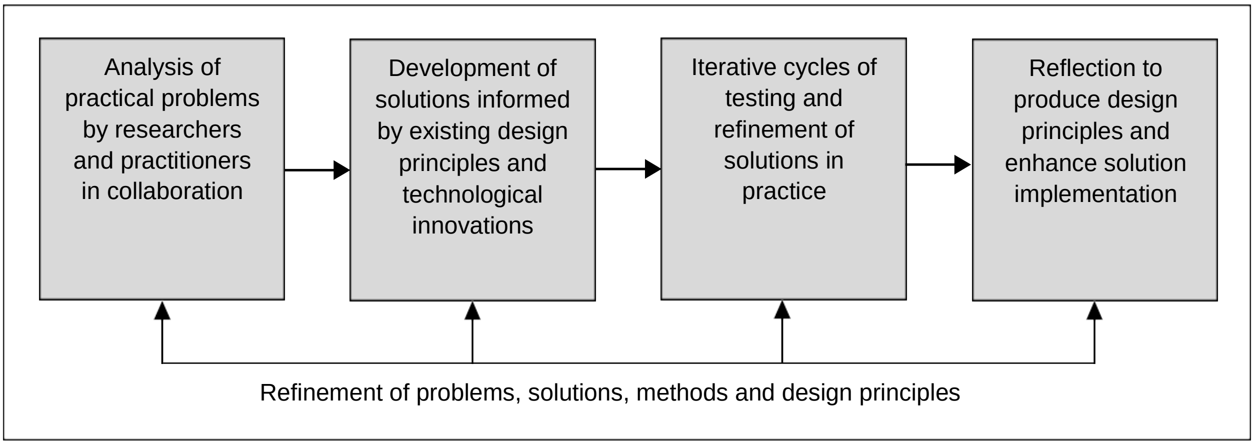

Figure 1-2: Four phases of design-based research

Source: Amiel and Reeves (2008:32)

The first step was to review the literature, as well as determine teachers' needs in terms of PD and SDL development, in order to gain insight into the problem, context and other relevant topics (Amiel & Reeves, 2008:34). In this study, outdated teaching practices, changes in the curriculum and teachers' lack of basic content knowledge of the subject created the need to investigate how TSCL as a teacher PD strategy could enhance Mathematics teachers' SDL. Informal discussions with participants also contributed to determining teachers' needs in terms of TSCL PD.

The second step in the process of DBR was to develop solutions that could be implemented in the educational setting (Amiel & Reeves, 2008:34). In this study, the design phase was realised by incorporating existing guidelines and principles in order to create a solution for the problem documented in the analysis phase. These were based on a review of the literature from which recommendations would be made regarding how to address the problems that had been recognised. Three prototypes (using the informal discussion and formal interviews with the participants) were formatively evaluated during this stage. According to Fauzan *et al.*, (2013:163), a prototype can be seen as a version of an intervention developed in collaboration with researchers and practitioners. In this study, the context (Mathematics teachers attending the intervention) and strategy of the TSCL stayed the same. However, the content of the tasks (e.g. designing a lesson plan using Google Docs, sketching straight line graphs using GeoGebra etc.) changed for each prototype. The researcher and the promoters met regularly after the end of every prototype, in order to reflect and discuss possible options that were viable for the next session of the intervention.

The third step in the process of DBR was that of implementing the solutions in practice through iterative cycles (Amiel & Reeves, 2008:35). In this study, cycles of implementation were carried out for the refinement of solutions in practice. Following Mathematics teachers' needs analysis, a suitable and appropriate intervention, in the form of the PD, was designed to assist teachers in their teaching practice. The process was iterative in that various prototypes of the TSCL PD were developed. Data collection and analysis (corresponding to the research questions of the study) were carried out. Based on the analysis of the data collected, the TSCL PD strategy was refined and tested again. The relevance of this PD strategy will be discussed in detail in Chapter Five.

The last step was the output phase, which involved reflecting on the principles to enhance solution implementation (Amiel & Reeves, 2008:36). In this step, the intervention was evaluated to see whether it addressed the problems and produced the desired outcomes.

This was done through semi-structured individual interviews. Final validations and recommendations (Herrington & Reeves, 2011:598) regarding how teachers experienced the TSCL PD, as well as their SDL development, were provided to inform future development and implementation decisions.

1.5.5 Population and participant selection

Population refers to people or cases from which a sample is selected and to which the findings can be generalised (Maree & Pietersen, 2010:7). A sample is used to represent the entire population (Creswell, 2013:48). There are different approaches to choose a sample for a study (McMillan & Schumacher, 2014:365), and for the current study purposive sampling was considered the most suitable method. Purposive sampling is designed to generate a sample that will address the research question (Brink *et al.,* 2012:27). The main research question for this study is how can TSCL PD enhance Mathematics teachers' SDL skills? In order to answer this research question, Mathematics teachers who regularly attended PD workshops once a week at the Royal Bafokeng Institute (RBI) premises in the Rustenburg area were identified and selected as they were knowledgeable and willing to engage and communicate their practices meaningfully and reflectively (Etikan, Musa, & Alkassim, 2016:1). At the time of the research, the participants were teaching Mathematics at different grades in primary schools attended by low socio-economic status learners in the Royal Bafokeng schools. These participants were selected as part of the sample because, according to the researcher, the participants held the necessary knowledge for the researcher to gather suitable and rich data, they were also available and willing to participate.

Maree and Pietersen (2010:177) draw attention to the fact that, to collect accurate, appropriate and meaningful data, the researcher needs to build up criteria by which the participants are chosen. For this study, the following criteria must be met in order for a participant to be appropriate for the study:

- participants had to teach Mathematics at different grade levels in their respective primary schools;
- participants had to have a minimum of three years' teaching experience; and
- participants had to attend PD workshops once a week at the Royal Bafokeng Institute (RBI).

The size of the sample is depended on what the researcher investigates. However, in a qualitative research study, the size of the sample is not prescribed by specific rules (Etikan, Musa & Alkassim, 2016:3). The participants (n=7) in the study comprised of Mathematics teachers who were willing to be interviewed and give answers regarding their needs and experiences in terms of TSCL PD and SDL development.

1.5.6 Data collection

Data collection is described as a process of collecting, measuring and analysing information obtained in a study (Maree, 2010:259). The data for this study were collected at RBI after the Research Ethics Committee at the North-West University (NWU) had approved the Research Ethics application. According to Yin (2009:99), the process of data collection includes, among others, questionnaires, interviews, case studies and observations. The current study used semi-structured interviews and follow-up interviews to collect data about teachers' needs in terms of TSCL PD and SDL development as well as their experience of TSCL PD.

According to Merriam (2009:87), a research interview refers to a discussion between two or more people that serves to evoke data relating to the research. Research interviews involve a two-way discussion aimed at obtaining data from the participants by the interviewer, so as to find out about their behaviour, beliefs, opinions, views and thoughts (Leedy & Ormrod, 2010:153). An advantage of using semi-structured interviews in this study was that it allowed the researcher to gain valuable insights into participants' opinions, feelings, emotions and experiences (Denscombe, 2010:173) and also it allowed participants to characterise their views in their own way (Merriam, 2009:90). This means participants were flexible in such that they were open enough to talk about any topic raised during the interview. A further benefit of using a semi-structured interview is that it took into account questions to be clarified or re-phrased where participants were vague about the wording (Creswell & Plano Clark, 2011:10).

Two rounds of interviews were conducted. The first round took place at the start of the semester and data was collected through an informal discussion, with the intention of establishing what teachers needs in terms of TSCL PD were and also how their SDL could be enhanced. The second round of data collection took place towards the end of the semester and this was done through semi-structured interviews, with the intention of determining how teachers experienced the TSCL PD. To arrange for the interviews, the researcher followed these steps:

- Made appointments with the teachers;
- Booked and prepared a room for face-to-face interviews;
- Positioned a cell phone for audio-recording;

- Placed questions ready so that the interview could start;

Before the interview began, the researcher

- Thanked the teacher-participant for agreeing to take part in the research;
- Informed the participants about the consent letter;
- Clarified to the participants that the interview would be semi-structured and follow-up questions would be determined by the responses provided;
- Asked permission to record the interview

All the interviews were scheduled with the participants, conducted in English and recorded. The interviews were transcribed, after which they were coded using ATLAS.ti™.

1.5.7 Data analysis

Mouton (2012:108) defines data analysis as a process of evaluating and summarising collected data. A similar definition is also given by Nieuwenhuis (2010:99), who argues that data analysis is a process of collecting, analysing and interpreting data in order to address the main aim of the study. Nieuwenhuis (2010:100) further emphasises that during the process of data analysis, it is important to plan and prepare data carefully in order to support interpretation. In this study, the data gathered from both the semi-structured interviews were prepared, processed and analysed with the help of a qualitative analysis computer data analysis system (QACDAS), ATLAS.ti™. Merriam (2009:193) describes ATLAS.ti™ as computer software that is used for the qualitative analysis by researchers, in order to organise text, graphics, audio and visual data files, along with their coding, memos and findings into a project. The following section will describe the manner in which trustworthiness was addressed in this study.

1.5.8 Trustworthiness

As indicated by Bless *et al.,* (2013:236), trustworthiness is the degree to which a study is worth paying attention to and the degree to which others are convinced that the findings can be trusted**.** In qualitative research, trustworthiness is ensured when the data accurately reveals in detail the experiences of the participants who are involved in the study. Therefore, trustworthiness ensures the quality of research. To maintain trustworthiness in qualitative research, four criteria were used, namely credibility, confirmability, dependability and transferability (Babbie *et al.*, 2008:276).

So as to accomplish dependability, the data gathered ought not to be dealt with in a manner favouring the researcher's interest (Sinkovics *et al.*, 2008:691). In this study, the researcher held the data gathered in its original format with no addition to what the participants introduced and what was observed. The interviews were transcribed and returned to the participants for verification and errors were corrected. Furthermore, several trustworthiness aspects were adhered to – these will subsequently be discussed.

1.5.8.1 Credibility

Credibility refers to the accuracy of the research process to which the findings represent the truth (Polit & Beck, 2012:724). Sinkovics *et al.* (2008:69) describe credibility in qualitative research as the extent to which the research that was conducted is reliable and trustworthy. In this study, credibility was ensured by comparing data collected from the interviews with data obtained from the literature review. This was done to relate the research study's findings with reality under the study, such that the research can demonstrate the truth about the findings.

1.5.8.2 Confirmability

Bless *et al.* (2013:237) describe confirmability as the degree to which the results of one's study could be obtained by other researchers, following a similar research process. In this study, the data collected from the interviews were transcribed verbatim. This means that responses were typed out word for word, exactly as they were spoken. The participants were contacted afterwards to confirm that what they said was what was captured. Follow-up interviews were also conducted to enrich and clarify the qualitative data. This was done by visiting the schools selected as per telephonic appointment with the participants.

1.5.8.3 Dependability

Babbie *et al*. (2008:278) state that dependability refers to the consistency of the researcher's record of how data were collected, coded and analysed, as well as changes to the research design as the research unfolds. Dependability is closely related to reliability, that is, the consistency of observing similar findings under comparable conditions (Bless *et al.,* 2013:238). In this study, evidence of the field research in the form of research instruments was used to draw the findings, conclusions and recommendations in order to ensure research dependability. Additionally, the strategy that was applied to ensure dependability, was coding of the data, checking each step of the process from literature, as well as getting advice from expert researchers.

1.5.8.4 Transferability

Transferability refers to the degree to which the results of the research can be applicable to the findings to another context (Babbie *et al.*, 2008:279; Bless *et al.*, 2013:237). Transferability in qualitative research means that the research findings or methods from one study can be applied to similar situations (Marshall & Rossman, 2011:252). In this study, evidence of transferability was provided through information about the context of the research and detailed descriptions of the participants.

1.6 ETHICAL CONSIDERATIONS

The NWU Faculty of Education Research Ethics Committee's application form was completed and submitted. After ethical clearance had been obtained (see Addendum H) for the study, the researcher requested permission for conducting the study from the RBI (see Addendum G). Once permission to conduct research at the institute had been obtained, teachers participating in the TSCL PD at the RBI were asked to give consent for participating in the study, should they feel comfortable to do so.

Participants were informed about the motivation behind the research, and they were assured of confidentiality. The researcher informed the participants of what the research was about, and the fact that they had the right to decline participation in the event that they decided to do as such. Creswell (2010:87) asserts that the researcher ought to disclose to participants what the study entails and what is required of them in terms of participation. An independent person asked participants who opted to participate in the research, to complete an informed consent form – the use of the independent person was to ensure that no coercion took place and that participants participated voluntarily. Each participant interested in participating in the research, was approached to sign an informed consent form, which served as an indication that they without a doubt comprehended what was disclosed to them and wilfully agreed to take part in in the research. Results produced in the study will be supplied to any of the parties involved upon request.

CHAPTER TWO

SELD-DIRECTED LEARNING, COOPERATIVE LEARNING AND TEACHER PROFESSIONAL DEVELOPMENT

2.1 INTRODUCTION

Chapter one provided a general background and orientation to this study. In this chapter, literature on Mathematics education, self-directed learning (SDL), cooperative learning (CL) and teacher professional development (PD) will be examined. These constructs form the groundwork of this chapter, and they are expanded in terms of theory and related literature review. The review concludes with a discussion of what constitutes effective PD for Mathematics teachers.

2.2 MATHEMATICS EDUCATION

In the field of Mathematics education, Mathematics is defined differently by different researchers (Beswick, 2012:128; Ernest, 1991b:250; Plotz, 2007:43; Setati, 2002:9). This chapter discusses Mathematics education by explaining what it is, followed by a discussion on the historical overview of Mathematics in South Africa, and the effect of teachers' knowledge, teaching strategies and the curriculum change in Mathematics education.

2.2.1 Defining Mathematics

Many researchers see Mathematics as a human activity that deals with critical thinking, making patterns and logical deduction (Department of Basic Education (DBE), 2014:8; Singh, 2016:107). Harel (2008:894) defines Mathematics in two sections: firstly as a relation between statements, definitions, equations, calculations, problems, and solutions to problems. The second section of Mathematics includes thinking that lead to answers for any of the structures mentioned previously. The DBE (2011a:8), on the other hand, defines Mathematics as a "language that comprises of numbers, notations and symbols to describe numeric, geometric and graphic representations and relationships." These definitions provided by Harel (2008:894) and the DBE (2011a:8) demonstrate that Mathematics is a perspective that deals with thinking and reasoning about issues that include numbers and symbols that are represented in different manners. Additionally, these definitions of Mathematics focus on observing and representing physical and social phenomena, while enhancing mental processes for logical- and critical thinking.

Mathematics is consequently, a method for "thinking" and "reasoning", which demonstrates the procedural idea of the subject (Harel, 2008:894). Mathematics is therefore not only a set of rules to be learnt and remembered, nor the science of computation (Spaull & Kotze, 2015:11); it is a vertically incorporated subject (Spaull and Kotze, 2015:11), in that it requires higher-order thinking skills.

Different authors describe Mathematics as the study of pattern and arrangements, which challenges the view that Mathematics is just only a branch of knowledge that deals with calculations (Van de Walle *et al.*, 2014:13). Singh (2016:107) holds a similar view to that of Van de Walle *et al.* (2014), namely that Mathematics is the study of making patterns and connections between abstractions. It is of great importance to understand that Mathematics is a human activity that encompasses “higher-order thinking skills such as observing, representing and investigating patterns and qualitative relationships in physical and social phenomena and between mathematical objects themselves” (DBE, 2011b:8). Van de Walle’s and Singh’s view as well as the definition provided by the Curriculum and Assessment Policy Statement (CAPS) document concerning Mathematics, endorse the fact that Mathematics is a human activity (social construction), which encourages one to discover or invent mathematical concepts or solve real-life situations.

2.2.2 The nature of Mathematics

Mathematics has been taught and learnt for centuries on various continents, however, it was not until the previous century that the nature and quality of teaching and learning Mathematics was studied (Kilpatrick, 2014:267). Dednam (2011:212) attests that, Mathematics has been part of humankind from the beginning of human presence. For instance, generally, Mathematics was utilised when exchanging, calculating and building. Many of the early researchers in Mathematics education were Mathematics teachers who had become intrigued by how Mathematics is taught and learnt (Kilpatrick, 2014:267).

From the literature, the researcher noted that the discourse about the nature of Mathematics dates back as far as the fourth century AD and that different terms or notions are utilised to describe and articulate the nature of Mathematics. According to Holm and Kajander (2012:7), how teachers decide to encourage Mathematics in their classrooms is affected by their beliefs about Mathematics and their capabilities. Likewise, Beswick (2012:127) attests that teachers’ behaviour and teaching practices are showed in their ideas, beliefs and preferences. The nature of Mathematics in this way should be explored so as to decide how the teaching and learning of Mathematics happens (Plotz, 2007:43). Ernest (1991b:250) perceives three fundamental types of beliefs about the nature of Mathematics that are held by teachers, to be specific the Platonist view, the instrumentalist view, and the problem-solving view. In the following paragraphs, each of these views, and how it influences the teaching of Mathematics, will be described briefly.

- **Platonist view of Mathematics**

In terms of this view, the nature of Mathematics entails a body of true knowledge, originating outside the individual in the external world, which human beings had to discover, not create, through rational activity (Ernest, 1991a:7). The Platonist view of Mathematics defines Mathematics as a body of knowledge that is stationary, which also compromised of a collection of facts, logic and reasoning (Shilling-Triana & Styliandes, 2012:393). Herein, emphasis is put on knowledge, to be transferred from one individual (i.e. teacher) to another (i.e. learner) (Beswick, 2012:113). Benadé (2013:12) has expressed a similar view that the main focus of the Platonist view, is placed on whether the answer is right or wrong, and that will depend on the satisfaction of the teacher. Accordingly, in the Platonist view, the teacher is the one in particular who has mathematical knowledge and the learners must absorb all the information from the teacher (Beswick, 2012:129).

A teacher with a Platonist view of Mathematics sees successful teaching as having the privilege to be in charge of a classroom, assigning tasks, monitor learners' work and offering guidance to learners (Benadé, 2013:15). According to Beswick (2012:129), this type of teaching prompts learners to develop disconnected pieces of Mathematical knowledge and being unable to identify or comprehend what they are learning (Beswick, 2012:129). The implication of such a view on Mathematics is that a teacher who holds this belief may consider Mathematics to be pieces of information that can be transferred to learners when needed (Benadé, 2013:12). Mathematics is accordingly something that can be learnt through instructions from the teacher, not something that can be discovered by the learners (Holm and Kajander, 2012:7). The significant component is the observation that the teacher is the provider of information, and the learners are just receivers of knowledge (Shilling-Triana & Styliandes, 2012:393).

- **Instrumentalist view of Mathematics**

The instrumentalist view sees Mathematics to be a lot of facts, rules and procedures (Ernest, 1991a:115). According to this view, Mathematics is seen as repetition and application of formulas with no understanding (Benadé, 2013:17). With the instrumentalist view, the focus is only on the final answer and it does not for the most part have any impact of how it is obtained (Benadé, 2013:19). Benadé (2013:30) further points out that the implication of the instrumentalist view is that the development of knowledge is ignored.

The instrumentalist teacher focuses on teaching learners how to follow correct procedures, in order to get the correct answer (Benadé, 2013:28). Learners just become familiar with following the rules and according to Webb and Webb (2008:14), they might find it a lot simpler than understanding where it originated from. Additionally, within the instrumentalist view, the role of the learner is to listen, respond to the teacher's questions, and do activities using techniques that have been demonstrated by the teacher (Domazet *et al.*, 2013:125). This model of Mathematics teaching often produces learners who are capable of performing operations with symbols, but who may not be able to connect the formal manipulation procedures with the real world (Webb & Webb, 2008:43). As a result, this way of teaching elicits much criticism because the ability to get the correct answer, performing algorithms and state definitions cannot be evidence of knowing Mathematics (Nieuwoudt, 2006:33).

- **Problem-solving view of Mathematics**

The problem-solving view means engaging in the process of tasks that promote critical thinking, reasoning and the ability to make connections between concepts (Ernest, 1991a:294; Conner *et al*., 2011:492). According to this view, the learning of Mathematics is seen as a process rather than a product (Gujarati, 2013:633). According to Benadé (2013:16), the problem-solving view encompasses aspects such as exploring, developing models and proving models and methods, as well as discussing, reasoning and solving. The problem-solving view describes Mathematics as a continuous process, rather than as a product (Benadé, 2013:16).

The emphasis of the teacher from a problem-solving view of Mathematics is based on creating own knowledge and applying it to real-life situations (Benadé, 2013:12). The teacher with a problem-solving view of Mathematics encourages learners to discover patterns and relationships by posing challenging questions that probe learners to think intuitively (Gujarati, 2013:634). The teacher will likewise urge learners to consider their own understanding and strategies so as to improve their capacity to assess their very own learning**.** In the light of this, one can say that according to the problem-solving view, Mathematics is perceived as a self-motivated**,** consistently growing discipline created by mankind, a cultural product, which is open to revision and construction (Beswick, 2009:154; Ernest, 1989:250).

It is evident from the preceding paragraphs that the nature of Mathematics is multifaceted and dynamic. What teachers think and believe about Mathematics influences their feelings towards Mathematics as a subject and their tendency to act out the consequence thereof (Blanco *et al.*, 2013:339). Thus, the beliefs teachers harbour in relation to the nature of Mathematics, underlie their instructional decisions, which ultimately shape the learners' educational experiences, and in turn affect the learners' academic performance (Woodcock, 2011:84).

2.2.3 Mathematics education and a need for change

There is some evidence to suggest how Mathematics could best be taught to improve learners' performance and to make the subject more interesting to learners (Barkatsas *et al.*, 2009). Many researchers have discussed how Mathematics could best be taught to improve learners' performance and to make the subject more interesting to learners (Barkatsas *et al.*, 2009**;** Li & Ma, 2010). However, results in national and international reports, such as the Annual National Assessments (ANA), National Education Evaluation and Development Unit (NEEDU) and the Trends in International Mathematics and Science Study (TIMSS) report that learners in South Africa are performing badly as compared to other foreign countries (Department of Education (DoE), 2014; Graven & Venkat's, 2014; Spaull, 2015).

This lack of improvement in Mathematics education was also confirmed by the most recent TIMSS data collection, which was in 2015 (Reddy *et al.*, 2016). The report has revealed that South Africa is amongst the five lowest-performing countries out of a total of 39 countries that participated in the TIMSS 2015 study (Reddy *et al.*, 2016:2). Both South African Grade 5 and Grade 9 learners ranked 48^{th} out of 49 participating countries (Mullis *et al.,* 2016). The average Mathematics score achieved was 372, which is far below the international benchmark of 550 for Mathematics (Reddy *et al.*, 2016:2). More data by the DBE (2017:50) also revealed that the pass rate of full-time South African matriculants who wrote the National Senior Certificate (NSC) examination in 2016 was 72.5%, an increase of 1.8% on the 2015 pass rate. According to the subject report on the 2017 NSC, the number of learners passing Mathematics at 30% and above, had increased from 129 481 in 2016 to 136 011 in 2017, while the number of learners passing Mathematics at 40% and above, increased from 84 297 in 2016 to 89 119 in 2017 (DBE, 2017:50). Even with these slight improvements in Mathematics performance, the achievements in South Africa continue to remain a challenge (Reddy *et al.*, 2016:15).

The poor performance of learners in Mathematics may be influenced by various aspects, such as the teachers' workload, school discipline and time management, as suggested by

Musasia *et al.* (2012:56). Mouton *et al.* (2013:32) confirm that the quality of how Mathematics is taught is partly to blame for the crisis in Mathematics education in South Africa. Taylor (2015:3) draws attention to the fact that South Africa has many teachers who are inadequately trained; yet, they are likely to remain Mathematics teachers for many years. This is due to the shortage of qualified Mathematics teachers in South Africa. Some studies (Gitaari, Nyaga, Muthaa & Reche, 2013:6; UNESCO, 2012:74) focus on the following variables that affect learners' learning of Mathematics results, namely the teachers' qualifications, their subject majors, their teaching experience and teacher PD. Some other factors that may affect the learners' poor performance in Mathematics are traditional teaching practices, changes in the curriculum, and teachers' lack of basic content knowledge of the subject (Fauzan *et al*., 2013:161). These aspects are discussed below.

2.2.3.1 Effect of traditional teaching strategies on Mathematics education

The impact of traditional teaching strategies on learners' understanding of Mathematics can also be seen in Stols' (2013) study. According to Stols (2013:1), South African teachers appear to experience difficulties in changing their teaching practices from traditional to a more learner-centred approach. Teachers still appear to lecture and use traditional teaching strategies more frequently than using learner-centred approaches, which links directly to the poor quality of Mathematics education (Fauzan *et al*., 2013:161). For Plotz *et al*. (2012:69), teachers teach in the manner they had been taught and they are not ready to change. A few teachers attempt to change, yet when they experience challenges they will in general fall back on their old teaching methods (Webb & Webb, 2008:43). This promotes the idea that, without a teacher, learners could not make it, which is unfortunately the opposite of what research sees as good teaching (Plotz *et al*., 2012:70).

In the traditional Mathematics classroom, the teacher is viewed as the source of all information, and the teacher is expected to share all this information with the learners (Schoenfeld, 2012:317). For Taylor (2009:7), these traditional classrooms allow learners to sit inactively in class, listening to the teacher's instructions. This does not support commitment in the learning of the subject. In the event that the learner did not get the information from what the teacher has taught, he or she is labelled as 'unteachable' (Benadé, 2013:12).

2.2.3.2 The effect of content knowledge of Mathematics teachers

The concept of teacher knowledge has been characterised as a collection of information that enables teachers to teach subject matter using appropriate teaching strategies (Ben-Peretz, 2011:8). Schoenfeld and Kilpatrick (2008:322) contend that knowing Mathematics is important, but not important enough to teach Mathematics effectively. Sepeng (2014:756) declares that teaching Mathematics requires of teachers to have good subject content knowledge. Venkat and Spaull (2015:121), who have done extensive research on various components of knowledge that affect teaching and learning of Mathematics, define mathematical knowledge for teaching as mathematical knowledge needed to facilitate meaningful learning of Mathematics with understanding. According to Hill (2010:515), a teacher's knowledge of Mathematics is identified with good teaching practices and is bound to influence the learner's academic achievement. It is therefore important that teachers are masters of the subject that they are teaching, on the grounds that those who do not possess good content knowledge are likely not going to deliver proper content to the learners (Verster *et al.,* 2018:2825).

2.2.3.3 The effect of curriculum changes on Mathematics education

Lattuca and Stark (2009:4-5) define 'curriculum' as a strategy that teachers use as the basis for their lessons. The following are different changes of the curriculum since the beginning of the democracy in South Africa:

- Curriculum 2005 (C2005);
- the National Curriculum Statement (NCS);
- the Revised National Curriculum Statement (RNCS); and
- now NCS-CAPS (DoE, 2002:8; 2011a:12).

According to the DoE (2006:4), "education reforms that were initiated after 1994 in South Africa elicited an urgent need to change the existing teaching profession and develop one that is relevant for a democratic South Africa in the 21st century".

In 1997, a new curriculum, Curriculum 2005, was implemented and it was later revised in 2002 to outcomes-based education (OBE). The outcomes-based curriculum relied on various learning support materials and teacher development programmes as tools, to interpret and give meaning to the learning outcomes and assessment standards (DoE, 2002a:11-14). It did not identify any one specific learning support material as primary and crucial to quality learning and teaching, but instead promoted teachers' self-developed learning support materials, textbooks and other published learning and teaching materials (DoE, 2002a:5).

Instead of the critical and developmental outcomes of the outcomes-based curriculum, the NCS Grades R–12 had general aims for the South African curriculum, such as the purpose of the curriculum, the principles on which it is based and its eight specific aims (DBE, 2011b:4). However, the NCS Grades R–12 specifically identified textbooks as crucial in teaching and learning, such that they re-emphasised their primary role in the classroom (DBE, 201ac:6–7). The CAPS was embarked on to improve the quality of teaching and learning (DBE, 2010). Its main focus was on content and assessment for each particular term, such that both the teacher and the learner know what is expected of them in each subject (DBE, 2010). According to Stols (2013), the new CAPS, was once more, being implemented without training the teachers sufficiently. In addition, topics such as data handling, probability and Euclidean geometry were new to most of the teachers (Stols, 2013:16).

It is of the utmost importance to note that teachers are the major influence of learners' academic performance and achievements (Singh, 2016:108). According to Guglielmino and Long (2011:1), one possible approach that may help to address, and consequently minimise, the problems of Mathematics learner performance in South Africa is to enhance Mathematics teachers' SDL in order to keep their teaching practices up to date (Wagner, 2011:4). The development of teachers into self-directed individuals can be explored as an opportunity for their professional growth, which in turn also benefit learners' learning in the classroom (Verster *et al*. 2018:2826).

2.2.4 The use of technology in Mathematics Education

The work of Yanik and Porter (2009:3) indicate that the use of technology "has increased incredibly and gained recognition and acceptance as an instructional tool in school mathematics both at elementary level and at the secondary level." Nowadays, the use of technology is increasingly supported by different application software which allow more visualisation and exploration of concepts, as well as more collaborative ways of working. For instance, GeoGebra can also be used to investigate and make conjectures on topics such as geometry, algebra, functions and calculus. Additionally, the use of technological tools and applications like Google Docs and Google Classroom (for cooperative writing and reflections through chatting), as well as Google Hangout (for videoconferencing and sharing computer screens) can provide teachers with an opportunity to share their ideas and accomplish the given tasks, without space and time constraint. Research by De Villiers (2007:47-48) suggests that it is not important to master an application software in order to use it, however, "with more or less ready-made sketches that only require dragging, and perhaps clicking, animation or construction button," learning can take place effectively.

2.3 SELF-DIRECTED LEARNING

SDL is a process that comprises the development of various 21st-century skills, such as lifelong learning, and could thus contribute to the development of Mathematics teachers (Bell, 2010:39). The definition of SDL, the necessity of SDL in education, as well as the discussion of a teacher as an adult learner will be explored in the next section.

2.3.1 Defining self-directed learning

A number of studies have established SDL as a basic fundamental ability that supports lifelong learning (Guglielmino, 2008:1; Knowles, 1975:15; Mok & Lung, 2005:34). The idea that teachers should take accountability in the process of lifelong learning is based on Knowles' (1975) adult learning theory, i.e. SDL. Knowles (1975:18) defines SDL as a process "in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing learning strategies, and evaluating learning outcomes". Merriam and Brockett (2007:137) on the other hand define SDL as an involvement of "adults assuming control of their learning". From the two definitions above, it is clear that SDL is more focused on the control that individuals have over their learning. SDL is a process that offers an individual (in the case of this study, the teacher) the opportunity to set goals, plan, evaluate and implement his or her own learning (Thornton, 2010:181). SDL has recently been defined as "an international learning process that is created and evaluated by the learner" (International Society for Self-Directed Learning, 2020).

2.3.2 Characteristics of a self-directed learner

The characteristics needed by learners (teachers in the case of this study) to be lifelong learners are:

- finding joy in learning;
- being motivated to learn;
- seeing change as a challenge rather than an obstacle;
- seeing solutions to problems through continuous learning; and
- being able to select and use different learning strategies (Guglielmino, 2013:3).

The characteristics of SDL, as stipulated by Guglielmino (2008:2), embrace having the option to search for new information and combining such information with existing information. This implies that teachers who are self-directed, ought to have the option to link the information and apply it to new situations. These teachers are able to receive information, analyse it and use it to their benefit, as well as the benefits of their learners. According to Guglielmino (2013:3), these teachers should also be able to set learning goals, and implement and evaluate their learning process (Guglielmino, 2013:3).

2.3.3 Self-directed learning skills

According to Gibbons (2002:62-64), there are several thinking skills needed for SDL. A self-directed learner should be able to ask questions, find relevant information, analyse a situation, make considerate decisions, formulate a point of view, determine action to be taken and lastly solve a problem (Gibbons, 2002:62-64). In support of this view, Francom (2010) included the accompanying four significant guidelines for fostering SDL. According to Francom (2010:29), the above mentioned SDL skills can be fostered through designing training programmes aimed at the development of SDL skills. Francom (2010) asserts that, in order to foster SDL, the following four major guidelines need to be implemented; a self-directed learner should be able to match the level of SDL required in learning activities; make progress from teacher-directed learning to learner-directed learning; support the acquisition of subject knowledge and SDL skills together; and learners should practice SDL in the context of learning tasks. These guidelines focus on what facilitators can do to give teachers opportunities to practice SDL skills (Francom, 2010: 32).

2.3.4 The need for teachers to develop SDL

Guglielmino and Long (2011:1) contend that the complexity and rate at which our world is changing influences our day to day existence, and requires lifelong SDL. SDL demands teachers to change their roles and take on new responsibilities of being active learners who are able to adapt and learn in a fast-changing environment. It is therefore important that teachers keep up with the changes, by enhancing their self-directedness and making sure they are able to meet the 21st century requirements, especially with regard to curriculum practice (Verster *et al.,* 2018:2825). It is through SDL that teachers can be responsible for their own self-development and improve their teaching methodologies (Wagner, 2011:2). Thornton (2010:160) expresses a similar view, namely that teachers who are self-directed are able to create a classroom culture that engages learners in creative and critical thinking activities.

The opinion of Wagner (2011:4) is that SDL is an opportunity for teachers' professional growth, where teachers take responsibility by equipping themselves in order to succeed in the fast-changing environment. In support of this argument, Thornton (2010:161) makes it clear that SDL could prove to have a strong impact on how teachers make decisions about their learning goals as well as enabling a personalised learning experience. Teachers are expected to be independent, self-directed professionals (Louws *et al.*, 2017a:172). Being self-directed in learning is "our most basic, natural response to newness, problems, or challenges in our environment" (Guglielmino & Long, 2011:2). SDL can therefore enable teachers to select suitable teaching and learning resources that arouse learner's interests in learning (Thornton, 2010:161).

Different strategies have been related with the promotion of SDL and amongst others, CL has been proved to be one of the best strategies (Loyens *et al.*, 2008:418; Mentz & Van Zyl, 2016:84). This strategy is discussed in detail in the following section.

2.4 COOPERATIVE LEARNING

There are different strategies that have been proven to promote SDL, and cooperative learning (CL) is one of the strategies (Mentz & Van Zyl, 2016:331). CL is one of the teaching strategies that engages individuals (i.e. teachers) to develop to their fullest potential through working together to solve a challenging set of tasks.

2.4.1 Background and definition of cooperative learning

CL provides an environment in which individuals apply their knowledge and skills to support and enrich each other's learning (Johnson *et al.,* 2008:1:5). Through interaction, CL empowers individuals to help one another develop to their fullest potential, in order to achieve a common goal (Loyens *et al.*, 2008:418). Felder and Brent (2016:161) argue that during CL, every individual of a group should have the responsibility to help others to learn, which makes an environment of accomplishment. Johnson and Johnson (2013:107) concur that this teaching strategy is grounded on the fact that learning is viable when the learners share ideas and work all together in a group to complete a given task. Furthermore, this approach encourages appreciation and respect amongst learners (Johnson & Johnson, 2009:111). Thus, understanding how to form groups, sustaining individual accountability, ensuring positive interdependence and resolving group conflict are critical aspects of the achievement of a successful CL experience (Millis, 2010:4).

2.4.2 Basic elements of cooperative learning

Johnson and Johnson (2013:102) contend that there are five basic elements to be adhered to for successful CL, namely positive interdependence, individual accountability, promotive interaction, appropriate social skills, and group processing. This section includes a discussion on the elements of CL.

2.4.2.1 Positive interdependence

Positive interdependence exists when group members rely on each other, for the success of the group (Johnson & Johnson, 2013:102). These authors refer to positive interdependence as "the heart of cooperative learning" (Johnson & Johnson, 2013:458). Positive interdependence involves the acknowledgement by each group members that the group can only reach the goal if each individual is successful (Johnson & Johnson, 2009:107). According to Hornby (2009:161), positive interdependence enables groups to establish mutual goals, share resources and enjoy joint rewards (Johnson *et al*., 2008).

The "higher the degree of interdependence, the better the group will operate as an entity, thus promoting the relatedness (connectedness) aspect of the self-determination theory" (Johnson & Johnson, 2009:107). When individuals given the opportunity to be actively involved in their own goal-setting they assume responsibility for their own learning which can promote their SDL (Johnson & Johnson, 2009).

According to Johnson and Johnson (2013:4), positive interdependence can be structured in different ways. For instance, (1) Positive goal interdependence, where the group shares a common goal, (2) Positive reward interdependence, where the focus is mainly on rewarding group members when the group achieves its shared goals, (3) Positive resource interdependence, where members work on a limited portion of the resources to complete a task, (4) Positive identity interdependence, where a group establishes its own name or motto and (5) Positive role interdependence, where members of different roles in a group work together.

Shimazoe and Aldrich (2010:53) propose that CL tasks should be organised so as to include all members of a group. Once group members realise the importance of positive interdependence, each member tends to understand that his or her contribution is crucial for his or her own success and the success of the group (Mentz *et al.,* 2008:250). Group members also become aware that they must complete their assigned work, in order for the group to attain its goal (Millis, 2010:16).

2.4.2.2 Individual accountability

Johnson and Johnson (2013:105) describe individual accountability as holding each group member accountable for making a contribution towards achieving the goal of the group.

Individual accountability involves two components, firstly, each student is responsible for his or her own learning and secondly, each member is responsible for helping the group (Johnson & Johnson, 2009:110). According to Mentz *et al*. (2008:3), each member will be assessed for his or her specific task or section of the work, as such, individual accountability avoid members to loaf around while they are supposed to complete a given task. However, it is important that independent members work cohesively together to ensure that the group task is completed. Felder and Brent (2016:162) summarise individual accountability as all members contributing to the group, while at the same time also acquiring knowledge themselves.

According to Johnson and Johnson (2013:105), individual accountability can be structured in the following ways: arranging members in small groups, assigning roles to each group member, holding each member accountable for a specific task or section of the work and assessing each member's understanding of concepts. Even though members work together, Mentz *et al.* (2008:3) emphasises that each member should be able to reach his or her goal at the end of the task.

2.4.2.3 Promotive interaction

Promotive interaction refers to the encouragement and support provided by the members of the group during the group activity (Johnson & Johnson, 2009:111). Johnson and Johnson (2013:89) state: "… the type of interdependence structured in a situation determines how individuals interact." They further state, "Promotive interaction occurs as individuals ... challenging each other's conclusions and reasoning ... and acting in trusting and trustworthy ways." Mentz *et al.* (2008:250) also emphasise that when members help each other to learn by motivating and uplifting each other, promotive interaction is stimulated (Mentz *et al.,* 2008:250). This help members to develop trust towards their group members, while at the same time reduces stress and anxiety (Tsay & Brady, 2010:78).

Promotive interaction is therefore a key to the effectiveness of the groups (Johnson & Johnson, 2013:106). Through members interacting with one another, members with different strengths can benefit a lot from exchanging information and other resources. Johnson and Johnson (2009) make it clear that positive interaction is characterised by group members who take viewpoints of other group members into consideration and explore various perspectives as possible outcomes. However, for interaction to be promotive, it is important that the element of appropriate social skills is necessary (Johnson & Johnson, 2013:107). The next section will elaborate more on the impact of social skills on CL groups.

2.4.2.4 Social skills

Social skills refer to the skills we use to communicate and interact with each other, in order for a group to function successfully (Huffman, 2012:28). Social skills include listening to each other, communicating clearly, sharing resources fairly, accepting and supporting each other and engaging in decision-making (Booysen & Grosser, 2014:51). Allen-Kosal (2008:220) also adds that social skills within groups should involve resolving conflict, discuss and share ideas, take criticism positively and assess own opinions. Johnson and Johnson (2013:106) emphasise that the above mentioned needs to be present in every CL activity since they contribute to positive and healthy relationships. These authors further mentions that CL will fail if members who lack social skills are put together in a group. An equally significant aspect is that of Gillies (2007:41) who states that "If children are not taught how to interact appropriately with each other, they are more likely to encounter conflict and difficulties with cooperating as they work in small groups." Evidently, it is the teacher's responsibility to facilitate the development of these skills in order for the group to cooperate effectively and achieve their goal (Johnson & Johnson, 2009:111).

2.4.2.5 Group processing

Group processing entails self-evaluation and the reflection of a group on how well they accomplished their goals (Johnson & Johnson, 2009:112). This involves looking back at (1) which actions were helpful or not and (2) making decisions about the actions to take or change (Johnson & Johnson, 2013:107). The more frequent the groups meet, the more likely the group function effectively towards the group goal (Felder & Brent, 2016:247).

According to Van der Merwe and Kruger (2012:4), there are four steps of group processing. These are: (1) receiving feedback from members of the group, (2) analysing and reflecting on the given feedback, (3) setting new goals on how to improve and lastly, (4) celebrating the effort made on accomplishing the task. Johnson *et al.* (2013:108) state that group processing helps groups to function more effectively by eliminating unnecessary and incorrect actions, while developing metacognitive abilities.

The application of these five elements of CL have been proved necessary for effective cooperation. According to Mentz and Van Zyl (2016:84), these five elements of CL are closely related to the development of SDL.

2.4.3 Benefits of cooperative learning

Johnson *et al*. (2008) summarise the benefits of CL into three different categories: intellectual benefits, social benefits and psychological benefits. Intellectual benefits comprise of benefits such as producing higher-order thinking and critical thinking skills, metacognitive skills and problem solving techniques. Social benefits on the other hand include building positive relationships, developing interpersonal skills and increased social support. Lastly, psychological benefits include the following indices: increased retention, greater positive attitude towards learning, higher academic achievement and a higher level of confidence (Johnson *et al.,* 2008).

2.4.4 Cooperative learning strategies

Various researchers have developed different CL strategies and each strategy has interesting characteristics for improving learning (Johnson *et al.,* 2008). These strategies are the Jigsaw strategy, think-pair-share, student team achievement divisions, reading comprehension triads, numbered heads together, round-table and three-step interview. This study used the Jigsaw CL strategy with the support of different computer application software as technological tools to facilitate the content of the session (see 3.6).

Jigsaw is a CL strategy that has been widely executed and studied throughout the years (Doymus, *et al.,* 2010:672). According to Maden (2011:913), the Jigsaw strategy has six different versions, namely: “the original Jigsaw; Jigsaw II developed by Slavin in 1987; Jigsaw III developed by Stahl in 1994; Jigsaw IV developed by Holliday in 2000; Reverse Jigsaw developed by Hedeen in 2003; and Subject Jigsaw developed by Doymus in 2007”. The basic components of all these versions are the same and consist of breaking home group members into small groups, where they become experts on the assigned topic, then regroup back to teach the home group about what they have learnt (Maden, 2011:911). The Jigsaw strategy allows expert group members to split up in small groups, where they are expected to gain more information on a sub-topic, then later each member explains a body of information clearly enough to teach it to the home group (Doymus, *et al.,* 2010:671). In this study, the Jigsaw strategy was used in order to allow teachers to work cooperatively, while ensuring that each teacher is accountable for explaining a section of the material to the group.

2.4.5 Cooperative learning professional development

Many studies have proved the positive effect of CL in areas such as: academic relationships (Callahan, 2013:10; Yin, 2009:159) and positive interpersonal relationships (Callahan, 2013:11; Mentz *et al*., 2008:250; Williams, 2012:14). The application of the five elements of CL has also been proven to be effective for cooperation to work well (Johnson *et al.,* 2008a:10). CL is likely to lead to “greater interpersonal liking, group cohesion, valuing of heterogeneity, and task-oriented and personal support" (Johnson & Johnson, 2008a:2). According to the findings of a study by Slavin (2009:10-1), interaction and building of trust allow individuals to communicate freely and openly, ensuring that everyone can express their opinions. This study therefore used CL as a viable option for teacher PD.

2.5 PROFESSIONAL DEVELOPMENT OF TEACHERS

The literature on teacher PD shows that this concept has evolved over time. The PD concept is referred to by several different terms, from 'in-service education' to 'staff development', 'PD' and 'current professional learning' (Kriek & Grayson, 2009:185; Mushayikwa & Lubben, 2009:375). The definitions of teacher PD highlighted above can be woven into the definition of the concept for this study, which is given below.

2.5.1 Defining professional development

The term 'teacher PD' in the context of teacher education is commonly used to refer to the improvement of teachers' practices (Iheanachor, 2007:19). Musset (2010:7) notes that the motivation behind teacher PD is to update, develop and broaden the knowledge, with new skills and professional understanding. Teacher PD is commonly recognised as a significant strategy used to enhance teacher knowledge and skills (Avalos, 2011:10). Teacher PD can also be described as any type of continual development of a teacher's professional role (Hirsh, 2009:12). For Murtaza (2010:215), teacher PD is one way in which teachers can deepen their knowledge while becoming innovative and adventurous in their teaching practices. Deepening teachers' knowledge involves creating and expanding the learning which teachers acquired during their underlying teacher training and, additionally, to provide them with new skills and professional understanding (Avalos, 2011:15). It must therefore be recognised that teacher PD is a requirement for all teachers to change and update their professional practices in order to overcome the challenges they are faced with in the classroom settings (Verster *et al.,* 2018:2825).

2.5.2 Historical background of teacher professional development in South Africa

Teacher PD is not a new concept. In fact, it has been fundamental to education for many years (Kriek & Grayson, 2009:186; Mushayikwa & Lubben, 2009:375). In South Africa, a vast amount of money and resources have been spent on helping teachers to develop their skills (Mphale, 2014:76). However, the focus has been on the traditional view of teacher PD according to which the teacher attends workshops, holiday sessions or afterschool seminars (Buczynski & Hansen, 2010:599).

There are claims that many teacher PD strategies are rarely able to make teachers change paradigms and improve their classroom practice (Guskey & Yoon, 2009:495). Research demonstrates that teacher PD activities, such as seminars, conferences and sit-and-get or one-time-only PD, have a minimum effect on the continuing PD of teachers (Murtaza, 2010:213; Taylor, 2008:23). According to Katz *et al.* (2009:24), teacher PD strategies such as workshops, conferences and seminars, seems to not equip teachers with the necessary skills required for the 21st century. Herein, "all teachers are treated more or less as if they are on the same level and have similar learning goals" (Louws *et al.* 2017b:488). Taylor (2008:22) also alludes to the fact that, although teacher PD is acknowledged as important in refining teacher's knowledge, traditional PD strategies tend to be ineffective. For these reasons, it can be noted that not all teacher PD opportunities are equally effective (Ono & Ferreira, 2010:59).

2.5.3 Effective professional development of teachers

Desimone (2009:181) emphasises that "understanding what makes teacher PD effective is critical to understanding the success or failure of many education reforms". For teacher PD to be effective, it needs to be on-site, intensive, ongoing and led by fellow teachers who model best practice (De Clercq & Phiri, 2013:78). In support of this view, Darling-Hammond *et al.* (2009:48) say that teacher PD cannot be perceived as an event that happens on particular days in a school calendar year, but instead it must be part of the daily work of teachers. Mouton *et al.* (2013:40) recommend that any training that teachers receive should be relevant and of a high quality. Opfer and Pedder (2011:184) also emphasise that high-quality teacher PD must be longer in duration, provide access to new technologies for teaching and actively engage teachers in meaningful activities for their individual contexts.

Steyn (2008:23) suggests that teacher PD enables teachers to view themselves as lifelong learners, where they respond to their learners' needs by evaluating and adjusting their teaching-learning practices. This means that teacher PD must help teachers to develop reflective teaching skills and lifelong learning. Lifelong learning is incorporated in and supported by SDL (Loyens *et al*., 2008:414). While SDL is present in every person to some degree, many individuals will need guidance and assistance in accepting responsibility for developing their SDL (Guglielmino, 2008:7). The lessons learnt by teachers from their exposure to reflective practice in their teaching should result in their engagement in new practices (De Clercq, 2008:9). Effective teacher PD should therefore be conducted in a way that generates a direct outcome on teacher practice (De Clercq & Phiri, 2013:77).

2.5.4 Professional development strategies in South Africa

This section will discuss various PD strategies that were implemented in South Africa with the intention of developing teachers' content knowledge and skills.

2.5.4.1 The UNIVEMALASHI professional development strategy

The UNIVEMALASHI teacher PD strategy was established by the partnership between the University of Venda and the Limpopo Department of Education, with the intension of introducing OBE to the foundation phase teacher (Onwu & Mogari, 2004:162). The authors reported that the UNIVEMALASHI teacher PD was successful in assisting teachers with the implementation of the education reforms. This three-year teacher PD strategy equipped teachers with content and skills necessary to alter their classroom practices. Teachers reported that they improved on how they asked questions in their classrooms and this helped in making their classes more interactive (Onwu & Mogari, 2004).

2.5.4.2 The Mpumalanga Secondary Science Initiative (MSSI)

The Mpumalanga Secondary Science Initiative (MSSI) was a PD strategy for Science and Mathematics teachers, carried out in Mpumalanga province. The MSSI teacher PD strategy used the concept of clustering and it operated from 2000 until 2006 (Mokhele, 2013:75). This teacher PD strategy was successful in enrolling many Mathematics and Science teachers who were reliable in terms of their participation during the PD sessions. The teachers reported that there were change in their knowledge and teaching practices, in such that, there was an improvement in terms of learners' results during the six year period (Jita & Ndlalane, 2009:59).

2.5.4.3 The Matthew Goniwe School of Leadership and Governance (MGSLG)

The Matthew Goniwe School of Leadership and Governance (MGSLG) was established in 2003 with the aim "to promote a central hub for professional growth of school leaders and governors; to design and present cutting-edge school leadership, governance and management training programmes; and to focus on improving practice through research" (Bush, 2014:182). The MGSLG was successful in helping the school governing bodies (SGBs), principals, district officials and the heads of departments (HODs) to "develop high-order leadership and governance skills" (Bush, 2014:183).

Evidence of the above strategies seems to indicate that a teacher PD that is implemented well and relevant to teacher's needs, has an impact on teachers' knowledge and teaching practices. The UNIVEMALASHI PD strategy for instance, was found to have impacted the skills, knowledge and attitude of 110 foundation phase learners in the Limpopo province (Onwu & Mogari, 2004:168). The Mpumalanga Secondary Science Initiative (MSSI) was a six-year PD strategy and, according to Jita and Ndlalane (2009:59), this PD strategy also succeeded in changing teachers' knowledge and approaches.

2.5.4.4 The Khanya project

The Khanya project was established in 2001 in the Western Cape (Isaacs, 2007:12). According to Van Wyk (2011:1), "[t]he Xhosa word Khanya means enlightenment". This means teachers and learners were supposed to gain exposure to ICT usage. The Khanya project was aimed at empowering teachers to use technology when delivering lessons. This project was also successful in such that a large number of learners doing Mathematics passed in 2002 (Van Wyk, 2011:1).

2.5.4.5 Govan Mbeki Mathematics Development Unit

In October 2002, the Govan Mbeki Mathematics Development Unit (GMMDU) was established (GMMDU, 2015). The aim of the PD strategy was to improve the mathematical problem-solving skills of learners and to help teachers to meet the challenges of the new syllabus for Mathematics. The GMMDU was fully aligned with the Curriculum and Assessment Policy Statements (CAPS) for Mathematics and Science, for Grades 10 to 12 and included video lessons, animated PowerPoint presentations, digital interactive Mathematics software, such as GeoGebra, self-assessment and feedback, interactive language support (in six indigenous languages), matric papers of previous years with their memorandums and more (GMMDU, 2015). The GMMDU also offered teachers laptop-based skills training and professional learning community programmes, which included an offline package called TouchTutor™ (GMMDU, 2015). This technology-supported PD strategy allowed for new ways to modernise classrooms, providing flexibility to teachers to organise their own resources and to adopt their own learning styles.

However, even with the implementation of the above mentioned teacher PD in different provinces, learners' poor results proves that these strategies have had a limited influence on teacher development (Mouton *et al.,* 2013:35; Murtaza, 2010:123). In the light of the above observations, it is important to make appropriate recommendations with regards to new strategies of teacher PD. This current study suggests the TSCL PD will provide teachers with a flexible and convenient way to strengthen and enhance their professional skills through discussing, engaging and interacting with each other. Instead of equipping school with computers, or sending representatives to be trained and report back, technology use in

PD creates new possibilities for introducing flexibility for individuals in terms of time, place and pacing of independent study (Assareh & Bidokht, 2011:791).

2.6 CONCLUSION

In this chapter, the groundwork of Mathematics education, SDL, CL and teacher PD was explained, and important concepts were clarified. The literature revealed that teachers hold different beliefs about Mathematics teaching and learning and this has a huge impact their classroom practices. It was also found that out-dated teaching practices, changes in the curriculum and teachers' lack of content knowledge affect learners' performance in Mathematics. This chapter also highlighted what SDL is, where it originated, what its benefits are and the role of the teacher as a self-directed learner. A history of CL was also given, followed by a discussion of the five basic elements of CL and CL as an option for PD. Teacher PD was defined and TSCL PD as an alternative to traditional teacher PD was proposed. The next chapter will report on literature relating to TSCL PD.

CHAPTER THREE

TECHNOLOGY-SUPPORTED COOPERATIVE LEARNING PROFESSIONAL DEVELOPMENT

3.1 INTRODUCTION

The purpose of this study was to enhance Mathematics teachers' self-directed learning (SDL) through technology-supported cooperative learning (TSCL) as a professional development (PD) strategy; furthermore, the study set out to determine how teachers experienced the proposed TSCL PD. In order to address this extensively, it was very important to explore literature relating to TSCL PD. This chapter starts with an explanation of educational technology, followed by the history of technology, benefits and barriers in the use of technology and the need for alternative PD. The chapter concludes by proposing a new way for PD (TSCL PD), which is flexible and convenient for teacher of 21st century learners.

3.2 EDUCATIONAL TECHNOLOGY

Technology has affected most aspects of life today, and education is no exception. In the hands of teachers, "a piece of chalk and a blackboard, or even a stick and a patch of sandy ground are educational technologies" (Terry & Daryl, 2013:199). This section includes a discussion on the terminology used in the field of educational technology.

3.2.1 Terminology used: Educational technology

Gentry (1983:7) defines educational technology as "the combination of instructional, learning, developmental, managerial and other technologies as applied to the solution of educational problems". A more recent definition is provided by Betrus *et al.,* (2008:1), who define educational technology as "the study and ethical practice of facilitating learning and improving performance by creating, using and managing appropriate technological processes and resources". The term 'technology' refers to any electronic tool that has the ability to collect, receive, share and control information (Bembridge, Jones & Jeong, 2010:18). "Technology is a huge driver of change" which has the potential to connect people through the use of the Internet, instant messaging and social media (Codrington & Grant-Marshal, 2011:86).

Another term that has been used interchangeably with technology is ‘information and communications technology’ (ICT) or ‘information technology’ (IT) (Vallance, 2008:284). ICT refers to technologies that provide access to information through telecommunications (Assareh & Bidokht, 2011:791). Both ICT and technology, however, can be seen as vehicles for different media use, to facilitate information. This study however used the term ‘technology’ to refer to a tool which teachers can use to convey teaching and learning.

3.2.2 Emerging terms regarding technology

New technological terms emerged as the technology advances. For instance “e-learning (electronic learning), m-learning (mobile learning), web-based education or learning, multimedia learning, and computer-based learning (CBL)” indicates how technology is used in education (Eke, 2010:276). E-learning refers to learning that is managed through the Internet using an electronic device (Maldonado *et al.,* 2011:67). Similar to e-leaning, the term m-learning puts more emphasis on accessing information using personal mobile devices (Gikas & Grant, 2013:18). Web-based education or sometimes referred to as Web-based learning refers to the type of learning that relies on an Internet connection for delivery of the content (Eke, 2010:277). Maldonado *et al.* (2011:67) write that learning on the web is one of the most promising and rapidly developing areas of technology in education.

3.3 HISTORY OF TECHNOLOGY IN SOUTH AFRICAN EDUCATION

For many years, communication has been a challenge, especially with regard to reaching out to colleagues, family and friends who are distances apart. As technology advances, telegraph, telephone and radio provided a new era of communication over long distances (Baruah, 2012:4). In 1946, the first digital computer was invented (Schifter, 2008:8). A few years later, in 1975, the first personal computer (PC) was born and in 1985, personal computers started to become more popular. Laptops, mobile phones and other electronic devices were developed in the mid-1990s (Schifter, 2008:9).

Computers were now introduced into the education system with the focus mainly being on administrative purposes, such as, keeping learners’ records, recording marks, making school reports and timetables (Popovich *et al.,* 2008:987; DoE, 2008:22–25). The post-modern society then transformed into the so-called “fourth revolution” (Warschauer & Matuchniak, 2010:179). According to Yelland *et al.* (2008:4), the fourth revolution is characterised by a multimodal approach, where acquisition of knowledge and information is driven by technology. Technology has empowered individuals to get things done in a simpler, quicker, more effective way (Baggaley, 2008:41). As technology is changing rapidly, teachers also must keep learning in order to survive in the workplace (Law *et al.,* 2008:14).

3.4 THE NEED FOR TECHNOLOGY-SUPPORTED COOPERATIVE LEARNING PROFESSIONAL DEVELOPMENTTECHNOLOGY

Some studies (Hendricks, 2004:16; Iheanachor, 2007:19; Murtaza, 2010:217) show that when PD strategies are held outside the school premises, there is very little impact on teacher's professional growth. Taylor (2008:22) also supports this statement, by arguing that few PD strategies that are planned by the Department of Education (DoE) and teacher unions are effective, in such that they target a limited number of teachers, with prepared activities that do not relate to teacher's needs. Most of these teacher PD strategies are specified towards meeting the demands of the policy while neglecting what the needs of the teachers are (Taylor, 2008:23).

The DoE used the cascade model (see Kennedy, 2005:240) to train teachers on policy implementation, and the model has proved to be ineffective (Shezi, 2008:97). According to Du Plessis (2010:157), the cascade model is affordable, hence it is preferred. Herein, teachers' interests, teaching strategies and experiences are not considered. They are instead being given a "one-size-fits-all" set of PD strategies (Lieberman & Pointer Mace, 2008:227).

According to Jita and Mokhele (2014:2), South Africa is faced with a challenge of finding a sustainable teacher PD that has the potential to develop teachers' knowledge and change their teaching practices. The study by Steyn (2010:157) shows that many PD strategies which aim to improve teaching and learning in the 21st century in South Africa, do not sufficiently provide teachers with the necessary competencies such as the knowledge, skills and dispositions concerned with subject content. Given this evidence, it is clear that traditional teacher PD has minimum impact on ensuring that teachers are well equipped with the necessary tools to become lifelong learners (Desimone, 2009:181; Guskey & Yoon, 2009:496).

With the rapid changes taking place in education and around the world, teachers are under pressure to keep up with these changes (Verster *et al.*, 2018:2825). There is therefore a need for teachers to enhance and update their knowledge regularly. One possible way for teachers to deepen their knowledge and become more self-directed is to be engaged in a PD that is continuous, effective and allows for working together (Murtaza, 2010:212). Howie (2010:507) notes that a successful PD strategy in the 21st century should provide the following key processes: teachers learn together, reflect on knowledge they have learnt, use technology, and receive assistance from the facilitators.

The common requirement amongst many studies is that, technology should form part of teachers' PD (Johnson & Johnson, 2014; Mentz & Goosen, 2013:131). The use of technology in PD can offer more opportunities than what the traditional PD strategies offered. Technology forms an important component that can inspire teachers, assisting them with the challenges of the teaching profession and promote their lifelong PD (Kriek & Grayson, 2009:186; Loveless & Dore, 2002:154). Such a PD strategy can create an opportunity for teachers to share ideas and material regardless of geographic proximity (Assareh & Bidokht, 2011:791).

3.5 THE USE OF TECHNOLOGY TO SUPPORT COOPERATIVE LEARNING

Various authors discuss different benefits of the use of technology to support CL (Johnson & Johnson, 2014; Mentz & Goosen, 2013:131). These authors argue that the use of technology in CL can allow members to exchange information, engage in democratic decision-making, accepting and supporting each other, as well as allowing effective communication. As an equally significant aspect, Callahan (2013:10) rightly points out that the use of technology to support CL, could improve individuals' (in this case, teachers') goals, such as inter-group relations, active participation, high levels of success and increased self-esteem. Technology can therefore be used to facilitate CL by creating an environment in which individuals apply their knowledge, support and enrich each other, as well as direct their own learning.

CL is commonly recognised as a pedagogical practice that promotes socialisation (Huffman, 2012:28). The opinion of Johnson and Johnson (2013:107) is that when people work together, they tend to encourage and motivate each other more frequently than when working alone. Mentz *et al.* (2008:250) also expressed a similar view that CL positively influences the social relationship within groups, by allowing individuals to communicate effectively, build trust amongst them, make better decisions and resolve conflicts. Mutual respect between group members, conflict resolution, decision-making skills and trust building are actions proposed by Johnson and Johnson (2009:111) to be undertaken in order for social skills to be stimulated.

Given that CL can promote socialisation, the incorporation of technology has now also changed how people interact with each other**.**

The fast changing pace of technology has opened new possibilities for enhancing social support through photos, videos, text, and music, irrespective of time and location (Johnson & Johnson, 2014:1). Different applications, for example Facebook, instant messaging, Snapchat, Skype and FaceTime have all created new ways of communication (Johnson & Johnson, 2014:1). These technological applications allow exchange of information between individuals, making it possible for every CL member to communicate in different locations and time (Assareh & Bidokht, 2011:791). It is clear therefore that TSCL opens new opportunities for better learning and teaching environments by allowing individuals to exchange information, and discuss, encourage and facilitate each other's efforts (Ekizoglu & Ozcinar, 2010:795).

The use of technology in a CL environment makes it possible for members to work on the same task simultaneously and actively collaborate in this manner (Assareh & Bidokht, 2011:793). Groening (2010:1332) also adds that TSCL allows members to choose the best and easiest method of learning, in the privacy of their own space and at their own pace. Technology also allows individuals to communicate with each other, regardless of the location (Assareh & Bidokht, 2011:791). Given this evidence, it can be seen that the combination of technology and CL strategies has the potential to improve learning by providing unlimited opportunities for teachers' PD.

Mentz and Goosen (2013:332) are of the opinion that CL (in a technology-rich environment) increases individuals' active participation in activities, while providing more opportunities for instant interaction. There is no doubt that TSCL can possibly be adopted as a successful PD strategy in which teachers have more control over their learning. The evidence from the literature seems to indicate that TSCL PD allows teachers to share equal responsibility of work and resources, helps with finding relevant information from the Internet, creates an atmosphere of independence, saves travelling costs and time and lastly, open doors for effective communication.

3.6 LEARNING TOOLS THAT CAN BE USED IN TECHNOLOGY-SUPPORTED COOPERATIVE LEARNING PROFESSIONAL DEVELOPMENT

This section includes a discussion on the learning tools that can be used in TSCL PD, in order to assist teachers to become both more independent and more interconnected with each other.

3.6.1 Social networking sites

Social networking sites (SNS) refer to an online platform that allow users to communicate and share various types of information, photos and videos (Veletsianos, 2010:72). Boyd and Ellison (2007:211) also describe SNS as a network of communication whereby individuals connect for instance with each other, due to some common interest. With an increasing growth in SNS, applications such as Facebook, Twitter, LinkedIn, Friendster, LiveJournal and MySpace can be used by teachers to share materials as well as to interact with each other, via writing and commenting on others' posts and profiles in chats and on walls (Johnson & Johnson, 2014; Shade, 2008:65). These applications mentioned above, provide a new way to end the isolation many teachers experienced, by linking them virtually, enabling exchange of knowledge and communication (Panckhurst & Marsh, 2011:253). Given this evidence, it can be seen that SNS creates new opportunities for teachers to build cross-cultural connections, while fostering interaction amongst themselves.

3.6.2 Online discussion forums

According to Song and McNary (2011:1), online discussion forums can enable teachers to post their thoughts about a topic or concept, as well as interact with each other by reading and responding to their colleagues' postings. Online discussion forums thus provide teachers with open discussions and communications (Mokoena, 2013:97). As Nandi *et al.,* (2011:125) mention, online discussion forums are more insightful than face-to-face discussions and can be longer and more academically focused compared to face-to-face discussions. This can help teachers to participate in longer discussions, giving them a chance to construct their own knowledge and analyse their own thoughts.

3.6.3 Learning management system

According to Adzharuddin and Ling (2013:248), a learning management system (LMS) is a form of e-learning that organises, tracks, monitors and assesses the learning process, while enriching cooperation between individuals. Some examples of LMSs are: WebCT™, Blackboard™, Moodle™, and SAKAI™. Watson and Watson (2007:28) states that, the most important features of an LMS is overseeing the learners, being able to create content, evaluating assessment and giving feedback. An LMS could help to improve the speed and effectiveness of the educational processes and communication amongst teachers (Veerasamy, 2010:66).

3.6.4 Portals, wikis and blogs

An Online Portal refers to a website that is accessible over the Internet, offering a wide range of services such as, emails, online forums and search engines (Beal, 2016). Wikipedia is an example of an online portal that provides open content to its users (Ferriera, 2008:23). Blogs, sometimes referred to as web-logs, are webpages that maintain an on-going discussion pertaining to a particular topic (Andersen, 2007:7). This author further explains that a blog consists of posts, diary entries, or online journals of one or multiple users. According to Koohang *et al.* (2010:35), social networking technology portals, wikis and blogs provides teachers with an opportunity to work cooperatively.

3.7 TECHNOLOGICAL BARRIERS THAT CAN BE ENCOUNTERED WITHIN TECHNOLOGY-SUPPORTED COOPERATIVE LEARNING. PROFESSIONAL DEVELOPMENT

A barrier is an obstacle that prevents the achievement of a goal (Oxford, 2010:106). Researchers have identified barriers that hinder Mathematics teachers' use of technology (Aslan & Zhu, 2016; Bingimlas, 2009; Law *et al.*, 2008). These barriers are for instance variables such as age, gender, institutional support and personal barriers. The vast majority of these barriers have existed for quite a while and have not yet been overcome effectively (Kim *et al.,* 2013:77). Evidence in support of this position can also be found in Angeli and Valanides (2009:155), who reveal that the most commonly cited barriers for teachers with regard to using technology effectively are that, teachers lack confidence, that they are afraid of losing control of the classroom, their attitudes and beliefs and the lack of support they experience.

Another barrier that hinders teachers from using technology is the digital divide. The term digital divide refers to the gap between those who have access to computers and the Internet, and those who do not (Howard *et al.*, 2010:110). According to Alzouma (2013:297), one of the main causes of the digital divide is peoples' socio-economic status. The cost of obtaining a technological device along with the cost of the Internet, are the reasons mentioned for the uneven distribution of the access to technology (Gould, 2013:50).

3.8 HOW TECHNOLOGY-SUPPORTED COOPERATIVE LEARNING PROFESSIONAL DEVELOPMENT CAN ENHANCE SELF-DIRECTED LEARNING

As discussed above, teachers need to be involved in a new strategy of PD, which provides many opportunities for teachers to connect with others, explore topics of interest, regardless of proximity. Technology can therefore be the answer to many teachers' PD, by putting teachers in control of their own learning. When teachers take the initiative to direct their own learning, they are engaged in the process of becoming more self-directed (Thornton, 2010:158).

Self-directedness is an important characteristic of teachers' professional growth, as it will enable teachers to demonstrate active involvement in the classroom, make appropriate decisions, implement learning paths in their work, set goals for themselves, find relevant information and analyse situations (Gibbons, 2002:62, Francom, 2010:29). Bell (2010:39) indicated that, when teachers are able to direct their own learning, they are able to make changes in their teaching practices. Changes in teaching practices have been proved to have a significant impact on the improvement of learners' academic performance and achievements (Louws *et al*., 2017a:171).

TSCL as a PD strategy sets out to inform teachers in teaching practice, by making use of technology and CL as both these aspects have been proven effective in PD as well as SDL development. Veletsianos (2010:74) further notes that with technology, the sharing of ideas and material between colleagues who are no longer, or have never been in geographic proximity to each other, is now feasible. TSCL PD therefore creates new possibilities for introducing flexibility for individuals in terms of time, place and pacing of independent study.

The amount of information available online, the availability of different application software and the possibility of cooperation through technology can provide teachers with the opportunity to become experts in their fields and to meet the demands of educational challenges for the 21st century (Kriek & Grayson, 2009:189). It is worth mentioning that TSCL PD provides boundless access for teachers to connect with others, explore topics of interests and be a part of opportunities and events across the globe (Ekizoglu & Ozcinar, 2010:5889).

3.9 CONCLUSION

This chapter highlighted exactly what technology is, the technology initiatives and the history of technology in South African education. It also reported on the need for TSCL PD to enhance teachers' SDL, as well as the learning tools that can be used within TSCL PD. The technological barriers that can be encountered were also discussed. The next chapter will present a discussion of the research design and methodology of this study.

CHAPTER FOUR

RESEARCH DESIGN AND METHODOLOGY

4.1 INTRODUCTION

This chapter presents the research methodology that was used in this study to provide answers to the research questions noted in Chapter One. This chapter starts with a discussion of the methods used in the data collection process, followed by an explanation of the data analysis and issues relating to the validity, reliability and trustworthiness of the study. Figure 1.1 in Chapter 1 illustrates the research design and methodology that were used in this study.

4.2 RESEARCH PARADIGM AND DESIGN

This section comprises a discussion of the research paradigm that framed the research design chosen for this study.

4.2.1 Research paradigm

Research is described as a basic, systematic inquiry employed to revise the current body of knowledge by collecting (empirical) data to develop new knowledge through analysis and interpretation (McMillan & Schumacher, 2014:354). Sepeng (2010:46) indicates that research can be motivated by the researcher's mental views, which are referred to as a 'paradigm'. The term 'paradigm' is defined as a perspective of the researcher's view about the world he or she lives in (Johnson & Christensen, 2012:32). This definition is similar to Lichtman (2013:324), who defines a paradigm as the way we see the world. A paradigm is an approach to conducting research which frames what has to be studied in a particular setting, what research questions should be answered in the study, and the way in which those questions will be analysed and interpreted through the collected data (Creswell, 2013:17).

This study was guided by the interpretive research paradigm as its framework because this study is based on a view that all individuals have their own unique interpretation of reality and that a single reality does not exist. From an interpretivist perspective, the interpretivist research paradigm allows the researcher to understanding the world as it is from the subjective experiences of the participants (Brink *et al.,* 2012:25). In this study, the views of Mathematics teachers from the data collected during the interview, were interpreted to get a better understanding of how teachers experienced the TSCL PD, as well as whether TSCL PD indeed impacted on teachers' SDL development.

4.2.2 Research design

Mouton (2013:56) describes the research design as a plan which guides the researcher by providing the necessary tools and procedures for conducting a study.These include the selection of participants, questionnaires, data gathering techniques and data analysis. A research design gives direction in terms of who or what would be studied as well as what methods of data collection will be used (Nieuwenhuis, 2010:70). The common research designs are qualitative, quantitative and mixed methods (McMillan & Schumacher, 2010:11).

There are many reasons why research designs are used in different studies. However, Creswell (2012:129) and Yin (2009:24) point out that selecting the appropriate method for research is important. This study used a qualitative research design in an attempt to obtain comprehensive descriptions of the participants (McMillian & Schumacher, 2010:16). As noted by Merriam (2009:13), a qualitative design is concerned with individuals' opinions, feelings and experiences to discover unanticipated occurrences. As such, a qualitative design was deemed suitable for this study, as it allowed the researcher to investigate what the teachers' needs were in terms of the PD as well as how they experienced the TSCL PD.

4.3 DESIGN-BASED RESEARCH METHODOLOGY

Anderson and Shattuck (2012:16) define design-based research (DBR) as an approach "designed by and for educators that seeks to increase the impact, transfer, and translation of education research into improved practice". DBR in education refers to a type of research methodology which is aimed at improving educational practices through iterative progression of solutions (McKenney & Reeves, 2014:131). These iterative progressions occur through numerous methods of data collection, data analysis and improvements (Wang & Hannafin, 2005:6). DBR is grounded in solving real-world problems while also contributing to new theory about teaching and learning (Barab & Squire, 2004:2). Figure 4.1 presents a graphical representation of the process of DBR according to Amiel and Reeves (2008:34).

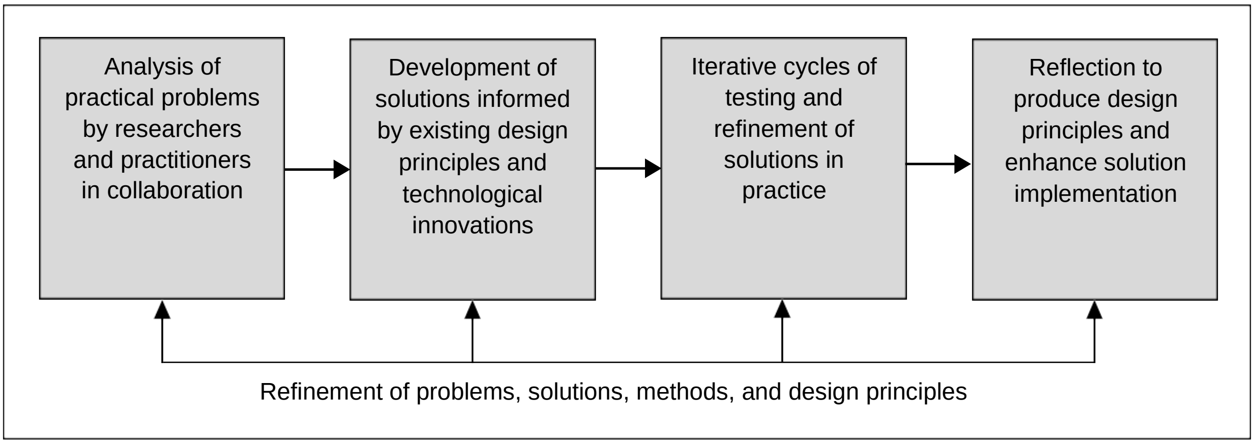

Figure 4-1: Four phases of design-based research
Source: Amiel and Reeves (2008:32)

The next section will discuss how an adapted version of the four phases of design-based research as presented by Amiel and Reeves (2008:32) was realised in this study.

4.3.1 The first phase

In this study, the first phase began by reviewing the literature in order to gain insight into the problem, context and other relevant topics (Amiel & Reeves, 2008:34). This was followed by doing a needs analysis of the teachers in order to establish what their needs in terms of TSCL PD were and also how their SDL could be enhanced. During the first session, members were informed about the purpose of the research and they were also assured of confidentiality during participation in the study. The facilitator (who is also the researcher) informed the participants what the research was about, and the fact that they had the right to decline participation in the research if they chose to do so. Members were also assured that normal PD activities would take place and that everyone would be involved in that, but only members who agreed to have their data used for research were asked to sign an informed consent form. The facilitator left the room and had an independent person be present while members signed the informed consent. Furthermore, participants were assured that they were not compelled to answer any questions and that no answers given would be held against them. After giving consent, members' needs and a context analysis was done through an informal discussion where the following questions were asked.

Questions for the needs analysis

1. Tell me about your experience with any professional development you have attended before you started doing the technology-supported cooperative learning professional development here at Royal Bafokeng Institute (RBI).

2. What influence did those sessions have on your motivation to take responsibility for your own learning?
3. What are your needs in terms of enriching your knowledge and skills during professional development?

4.3.2 The second phase

The second phase in the process of DBR involves developing solutions that can be informed by existing design principles and technological innovations (Amiel & Reeves, 2008:34). In this study, the development of solutions was realised by implementing the first prototype of the intervention in order to create a solution for the problem documented in the analysis phase. Following Mathematics teachers' needs analysis and the review of the literature, a suitable and appropriate intervention, in the form of PD, was designed to assist teachers in their teaching practice. The process was iterative in that a number of prototypes of the TSCL PD were developed. Three prototypes (using the feedback from the participants) were formatively evaluated after every PD session. It is important to note however that the context, in terms of the Mathematics teachers attending the intervention, and the strategy of the TSCL stayed the same, but the content of the tasks (e.g. designing a lesson plan using Google Docs, sketching straight line graphs using GeoGebra etc.) changed for each prototype. Although each prototype constituted different content, the process of designing and presenting the TSCL PD was refined each time. Hence, I will refer to three different prototypes. The relevance of the first prototype is discussed in detail below.

Prototype 1

To address teachers' needs in terms of PD and SDL development, the TSCL as a teacher PD strategy was implemented as an opportunity for teachers to share ideas and material regardless of their geographic proximity. The TSCL PD as a PD strategy provides teachers with a flexible and convenient way to strengthen and enhance their professional skills through discussing, engaging and interacting with each other, in a cooperative environment. The TSCL PD consists of a small group of teachers, using technology, supported by CL strategies, in which individuals apply their knowledge to support and enrich each other, as well as direct their own learning. The TSCL PD incorporated multimedia elements such as video streaming, instant messaging, video calling, interactive websites and real-time chat sessions.

The first prototype was grounded in the use of GeoGebra in Mathematics teaching and learning. Teachers were challenged with three different tasks (see Addendum A), where they had to use GeoGebra to investigate straight-line functions. The facilitator started the session by explaining to the members that they were going to participate in a Jigsaw strategy, the rules for which include contributing to the team effort, listening to team members, and helping other team members. The facilitator then divided the participants into small groups, two groups of three each), for the 'home group', and three groups of two each for the 'expert group'. Each group was assigned a virtual chat room to foster collaboration e.g. Google Hangout and Google Meet.

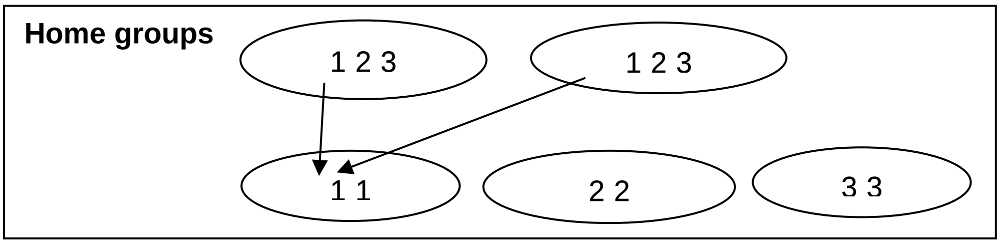

Figure 4-2: Grouping of teachers
Source: Author's own compilation

The facilitator further assigned members to different roles: a 'leader' (provides direction, instructions and guidance to a group), the 'scribe' (records all decisions and actions that the group makes) and the 'presenter' (time keeping, presents task back to large group and facilitator). Each member has a specific role to fulfil, so that every member feels important and needed in order for the group to succeed. The opinion of Johnson and Johnson (2013:102) is that positive interdependence exists once all the learners fulfil their roles.

Expert group 1 had to investigate the role of m and c in the equation: $y = mx + c$, using sliders. Expert group 2 focused on solving linear equations, using graphical methods. Expert group 3 on the other hand, put more emphasis on finding the equations of parallel lines, given any point on the line. Members who had the same task (e.g. expert group 3 – investigating parallel lines) met to form groups of experts, where they were expected to share one computer screen, in order to complete the given task. By allowing members of a group to share limited resources and also to be dependent on one another, stimulated positive interdependence. The facilitator moved amongst groups to ensure that members helped each other to make associations between concepts, and that they encouraged and facilitated each other's efforts. Through members helping each other to connect present and past learning**,** promotive interaction was stimulated. By also encouraging members to communicate accurately during the task, listen carefully to one another and resolve conflict where necessary, ensured that social skills were stimulated.

After the expert group meeting, members did not have to move to their home groups, but instead, they would invite their home group members from their respective positions to share their expertise with the group and complete the given task. During this section of work, the group leader would ask critical questions and reflect on the task at all times. The scribe, on the hand, had to do the task on the computer in preparation for the presentation. The presenter kept a record of the time and presented the task to the large group and the facilitator.

After the large group presentation, members were given time to reflect on how well they had accomplished the task and how they could improve as part of group processing. The presenter had to reflect on what worked and what did not work during group activities. Afterwards, each group member had to complete the expert group members' rubric (see Addendum A). The expert group members' rubric was designed in order to allow group members to evaluative their commitment to goals, communication with each other and how well they have worked together as a team**.** These actions helped to clarify and improve the effectiveness of the group, thus group processing was stimulated.

4.3.3 The third phase

The third phase in the process of DBR is that of implementing the solutions in practice through iterative cycles (Amiel & Reeves, 2008:34). In this study, cycles of implementation using collected data (corresponding to the research questions of the study) were carried out for the refinement of solutions in practice. Based on the analysis of the data collected, the TSCL PD strategy was refined, and tested again. The second and third prototypes, where the refinement took place are discussed in detail below.

Prototype 2

During the second prototype, the content of the TSCL PD was refined and members were assigned different roles. The facilitator again explained to the members that they were going to participate in a Jigsaw activity where they were sub-divided into three expert groups. In this session, members worked cooperatively to design a Grade 7 lesson on integers, using Google Classroom (see Addendum E).

Expert group 1 focused on creating a possible lesson template to use when designing a Grade 7 lesson on integers. Expert group 2 on the other hand, focused on collecting more information on mathematical content and interactive websites relating to a Grade 7 lesson on integers. Expert group 3 focused on creating a multiple-choice quiz in Google Classroom, on Grade 7 integers.

Members who had the same task (e.g. Expert group 1 – designing a lesson template) met to help each other to begin with the same information and understand the nature of the task. Then they returned to their home groups using their home group class code in Google Hangout, in order to complete the task as a group (see Addendum E). The facilitator ensured that individual accountability among members was stimulated by providing members with the rubric (see Addendum A) to use as a guideline at the start of their work. This rubric helped members understand what was expected of them and how their participation will be evaluated. This helped to avoid having one person responsible for all the work, and one or more who do not contribute during the task.

All expert group members used the stream tab of Google Classroom for regular communication with other group members during the task. Mutual respect between group members, conflict resolution, decision-making skills and trust building contributed to stimulate members' social skills. Promotive interaction was stimulated when members helped each other out, exchange needed resources and provided each other with feedback. This interaction was facilitated through the use of Google Classroom.

After obtaining information from the expert groups, members had to team up with their home group members, where they worked cooperatively to produce one document authored by the whole group on Grade 7 integers. Here, the group leader had to provide guidance to his or her group, while the scribe had to put together all the information required for the presentation. The presenter had to present a fully designed Grade 7 lesson on integers to the whole group.

After task completion within the home groups, members were given time to share with each other what actions did not work or were not acceptable, and complete the expert group members' rubric. Feedback from the group members gave an indication about which aspects were difficult and therefore needed extra attention. When members looked back on how they worked together, as well as reflected on their process and discussed what worked and what did not work, group processing was stimulated.

Prototype 3

During the third prototype, the same happened as in the previous sessions described above, but the intervention was refined and tested again. The facilitator assigned members different roles of a 'leader', a 'scribe' and a 'presenter'. The group leader studied and shared the material with the rest of the group. When everyone was familiar with the material, members were divided into three expert groups where they had to prepare a Grade 6 test on measurement, using real-time collaboration with Google Docs. Members of each expert group were given a task (see Addendum C) with limited time, in order to stimulate positive interdependence and individual accountability. During these tasks, members had to strive to reach a mutual goal, but on the condition that each member achieve his or her own goals. The time constraints encouraged the splitting up of the work load, with each member performing different, but complementary tasks. The facilitator moved from group to group, observing the process and doing appropriate intervention. The visibility of the facilitator also promoted individual accountability.

Promotive interaction was stimulated when expert group members exchanged information, discussed, encouraged and facilitated each other's efforts. This was established when expert group members invited other members of the same task directly from their Google Docs to access the document. In addition, group members were able to open up the Google Docs messenger feature and chat live with each other, and write in the document about the changes they want to make together. This allowed members to engage in democratic decision-making, accepting and supporting each other, as well as allowing effective communication, thus stimulating social skills.

After task completion within the expert group, members returned to their home group, where they compiled a final version of a test for presentation. During this section of work, the group leader would ask critical questions and reflect on the task at all times. The scribe would do the task on the computer in preparation for the presentation. The presenter would present the prepared Grade 6 test on measurement to the whole group.

After the large group presentation, members shared their experience, discussed how the problem could be solved differently and also completed the group members' rubric. When members looked back on how they worked together, as well as reflected on their process and discussed what worked and what did not work, group processing was stimulated.

4.3.4 The fourth phase

While the third phase of the DBR process is centred on refinement and improvement, the fourth phase involves the final evaluation of the PD strategy. In this step, the intervention was evaluated to see if it addressed the problems and produced the desired outcomes (Herrington & Reeves, 2011:598). This study used semi-structured individual interviews in order to get a better understanding of how teachers experienced the TSCL PD. The semi-structured interviews for this study were conducted after the TSCL PD in a quiet room at RBI (see Addendum K).

Follow-up interviews were also conducted to enrich and clarify the qualitative data. This was done by making an appointment with all the participants, then visiting them in person at a time convenient as per telephonic appointment. Final validations and recommendation on how teachers experience TSCL PD, as well as their SDL development, will be provided in Chapter Six.

4.4 POPULATION AND PARTICIPANT SELECTION

Maree and Pietersen (2010:7) refer to the population as all the people required in a study to generalise the finding that is being studied in order to answer the research question. Johnson and Christensen (2012:12) claim that it is risky to generalise the findings to a larger population. As a result, a sample is used to represent the entire population (Creswell, 2013:48). Different sampling approaches can be used, such as probability sampling (simple random, stratified random, cluster and systematic sampling) and non-probability sampling (purposive, convenience, quota sampling) (McMillan & Schumacher, 2014:365). This study used purposive sampling to select the population. The following criteria had to be met for a member of the population to be an appropriate participant in the study:

- participants had to teach Mathematics at different grade levels in their respective primary schools;
- participants had to have a minimum of three years' teaching experience; and
- participants had to attend PD workshops once a week at the RBI.

The participants of the study comprised Mathematics teachers (n = 7) who attended PD workshops once a week at the Royal Bafokeng Institute (RBI) premises in the Rustenburg area. The seven participants were all experienced Mathematics teachers, from different primary schools, teaching different grades. The schools at which the participants teach are attended by learners from low socio-economic backgrounds in the Royal Bafokeng area. These teachers held the necessary knowledge for the researcher to gather suitable and rich data.

4.5 DATA COLLECTION

According to Maree (2010:259), the qualitative researcher "collects words (texts) and images (pictures) about the central phenomenon; the data are collected from people immersed in the setting of everyday life in which the study is framed". In the current study, data were collected during various phases of the DBR process, during the course of one semester. The first round of data collection, which was done at the start of the semester, was done through an informal discussion, with the intention of establishing what teachers' needs were in terms of PD, and also how their SDL could be enhanced. Based on this data as well as the literature review, the researcher designed and implemented the TSCL PD.

This was followed by the second round of data collection, which involved determining how teachers experienced the TSCL PD and their SDL development. This was done by way of semi-structured interviews, which took place towards the end of the semester. Merriam (2009:87) points out that a research interview refers to a discussion between two or more people that generates data relating to the research. Leedy and Ormrod (2010:153) also claim that a research interview involves a two-way discussion aimed at obtaining data from the participants by the interviewer, so as to find out about their behaviour, beliefs, opinions, views and thoughts. Nieuwenhuis (2010:87) adds that research interviews aim at seeing "the world through the eyes of the participants", and the interview, for this situation, whenever used correctly, gives an important source of information. Research interviews are essential for the researcher to gain valuable insights into participants' opinions, feelings, emotions and experiences, which need in-depth and detailed exploration (Denscombe, 2010:173).

The semi-structured interviews were conducted in English with all the participants. They were audio recorded on a mobile phone, and notes were taken during the course of the interview. The researcher was responsible for all the transcriptions of the interviews which ensured his first engagement with the data. Thereafter, the interviews were coded using ATLAS.ti™, computer assisted qualitative data analysis software (CAQDAS). Semi-structured interviews were chosen for this study, because they allow participants to characterize their views in their own way (Merriam, 2009:90). Semi-structured interviews allowed enough flexibility for the interviewee to talk openly about any topic raised during the interview. A further benefit of using a semi-structured interview is that it took into account questions to be clarified or re-phrased where participants were vague about the wording (Creswell & Plano Clark, 2011:10).

4.6 DATA ANALYSIS

The process of breaking down the collected data into smaller themes or categories, so that it can be more useful and manageable is referred to as data analysis (Mouton, 2012:108). Nieuwenhuis, (2010:99) regards data analysis as a process of collecting, analysing and interpreting data in order to address the main aim of the study. This study used a qualitative analysis computer data analysis system (QACDAS), ATLAS.ti™ to analyse the qualitative data. ATLAS.ti™ is a computer software that is used for the qualitative analysis by researchers, in order to organise text, graphics, audio and visual data files, along with their coding, memos and findings into a project (Merriam, 2009:193). Computer assisted software such as ATLAS.ti™ enables researchers the opportunity to analyse data systematically. The data collected from the semi-structured interviews for this study were analysed according to the process for analysing qualitative data proposed by Creswell (2009).

Step 1: Organising and preparing data for analysis

In this step, the interviews are transcribed and data is sorted in preparation for data analysis (Creswell, 2013:182). The semi-structured interviews for this study were conducted in a quiet room at the RBI and the conversations were recorded as MP3 files. After the interview process, recorded interviews were transcribed verbatim. Verbatim transcription is explained by Babbie (2011:283) as an approach which involves converting spoken word into text exactly as they have been spoken. This means that every single word from an audio file is typed out word for word, without being paraphrased or summarised, as well as without correcting bad grammar or poor word choice (Blaikie, 2010:25). Merriam (2009:110) makes clear that verbatim transcription provides the best database for analysis.

Step 2: Data reading

Creswell (2009:186) emphasises that it is important to read all the data carefully before starting the coding process. In this study, the researcher read all the transcribed documents in order to get an overall impression of the data. While doing this, the names of participants were removed, to uphold confidentiality.

Step 3: Coding process begins

Once interviews had been transcribed and read thoroughly, ATLAS.ti™ was used for coding. According to Babbie (2011:504), coding refers to a process which involves identifying passages of text so that they can be linked to a common theme or idea. Creswell (2012:184) clarifies this by explaining that coding is is an essential part of qualitative research, whereby data or images that belong together is grouped into meaningful categories of information. These categories are then organised into themes, compared and analysed (Boeije, 2010:94).

Creswell (2009:185) adds that there are three ways in which texts can be coded and these are, open coding, axial coding and selective coding. Open coding involves labelling concepts from the transcribed data. Axial coding entails relating codes between categories. Lastly, selective coding refers to choosing a core category and linking it to other sub- categories.

This study used open coding because it allowed the researcher to explore ideas and meanings that were contained in the interviews.

Step 4: Use the coding process to generate categories

After the coding process, the final list of codes was compiled in order to create the codebook. According to Saldaña (2009:21), a codebook serves as a data management tool for organising segments (i.e. codes, description content and short data examples) in order to help with interpretation of data. The detailed codebook is presented in Table 4.1 below.

The list of codes was further grouped into categories and themes (Creswell, 2009:184). The information within the categories and themes had to be contrasted in order to have subtle differences and variations in meanings. The aim is to merge the themes in order to answer the research questions (Mouton, 2005:56). The themes that emerged from the data through coding were used as the foundation for an interpretive process that was aimed at bringing meaning and coherence to the identified patterns and categories (Creswell, 2012:44, 101). The main themes that were identified from the semi-structured interviews were Mathematics education, SDL, CL, technology and PD.

Step 5: Analyse and interpret the data

Creswell (2009:185) explains that this step involves presenting descriptions and themes to convey the findings of the analysis, as well as interpreting the findings of the analysis and reporting on it in a narrative format. Newby (2010:459) adds that analysis of qualitative data provides the researcher with the advantage of having insight and in-context knowledge about the research and this enables him or her to establish a link between the data gathered, the research question and the aims of the research. In this study, the researcher decided which evidence was relevant and which was not. Care was taken not just to interpret or summarise the data, emergent codes and themes, but to seek deeper meaning from it in an effort to understand why certain information was included in a specific way.

Table 4-1: Codebook table

Codes	Description	Example
Teachers' needs in professional development	Refers to all aspect that teachers require in order to improve their practices.	Professional development should not be a once off thing because there are many teachers out there who struggle with a lot of different thing, so it will be nice if different concepts are treated on different days (D13:3).
Technology	The term 'technology' refers to any electric tools that has the ability to collect, receive, share and control information (Bembridge, Jones & Jeong, 2010:18).	I usually use technology in my classroom in most of my lessons. … however, I was impressed about learning more new stuff, like video calling using Google, chatting on a web browser (D11:3).
Benefits of using technology	The advantages of using technology in professional development.	What I have learnt from all the sessions we had is that with technology, it is possible for us as teachers during our own time, to have our own sort of professional development, or platforms whereby we communicate and share ideas regularly, even in the absence of a facilitator (D14:3).
Experience using technology	The experience teachers had while using technology in the professional development.	Using technology in our sessions allowed me to learn new ways of using different software which I can use in my classroom to improve how I teach (D2:6).
Characteristics of a self-directed learner	This refers to all aspects of being aware of your own learning desires and interests.	Well, as a group, we tried as much as we can to minimise conflict and reach a consensus decision without critically evaluating each other's ideas. … because of this, I would say, we managed to take responsibility for our own learning (D13:6).
Mathematics education	Mathematics education centres around engaging learners in critical thinking circumstances that require reasoning, finding, creating and communicating ideas (Nieuwoudt, 1998:77; Plotz, 2007:43; Van de Walle *et al.*, 2014:2).	Let me say, the technology-supported cooperative learning professional development provided me with the opportunities for creating learning environments that extend the possibilities of advancing my skills as a teacher, … to a point now where I can make Mathematics classes more interesting and more fun (D17:12).
Mathematics teaching and learning	This refers to the teaching methods teachers use in order to help learners learn Mathematics.	I just have to adopt these new best practices and see how I can incorporate them into my teaching (D11:5).
Mathematical content knowledge	Mathematical content knowledge refers to the body of knowledge that a teacher possesses, in order to teach Mathematics effectively.	Well, I can say, my mathematical content knowledge was developed through planning Maths activities, lessons and tests with other teachers. … The reason why I am saying this is because … I managed to observe and learn how other teachers introduce their lessons, from the activities we were

Codes	Description	Example
		doing and also how they phrase questions nicely so that learners can understand them easily (D18:10).
Cooperative learning	Cooperative learning (CL) is defined by Johnson *et al.* (2008:1-14) as an approach that involves a small group of learners, each with different levels of ability, working together as a group to tackle an issue in order to accomplish a common goal.	I guess … learning with other colleagues helped me to acknowledge, understand, and work diligently to overcome the challenges and obstacles standing in the way during the task that we were given (D17:3).
Elements of cooperative learning	Johnson and Johnson (2013:102) contend that there are five basic elements to be adhered to for successful CL, namely positive interdependence, individual accountability, promotive interaction, appropriate social skills, and group processing.	Ensuring that your teams are working together toward a common goal is never an easy task. You know … the more you try to force your team to work together, the less likely you are to achieve the results (D22:7).
Group processing	Group processing entails self-evaluation and a reflection of a group on how well they accomplished their goals (Johnson & Johnson, 2009:112).	I enjoyed the reflection sessions [group processing] that took place after every session (D19:2).
Individual accountability	Johnson and Johnson (2013:105) describe individual accountability as holding each group member accountable for making a contribution towards achieving the goal of the group.	I experienced that roles helps to distribute responsibility among group members and ensures accountability for all individual's participation (D22:6).
Social skills	Social skills refer to the skills we use to communicate and interact with each other, in order for a group to function successfully (Huffman, 2012:28).	The chatting tools and videos calls we used during the sessions allowed us to be able to listen to each other and gave one another a chance to share and demonstrate our ideas to the best of our ability (D13:4).
Positive interdependence	Positive interdependence exists when group members rely on each other, for the success of the group (Johnson & Johnson, 2013:102).	I have learnt that when a team is able to work well together, they can accomplish more than what an individual can accomplish on his or her own (D10:6).
Promotive interaction	Promotive interaction refers to the encouragement and support provided by the members of the group during the group activity (Johnson & Johnson, 2009:111).	Nothing fosters unity like working through something together. Well, learning with other teachers helped me to seek out for advice and also to find long-lasting, solid solutions (D22:2).
Resolve conflicts	Refers to when two or more members engaged in a disagreement, dispute, or debate, then reach an agreement resolving it.	We tried as much as we can to minimise conflict and reach a consensus decision without critically evaluating each other's ideas (D13:6).
Challenges in cooperative	Refers to a number of obstacles that occurred during the CL strategy (Johnson, 2008:106).	I enjoyed how we managed to overcome the challenge we had when we were using Google Classroom (D17:1).

Codes	Description	Example
learning		
Mutual respect	Refers to the respect shared between two or more members.	I have learnt to respect my group members. You see, respect allow you to take other people's opinions and feelings into consideration (D12:5).
Benefits of working cooperatively	Refers to the advantage of working together in groups.	I can simply say the professional development sessions met my expectations by creating a space for us as teachers to share ideas and work cooperatively (D19:9).
Teachers' professional development	It is commonly recognised as a significant approach used to enhance teacher knowledge and skills (Guskey, 2000:16).	Teachers need to be encouraged to choose professional development that challenges them and gives them a hard-earned sense of accomplishment (D11:9).
Current professional development	Refers to the technology-supported cooperative learning professional development.	I'm very pleased with what I have achieved in the professional development we had. How the sessions were structured, teachers being hands-on and the discussions we had about what worked and what did not. … I will say, all expectations were met accordingly (D11:8).
Previous professional development	Prior activities that developed teachers' skills, knowledge, expertise and other characteristics.	Well, in our previous professional development we would usually gather in a big auditorium then talk about the new technique or new initiative we are adopting as a school or district, then from there we will be given materials and sign the register (D10:1).

4.7 TRUSTWORTHINESS

Trustworthiness refers to the reliability and validity aspects of determining to which others are convinced that the findings can be trusted (Bless *et al.,* 2013:236). Creswell (2012:259) describe trustworthiness as an important concept in qualitative research because it allows the researcher to accurately reveal in details the experiences of the participants who are involved in the study. Trustworthiness therefore measures the quality of research, taking into consideration what is worth paying attention to. According to Babbie *et al.* (2008:276), in order to maintain trustworthiness in qualitative research, the following four criteria needs to be taken of in a research; credibility, confirmability, dependability and transferability.

In a qualitative research, trustworthiness is achieved by not tampering with the collected data in any manner (Sinkovics *et al*., 2008:691). In this study, the researcher held the data gathered in its original format with no addition to what the participants introduced and what was observed. Additionally, the interviews were transcribed and returned to the participants for verification and errors were corrected.

4.7.1 Credibility

Polit and Beck (2012:724) describe credibility as the accuracy of the research process to which the findings represent the truth. In the words of Sinkovics *et al.* (2008:69), credibility is defined as the degree to which the research was conducted is reliable and trustworthy. Credibility was ensured in this study by comparing data collected from the interviews with data obtained from the literature review. The research study's findings were associated with reality under the study in order to demonstrate the truth about the findings in this study.

4.7.2 Confirmability

According to Bless *et al.* (2013:237), confirmability refers to the ability to which the results of one's study could be obtained by other researchers, following similar research process. The use of confirmability in this study involved verbatim transcription of data collected from the interviews. The responses of participants were typed out word for word, exactly as they are. In addition, the researcher also contacted the participants to verify that the findings are captured correctly.

4.7.3 Dependability

Dependability refers to the researcher's responsibility of keeping records on how data was collected, coded and analysed, including accounting for any change that unfolded during the study (Babbie *et al*. 2008:278). The opinion of Bless *et al.* (2013:238) is that, dependability ensures that the findings of a research are consistent and repeatable. The researcher ensured dependability in this study by regularly checking for mistakes in conceptualizing the study, data collection and data analysis. Additionally, the supervisor and the co-supervisor were engaged to provide guidance throughout the research study.

4.7.4 Transferability

Babbie *et al.* (2008:279) and Bless *et al.* (2013:237) describe transferability as a process of providing evidence that the research can be applicable to the findings to another context. Marshall and Rossman (2011:252) also affirm this by stating that the research findings or methods from one study has to be applicable to other context when generalized or transferred. In this study, the researcher ensured transferability by providing enough about the context of the research and detailed descriptions of the participants.

4.8 ETHICAL CONSIDERATIONS

This study was done with primary school Mathematics teachers as participants. Permission was granted by the NWU Faculty of Education Research Ethics Committee for the research title ""[e]nhancing Mathematics teachers' self-directed learning through technology-supported cooperative learning", with ethics number: NWU-00138-19-A2 (see Addendum H). Permission for conducting the study from the RBI was also granted (see Addendum G). Once permission to conduct research in the institute was completed, teachers were asked to grant consent for participating in the study should they feel comfortable to do so. Teachers were also informed about the purpose of the research and they were assured of confidentiality. Each participant (interested in participating in the research) was asked to sign an informed consent form, which is an indication that they indeed understood what was explained to them and voluntarily consented to participate in the research.

The researcher informed the participants about the purpose of the research and assured them confidentiality. Participants were also informed about the nature of the investigation, their right to refuse to be interviewed and their right to withdraw from the study at any stage. An independent person asked participants who opted to participate in the research to complete an informed consent form. Participants' confidentiality was also ensured by omitting participant's names. The final results of this study will be supplied to any of the parties involved, upon request.

4.9 CONCLUSION

In this chapter, the research design and methodology used in this study were discussed. The interpretivist paradigm that guided this study, as well as the research design were also described. This was then followed by exploring the criteria for selecting the participants. Seven participants took part in the study, and the necessary ethical guidelines, namely informed consent, confidentiality and voluntary participation, were followed. The intervention was implemented and discussed**.** In the next chapter, the data generated during this study is discussed and analysed.

CHAPTER FIVE

PRESENTATION OF DATA AND DISCUSSION OF FINDINGS

5.1 INTRODUCTION

This chapter presents the research data and findings obtained from the teachers through the informal discussion (needs analysis) and the use of semi-structured interviews, as well as follow-up interviews. All examples of data collected from the participants are referenced, stating which comment or interview it was from. The transcriptions in this study have not been changed in any manner and participants' names have been omitted to uphold confidentiality. When reference is made to D1, D2, D10, D12, D13, D14 or D11, these seven references refer to participants' numbers one to seven. These are the pseudonyms given to participants in the study. A summary of the findings based on all the results with regard to all the research questions will be provided in Chapter Six.

5.2 DATA COLLECTED FROM THE NEEDS ANALYSIS

The needs analysis is the first step in DBR, which allows the researcher to gain insight into the problem, context and other relevant topics (Amiel & Reeves, 2008:34). The needs analysis is defined as the process of distinguishing the gap between what is happening and should be happening (Kiley, 2010:389). According to Morales *et al.* (2010:47), the needs analysis is necessary to provide information on what is needed for developing and designing a training plan. A needs analysis is an important tool for determining the learning needs of individuals (i.e. teachers). This study started with a needs analysis of what teachers' needs were in terms of enriching their knowledge and skills during PD. Seven primary school teachers participated in an informal discussion from which the first prototype of the teachers' PD was developed.

Most participants in this current study clearly described what their needs were in terms of the type of PD they would like to be involved in. One participant pointed to the need of having choice during PD. Please note that all direct quotations are reproduced verbatim and unedited.

> *I think this will help us as teachers to best select workshops, which have areas we know we would like to improve on (D2:13).*

Another participant added:

> *Professional development should not be a once-off thing, because there are many teachers out there who struggle with a lot of different thing, so it will be nice if different concepts are treated on different days (D13:3).*

These findings seem to be consistent with the literature, which revealed that the PD of teachers should be an ongoing process that enriches teachers with knowledge and skills necessary to model best practice (De Clercq & Phiri, 2013:78). Opfer and Pedder (2011:184) also emphasise this, by making clear that the PD of teachers is one of the best strategies that could help teachers improve and in turn improve learners' results.

Other participants mentioned that they need a flexible PD that fits into their schedule. Participant 5, for instance, stated:

> *I would recommend a professional development that is flexible like the one we had, whereby you can simply communicate with people even if they are far (D12:10).*

Another participant added:

> *I would recommend an on-going professional development that creates a culture of learning throughout each session and additionally supports teachers' efforts to engage their own learning (D11:9).*

The same participant further mentioned:

> *Teachers need to be encouraged to choose professional development that challenges them and gives them a hard-earned sense of accomplishment (D11:9).*

An emerging pattern from participants was that PD strategies that are interactive and ongoing, are the most effective. This was in line with the literature where various researchers advocate for teacher development models that are practical and happen in multiple cycles in order to develop in-depth knowledge, skills and practices of teachers (Opfer & Pedder, 2011:376; Smith & Gillespie, 2007:233; Steyn, 2008:23).

Other participants mentioned that they need a PD that allows time for reflection. Participant 2, for instance, stated:

> *For me, the professional development need to be more frequent so that we can have more time interact, learn, reflect, and give feedback on application of principles in order for learning gaps to be addressed (D2:17).*

Another participant added:

> *I recommend a professional development that provides teachers with adequate time to learn, practice, implement, and reflect upon new strategies that facilitate changes in their practice (D10:10).*

The above perception of all the participants demonstrated a good mind-set that teachers would like to be engaged in the process of PD activities that improve their teaching practices in order to meet the demands of the 21st century. From the needs analysis of teachers, it became evident that teachers view PD as an opportunity to improve their teaching careers and therefore these needs guided the choice of the TSCL PD.

5.3 DEVELOPMENT OF SOLUTIONS

In Chapter Two, teachers' PD was described and discussed. The TSCL PD has been noted as a viable option for enhancing teachers SDL. The researcher designed the teacher PD (TSCL PD) according to the literature and needs analysis, and then presented it to the teachers. The TSCL PD used the Jigsaw CL strategy with the support of different computer application software as technological tools to facilitate the content of the session. The TSCL PD consisted of five sessions, which were two hours long each. After the completion of all sessions, interviews (±40 minutes) were scheduled for a time and place convenient for the participant. Follow-up interviews were also conducted and the procedure that was followed was the same for each participant. The participants' responses to the open-ended questions were recorded on a mobile phone and the remarks made by the researcher were written down. Below are the results of the intervention.

5.4 DATA COLLECTED FROM THE PARTICIPANTS

The data which was collected from the participants through interviews and follow-up interviews, was built on ten questions (see Addendum K) and the responses were analysed and grouped into five central themes. The data presented in this study were drawn from the opinions and experiences of the participants. Figure 5.1 indicates the identified themes, which will be discussed.

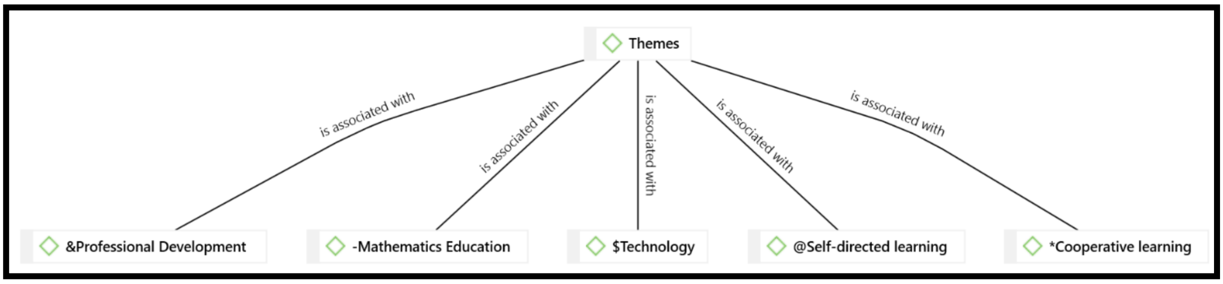

Figure 5-1: Identified themes from the semi-structured interviews

5.4.1 Mathematics education

This section discusses Mathematics education, Mathematics teaching, and teachers' content knowledge of Mathematics and learning – all of which add to answering the research question: "What are Mathematics teachers' needs in terms of TSCL PD and SDL development?" Figure 5.2 illustrates the network view of the coding structure for the participants' perception of Mathematics education for this discussion.

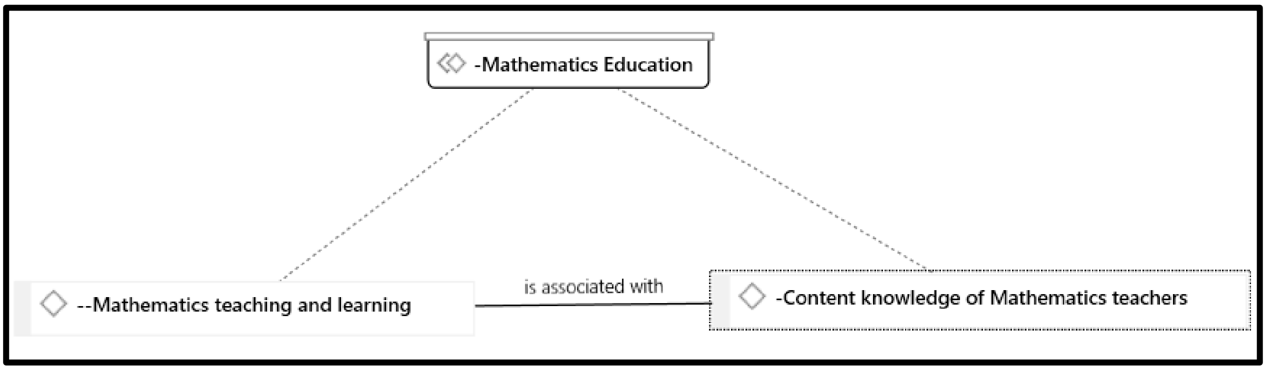

Figure 5-2: Coding structure for the participants' perception of Mathematics education

5.4.1.1 Mathematics teaching and learning

Mathematics teaching strategies are essential to helping learners develop confidence in their own abilities to do Mathematics, so that they can be able to relate, discover, describe and assess their learning progress (Ball *et al*., 2008:395). Thus, it is the view held in this research that for effective Mathematics teaching to occur, the teaching strategies need to take learning in a direction that improves Mathematics learner engagement.

Participants in the current study acknowledged the importance of improving the quality of their own teaching and how this affects learners' understanding of Mathematics.

> *As I have just said, I want to make learning more fun, the professional development afforded me an opportunity of using different computer applications so that I … myself, can use multiple representations to help students understand Maths concepts (D22:4).*

> *I managed to observe and learn how other teachers introduce their lessons, from the activities we were doing and also how they phrase questions nicely so that learners can understand them easily (D18:10).*

Other participants seemed to appreciate the fact that their Mathematics teaching strategies have improved, by learning new skills during the TSCL PD.

I just have to adopt these new best practices and see how I can incorporate them into my teaching (D11:5).

Similar to this example, other participants mentioned:

I think from the session we had on GeoGebra, I learnt a lot of in such a way that, … I think I can be able to use it on my own, not only to draw straight lines, but, … with other topics in Mathematics (D20:8).

The professional development sessions has empowered me in every level by allowing me to create lessons that can reach not just struggling learners and spend more time on one concept (D25:4).

The same participant further mentioned:

Now, with the few skills that I have learnt, I can now create lessons that can accommodate a variety of learners (D25:4).

The work of Mentz and Van Zyl (2016:331) also reveals that learning together creates a better learning experience in such a way that, teachers can plan, share and support each other in the process of becoming lifelong learners. This was also evident in this study as one of the participants mentioned:

Sharing ideas with other teachers during activities helped me to reflect back on my teaching methods. So, I was able to think as to how I will now approach my Maths lessons, using everything I have learnt from the sessions (D19:9).

Based on the preceding comments, it was evident that Mathematics teachers were aware of what worked for them, and hence they were able to decide on the best teaching strategies that would excite their learners and engage them in learning. This supports what has already been noted about the relevance of improving teaching strategies on Mathematics education (see 2.2.3.1). Many of the participants agreed that it is important to stay abreast of the emerging teaching practices, which is in line with Kriek and Grayson (2009:188), who comment that teachers need to be prepared to become lifelong learners, in order to meet the demands of educational challenges for the 21st century.

5.4.1.2 Content knowledge of Mathematics teachers

Participants had a variety of, and some interesting, views on Mathematics content knowledge. The findings indicated clearly that the participating teachers were positive about staying up to date with content knowledge and moving towards teaching and learning that promotes learners' conceptual understanding. This viewpoint is similar to the argument put forward in the literature (see 2.2.3.2), which advocated that teachers need to have good content knowledge of

Mathematics, in order to effectively facilitate the content to the learners. The participants' views were as follows:

> *I need to apply what I have learnt from the professional development into practice. … This will help me try new things in my classroom and hopefully I can make my learners more interested in my subject (D11:4).*
>
> *The professional development also helped me in using appropriate styles by allowing me new opportunities for curriculum and instruction by bringing real-world problems into the classroom for learners to explore and solve (D19:4).*
>
> *I'd like to say that, being part of the professional development helped in such a way that I will now create an active environment in which my learners not only solve problems, but also find their own problems (D23:4).*

These comments cited by the four participants reflect that participants were therefore willing to change their roles and take on new responsibilities. Desimone (2009:182) expresses a similar view that successful teacher PD is noticeable when there are changes in a teachers' knowledge and practices (see 2.5.1).

Another participant shared his experience by indicating how TSCL PD improved his knowledge and teaching.

> *The technology-supported cooperative learning professional development improved my mathematical content knowledge by providing me with an opportunity to learn with other teachers of the same subject, new skills and content which I can use in class (D17:8).*

The above comment seems also to be consistent with the findings of Gujarati (2013) on the relationship between Mathematics teachers and their classroom practices**.** Gujarati (2013:635) argues that the teachers' beliefs, values and practices have a huge impact in the learning and teaching of Mathematics. The review of related literature revealed that positive attitudes and skills towards teaching Mathematics can bring about more improvement in the quality and success rates of mathematics learners (McGraner *et al*., 2011:2).

5.4.2 Self-directed learning

Figure 5.3 illustrates the network view of the coding structure for the aspects of SDL, as highlighted by the participants. The characteristics of a self-directed learner and SDL skills are the two sub-themes that emerged within this main theme.

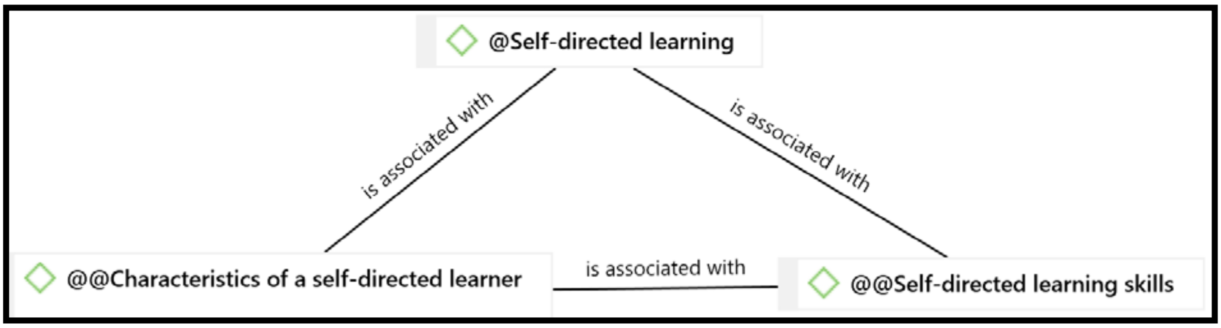

Figure 5-3: Coding structure for the facets of self-directed learning as highlighted by the participants

5.4.2.1 Characteristics of self-directed learning

As was discussed in 2.3.2, there are various characteristics of a self-directed learner. Teachers have to develop a set of characteristics to enable them to become self-directed. It is also for this reason that the research question of this study specifically focuses on the possible impact the TSCL PD had on teachers' SDL development. The possible change in SDL development was determined by the characteristics and skills (see 5.4.2.2) of SDL that were revealed in the data from participants.

Some of these characteristics, for instance, self-awareness, linking of learning content to a real-life context, taking initiative in the learning process and a tendency to enjoy learning, were evident in the data. One of the participants indicated that the TSCL PD helped her to become self-aware and this perception was expressed in the following quote:

> *Learning with other colleagues helped me to acknowledge, understand, and work diligently to overcome the challenges and obstacles standing in the way during the task that we were given (D17:3).*

The same participant further mentioned:

> *The technology-supported cooperative learning professional development provided me with the opportunities for creating learning environments that extend the possibilities of advancing my skills as a teacher, … to a point now where I can make Mathematics classes more interesting and more fun (D17:4).*

Another characteristic of SDL, as stipulated by Guglielmino (2008:2), is to be able to link the information and apply it to new situations. Participants indicated a few examples of how they linked what they have learnt during the TSCL PD, to their classroom practices.

The professional development afforded me the opportunity to use different computer applications so that I can use multiple representations to help students understand Maths concepts (D25:5).

Now, with the few skills that I have learnt, I can now create lessons that can accommodate a variety of learners (D23:4).

Some of the participants expressed their views regarding how they found joy in learning (see 2.3.2) during the TSCL PD sessions, as well as the reflections and feedback they received from other participants.

Well, seeing other group members being fully hands on and enjoying their work, made me realise that I also have to take part and be involved as well. So, ya, seeing everyone working, motivated me to take responsibility for my own learning (D14:5).

I guess … learning with other colleagues helped me to acknowledge, understand, and work diligently to overcome the challenges and obstacles standing in the way during the task that we were given (D17:3).

These responses seem to suggest that teachers exhibit some common characteristics of a self-directed learner. It also emerged that some of the participants were able to evaluate their learning process. For example, participant 3 pointed out:

Being able to engage and see what other teachers are doing differently … I guess … I'm finally in a position to reflect more specifically on concepts that I'm teaching (D19.6).

This relates to Guglielmino's (2013:3) opinion, that when individuals choose to control certain factors (such as analysing, evaluating and reflecting) to support their learning, SDL is promoted.

5.4.2.2 Self-directed learning skills

Various 21st century skills associated with SDL, such as goal-setting skills, information-processing skills, decision-making skills, finding relevant information and analysing a situation were discussed (see 2.3.5). The foremost common SDL skills, as is evident from Figure 5.3, are decision-making, finding relevant information and taking responsibility for own learning. One participant clearly emphasised how the TSCL PD helped her to become responsible and accountable for her decisions and actions with regard to her learning.

I would usually think of a familiar experience I had, then compare it to a new experience and make a decision on the relevance of that new experience (D22:8).

Another participant expressed his opinion:

The technology-supported cooperative learning professional development support me in using appropriate learning styles to solve challenges I face in teaching by helping me see how I can plan and prepare for better lessons and even changing my teaching practices (D25:4).

From the above responses, it emerged that the TSCL PD supported teachers in improving their teaching practices, as well as assisted them in becoming more self-directed. As was discussed in 2.3.3, the signs of readiness for self-directed learning include being able to make decisive decisions and also being able to engage in self-evaluation and self-reflection.

Another participant identified his strengths and weaknesses as a learner during the TSCL PD. This participant appeared to understand the significance of taking responsibility for his own learning, which is a key aspect in SDL (see 2.3.1). In this regard, he said:

During reflection sessions, I would usually think of a familiar experience I had, then compare it to a new experience and make a decision on the relevance of that new experience (D22:8).

Another participant mentioned how the TSCL PD supported her in gathering relevant information.

Access to learning opportunities today is unprecedented in scope thanks to technology. … massive amounts of information, books, audio, images, videos are available at one's fingertips through the Internet. So … I honestly used the Internet a lot to get access to the required information in order to complete some of the task in our session (D20:4).

All of the participants' responses above are consistent with the literature as a number of studies argue for lifelong self-directed learning (see 2.3.1). The realisation of the above-mentioned skills, as well as the expanded ability to use a variety of techniques to achieve learning goals, is a strong indication of self-directedness (Guglielmino, 2013:11–12).

5.4.3 Cooperative learning

From the literature review it became evident that teacher PD is most successful when done under the umbrella of collaboration. This section includes a discussion of CL as highlighted by the participants, elements of CL and the benefits of CL as a PD strategy. Figure 5.4 indicates the coding structure for the facets of CL.

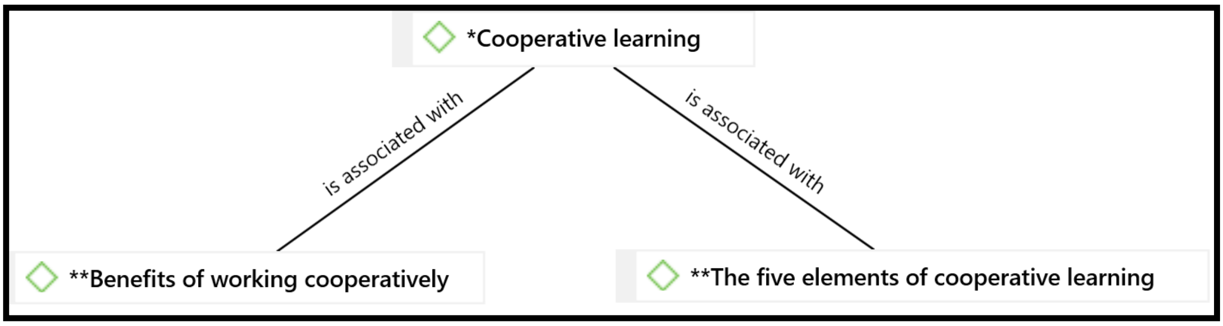

Figure 5-4: Coding structure for the facets of cooperative learning as highlighted by the participants

5.4.3.1 Benefits of cooperative learning as a professional development strategy

Sharing of information was highlighted as a source for more insight into the participants. Previous work done by Slavin (2009:11) showed that teachers learnt a great deal through cooperating with colleagues. Through sharing knowledge, information, experiences and skills, teachers developed in terms of their confidence and teaching practices (see 2.4.3). Participants stated that through different technological applications, they managed to share resources, screens and ideas and these helped them to accomplish the given tasks. One participant pointed out:

> *I can simply say the professional development sessions met my expectations by creating a space for us as teachers to share ideas and work cooperatively (D19:9).*

A second participant also pointed out:

> *I enjoyed the reflection sessions [group processing] that took place after every session (D25:2).*

This participant further mentioned:

> *Those reflections gave me time to process everything we learnt … they gave also gave me a chance to share my ideas with the whole group and to hear what others experienced and have to say (D19:2).*

Johnson and Johnson (2013:121), also make it clear that the most important aspect of group effectiveness is “sharing” because it builds trust within a group, while providing the information that the rest of the group needs to accomplish their goal.

Some participants also alluded to the fact that respecting one another within their groups played an integral role in building good working relationships as well as friendships. They expressed their opinions that they were able to listen to each other and gave one another a chance to give input without being interrupted. One participant acknowledged the importance of respect in group work:

> *I have learnt to respect my group members. You see, respect allow you to take other people's opinions and feelings into consideration (D12:5).*

> *I have learnt to respect my group members. You see, respect allow you to take other people's feelings into consideration when working together (D12:5).*

The above mentioned benefits of CL have been proved to influence each other by creating an effective environment for learning (see 2.4.3). For instance, how group members demonstrated respect amongst themselves during the TSCL PD sessions was an important aspect of building positive relationships whereby members communicated openly and effective and this in turn had a positive impact on the group's ability to achieve its goal.

5.4.3.2 Elements of cooperative learning

The five elements of cooperative learning, according to Johnson and Johnson (2013:102), need to be present in any group activity, for it to become a success. The basic elements (positive interdependence; individual accountability; promotive face-to-face interaction; social skills and group processing) of CL were evident in this study (see Figure 5.4). These elements will now be discussed.

Participants attest their experiences with group work.

> *You see, working in groups creates more opportunities for critical thinking and this I can say, promoted learning and achievement for me (D12:6).*

> *Let me say, the discussion with other colleagues helped me to understand mathematics in ways that allow me to explain and unpack ideas better than I used to (D17:6).*

> *Working in groups allowed me to interact with different kind of teachers, who brought different skills on the table (D2:8).*

According to the above responses, it showed that CL was essential for the sake of smooth progress of the task at hand. In this study, participants indicated that the presence of the group members during their group sessions was very helpful. They knew if they had problems with a particular task during the session, other group members were available to intervene in such cases. Keeping the group small increased the participants' feeling of accountability as well as positive interdependence. This allowed participants to be able to view different suggestions and learn how others' contributions assisted them to understand the work better. Some of the participants pronounced a similar sentiment regarding how well they worked with other members during the TSCL PD.

Nothing fosters unity like working through something together. Well, learning with other teachers helped me to seek out for advice and also to find long lasting, solid solutions (D22:2).

Learning with other teachers helps with building interpersonal relationships and working towards a healthy relationship (D23:2).

The professional development sessions met my expectations and even exceeded my expectations through the support and help I received from the group members and facilitator. These people explained to me so well, I was struggling, to a point whereby I would fully understand (D10:9).

Promotive interaction was visible when participants learnt to work with each other and exchanged needed resources. Some participants provided the same response that they were aware they could at any time call for help.

In our group, we would encourage each other to work as a team towards a common goal and this allowed us, individually to be more responsible in our respective task and also depend on each other for help (D11:7).

With the help of instructional document we had and the help of my group members, we finally won the battle (D9:7).

It also seemed clear that participants were willing to share their ideas and resources.

The professional development sessions support me to gather relevant information by opening an opportunity for me to learn with other teachers and share the workload that comes with lesson planning, allowing everyone more time to do what they do best (D19:3).

With regard to sharing, another participant mentioned:

I have learnt that teachers can share advice, expertise and also provide guidance, when they are working together towards a common goal (D25:11).

The existence of social skills was also evident from the participants when they were able to communicate accurately and listen carefully to one another.

The chatting tools and videos calls we used during the sessions allowed us to be able to listen to each other and gave one another a chance to share and demonstrate our ideas to the best of our ability (D13:4).

Other participants alluded to the importance of reflection in the form of group processing after every TSCL PD session in the following statement:

When planning a professional development, we should provide a clear learning targets and a reflection time like the ones we had in our sessions. In this way, teachers never leave us feeling confused or doubtful about what we've been teaching them and whether they've grasped it (D14:8).

There is sufficient evidence that positive group processing was fostered between most of the participants during the TSCL PD. Participants' responses suggested that the participants were able to engage in group processing by reflecting on their process and discussing what worked and what did not work.

To ensure positive interdependence, Johnson and Johnson (2013:4) suggest that participants have to rely on each other to complete tasks. In this study, each group member was responsible for a specific section of a topic, and all members had to teach their sections to the group, in order for the group to master the topic. One participant pointed out:

Learning with other colleagues and teaching each other what we learnt provided me with the opportunity to continue to refine and reflect on my activities during tasks (D19:1).

Another participant noted the importance of relying on each other to complete tasks and he had this to say.

I have learnt that when a team is able to work well together, they can accomplish more than what an individual can accomplish on his or her own (D10:6).

According to Johnson and Johnson (2013), assigning roles to individuals helps with providing a clear avenue for participation. In this study, individual accountability among members was stimulated by assigning roles to each group member (see 4.3.2). Each participant had a specific role to fulfil, therefore every participant felt important and needed, in order to succeed. The participants shared their views of specific roles in the TSCL PD as follows:

Having a role in the professional development allowed me to stay on task and pay closer attention to the task at hand, while also trying to make sure that all my group members are also focused (D18:8).

I experienced that roles helps to distribute responsibility among group members and ensures accountability for all individual's participation (D22:6).

I guess, the use of specific role is the professional development allowed us to share responsibility for the effective functioning of the team (D23:6).

Being a team leader […] it was difficult for me to step in and make sure that everybody is heard and treated fairly (D18:9).

The literature review made it evident that when CL is implemented with the five elements identified by Johnson and Johnson (2013), members become engaged in their learning (see 2.4.2). From teachers' responses, it seems evident that the five elements of CL contributed to enhancing teachers' learning. The use of CL in teacher PD clearly enhanced teachers' experience of the TSCL PD.

5.4.4 Technology

Figure 5.5 illustrates the network view of the participants' ideas about the support of technology in a PD. The three sub-themes that emerged within this main theme are teachers' experiences of using technology, the use of the Internet and the benefits of using technology during the PD.

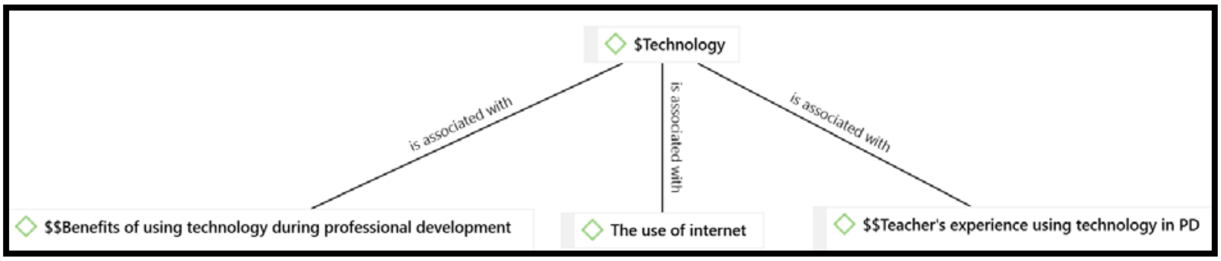

Figure 5-5: Coding structure for the participants' ideas about the support of technology in professional development

5.4.4.1 Teachers experiences of using technology in professional development

Technology was hailed by all teachers as a better method of PD than the traditional PD they have experienced. All participants felt confident in their abilities to implement what they have learnt immediately following the TSCL PD, due to the relevancy of the session and the general excitement about using recently introduced technological skills and resources. The participants shared their experiences as follows:

> *Yoh, it was very nice to use technology during the professional development, hey. You see, with previous professional development workshops I attended, we had to sit, listen and take notes, but now, due to the fact that there is a computer in front you, there is this feeling that you have to engage with it, press it, research or do something on the computer (D10:5).*

> *Being part of the professional development helped in such a way that I will now create an active environment in which my learners not only solve problems, but also find their own problems (D23:4).*

Other participants expressed their opinions on how technology made communication possible across vast distances.

> *Well, with the power of technology, I was able to participate in the professional development sessions, which were very far away from where I stay, even if I was in a different location. I had the same experience as with everyone who was in the same room with the facilitator and this for me proves that, learning can occur simultaneously, regardless of location (D12:4).*

> *My favourite activity in the professional development was using real-time collaboration with Google Docs. … I was so impressed about how we can work together in the same document in real time and in different locations (D20:1).*

From the participants' responses, it seems evident that one of the advantages of technology is that it enables participants to meet in a single online location literally anywhere in the world. As was discussed in 3.10, the nature of communication due to the advancement of technology has changed. As a result, technology has made it possible to work with people in remote areas, as if they are right next to us.

Other participants acknowledged that the use of technology in Mathematics Education has the potential to facilitate an active approach to learning, allowing them to become involved in discovering and visualising concepts, thus developing a deeper approach to learning. As was mentioned in 2.2.4, the use of different application software makes Mathematics more interesting, inventive and exploratory.

> *Classroom communication technologies, such as Google Classroom, can promote more active learning in large classes if used appropriately (D17:11).*

> *I really enjoyed using GeoGebra a lot in the professional development session. You see, similar applications like GeoGebra can help students with visualisation, increasing their understanding and the likelihood of transferring what they have learnt in school to a non-school settings (D18:3).*

It is evident that technology afforded teachers a greater feeling of ownership of the learning process and also expanded their ability to work on a space of their own. This provided participants with an opportunity to think critically and to work cooperatively with others, all the skills required in the 21^{st} century and the network society (UNESCO, 2012:6).

5.4.4.2 Benefits of using technology during professional development

The participants in general expressed that the use of technology during the TSCL PD helped with the exchange of resources and ideas, acknowledged their different learning styles and personality types, and also improved their communication as well as their teaching strategies. Their responses were as follows:

> *I liked using different computer application software during the sessions. I noticed how most of this software helps to create a virtual classroom space, with feedback and monitoring tools. Such experience can be shared and extended into a classroom setting, to accommodate different learning styles (D13:4).*

The same participant further expressed her views on how she benefited from cooperating with others, using technology during the TSCL PD.

> *Well, I found myself being a new person who has acquired new knowledge and skills and even exposed to more use of a computer (D13:4).*

Another participant mentioned:

> *I have learnt that working cooperatively together in small groups is very important, as you can easily exchange ideas and resources. Another thing that stood out for me during the sessions, is that we were able to work with different colleagues without a need to physical get to them (D9:9).*

A third participant also added:

> *What I have learnt from all the sessions we had is that with technology, it is possible for us as teachers during our own time, to have our own sort of professional development, or platforms whereby we communicate and share ideas regularly, even in the absence of a facilitator (D14:3).*

On the basis of the above findings, the data indicates that technology forms an important component of PD. Given this evidence, it can be seen that technology provide increased opportunities for teachers to work cooperatively with each other, at a time and space which is convenient to them.

5.4.4.3 The use of the Internet

The use of the Internet to during the TSCL PD sessions was commended because it helped participants to get a large amount of relevant information to use in completing their respective tasks. Many participants explained how the Internet benefited them.

> *Because there is a lot of seemingly limitless information online, working with group of teachers who share a common goal with, allowed me or should I say us as a group, to gather a lot of relevant information (D25:3).*

> *Well, the help of the Internet during the professional development sessions provided me with access to a vast array of information, hence I was able to gather relevant information (D22:4).*

From these comments, it can be understood that the use of the Internet improved participants' interest, understanding and concentration. This point is also sustained by the work of

Veletsianos (2010). Veletsianos (2010:74) states that, the Internet encourages participants to conduct independent research and this, according to Thornton (2010:161), is another aspect conducive to SDL development. Having access to world databases at the tips of their fingers enhanced participants' access to information by making searching convenient, easy and quick. It is the view of Maldonado *et al.* (2011:67) that, by having access to thousands of books, games, websites, etc., participants realised that their interactive teaching methods, supported by the Internet, can be enhanced, such that they can give more attention to individual students' needs and support.

5.4.5 Professional development

This section includes a discussion of teachers' previous experience of PD, as well as their experiences with regard to the current PD (TSCL PD). Figure 5.6 indicates the coding structure for the participants' experiences with regard to previous and current professional development.

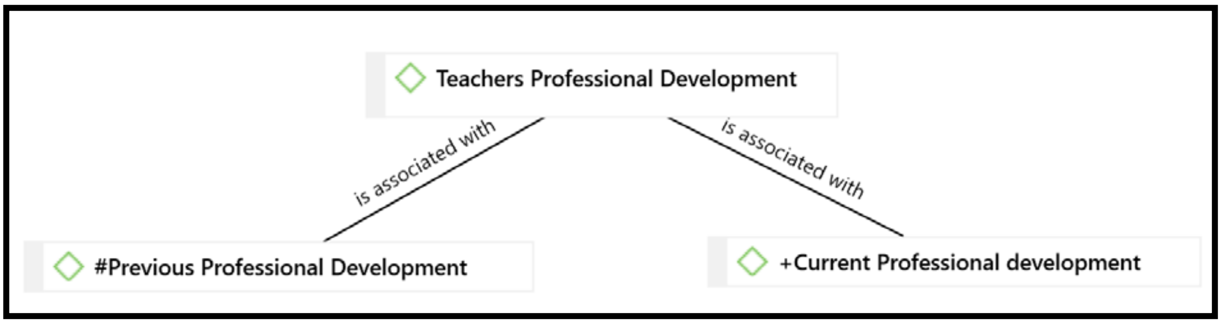

Figure 5-6: Coding structure for the participants' experiences with regard to previous and current professional development

5.4.5.1 Previous professional development

The literature reveals that traditional strategies to teachers' PD have been ineffective and inappropriate (see 2.5.2). Evidence is supplied in Ono and Ferreira (2010:59), that these traditional teacher PD strategies had no or little impact on improving teachers' teaching practices. In this current study, all participants expressed a concern about previous PD endeavours, noting that the sessions were inadequate and time consuming. One teacher indicated his discontent with previous PD programmes. He indicated:

> *Most of the professional development I have attended, there was little attention given to individual teachers' needs (D9:2).*

When asked to elaborate, he mentioned that in most cases:

The district or principals would hire a consultant or an expert in some instructional area, for instance, an expert on how to use geometry, technology or problem solving, and this expert will offer a pre-packaged workshop that is tailored to the needs of the district or the school (D9:2).

As mentioned in 2.5.2, these workshops or conferences do not support teachers during the stage of learning. Another participant further mentioned:

One of the problems with traditional professional development is that the agenda is already set and is very inflexible to meet the needs of diverse teachers (D2:1).

It becomes apparent that traditional teacher PD leaves no room for progression. Other participants felt that, during these sessions, they were given more work which does not relate to the curriculum as well as their teaching and learning needs.

We would usually gather in a big auditorium then talk about the new technique or new initiative we are adopting as a school or district, then from there we will be given materials and sign the register (D10:1).

Too often, there's too much talk in these professional development sessions, however, there was not enough practice and not enough follow-up (D13:2).

My experience with previous professional development is that they do not address the real challenges that we as teachers face in our schools and classrooms (D11:1).

The same dissatisfaction was observed in the literature review in this current study (see 2.5.2). Research has also shown that traditional PD fails to improve the knowledge and skills of teachers, as they do not provide enough time and content. Another participant affirmed that previous PDs were a waste of time and money.

I would travel for a very long distance just to get to the sessions, only to find out that the discussion is on something I know about or even worse, something we did a year ago. I would then have to drive back home again (D14:1).

Comments by participants indicated a high level of dissatisfaction and frustration. A point worth mentioning is that traditional PD is still being criticised for being ineffective (see 2.5.2).

5.4.5.2 Current professional development

TSCL, as a PD strategy, is one of the alternatives to traditional instruction-based PD. The TSCL PD was developed by the researcher as a new alternative to teacher PD in answer to teachers' needs regarding PD. As discussed in 3.5, a successful PD strategy in the 21st century should include the following: collaboration, reflection, technology-use in knowledge construction and mentoring from subject experts.

All participants in this study agreed that the current PD helped them to solve new challenges they face in their classroom, gather new information, develop mathematics content knowledge and have control over their own learning. Participant 7, for instance, alluded to the benefit of TSCL PD in the following statement:

> *The technology-supported cooperative learning professional development helped me to visualise difficult-to-understand concepts, … such effects of changing some variables on a linear function, when we were using GeoGebra and this for me is one the concepts that takes time to explain to learners, but now with the help of GeoGebra, this will now become very easy (D23:3).*

Another participant pronounced a similar sentiment regarding how the TSCL PD benefited him:

> *Let me say, technology-supported cooperative learning professional development afforded me new possibilities, new knowledge and new skills, especially with regards to getting better with using Maths application software (D12:7).*

There is also evidence from the results of this study that suggest that teachers experienced a high level of ownership towards their learning during the current PD. Participants shared their ideas on this aspect.

> *The idea that we were not sitting together in a group but working individually on separate parts of task [fulfilling the role he/she was given], motivated me to be more involved with what I was doing and it also gave me time to think and research more (D9:13).*

With regard to teaching practice, one participant mentioned:

> *I'm not going to lie, I always knew that coming up with lesson plans was not easy, so I'm glad that I was able to have this experience to meet, engage and collaborate with other teachers whom you can plan with (D23:5).*

Participants indicated that the outcomes of the TSCL PD strategy influenced them to transform and improve their teaching practices. This was in line with the literature where various researchers advocate for a teacher development model that stresses teachers being actively engaged in meaningful activities and change in teaching practices.

5.4.6 Challenges encountered during technology-supported cooperative learning professional development

There are a number of challenges that accompany the CL strategy (Johnson, 2008:106) and so there were also challenges experienced during the TSCL PD. As illustrated in Figure 5.6, some of the challenges that emerged during the course of the study are discussed below.

One of the challenges participants encountered during the TSCL PD was working together in diverse groups. Participants expressed their opinions about the challenges they encountered during the TSCL PD as follows:

> *The most difficult thing about working together in groups was when I was faced with a situation … whereby some members will prefer to observe rather than to participate vocally and others wished to contribute but feel too shy, fear self-disclosure or lack confidence (D17:2).*

> *Ensuring that your teams are working together toward a common goal is never an easy task. You know … the more you try to force your team to work together, the less likely you are to achieve the results (D22:7).*

According to Johnson and Johnson (2009:111), by participating in diverse groups in CL, individuals learn to accept and respect opinions of each other. Respect in CL groups allows positive interpersonal relationships to be developed (see 2.4.1). Another participant mentioned:

> *We tried as much as we can to minimise conflict and reach a consensus decision without critically evaluating each other's ideas (D13:6).*

This viewpoint is similar to the argument put forward in the literature by Johnson and Johnson (2013:107), who said that effective communication in groups assist in resolving and diffusing the situation.

Another participant mentioned:

> *I enjoyed how we managed to overcome the challenge we had when we were using Google Classroom (D17:1).*

Despite initial challenges with the technology, participants saw the value thereof.

> *But once you get along with it, everything becomes easy (D17:1).*

Similar to this example, participant 1 mentioned:

> *It was a challenge for me to familiarise myself with Google Classroom tools, as well as figuring out how to navigate through the application itself. However, with the help of the instructional document we had and the help of my group members, we finally won the battle (D9:7).*

Through these challenges, participants benefitted from the use of TSCL PD. As outlined in the literature by Sharan (2010:300), it is important for group members to deal with challenges in CL in order to gain from the benefits of CL. Teachers also had to overcome challenges with technology and having the responsibility of learning shift to them; however, teachers overcame these adversities and in the end expressed positive experiences regarding all aspects of the TSCL PD.

The study was conducted according to the phases of DBR as suggested by Amiel and Reeves (2008:32). The literature review and needs analysis formed the foundation for analysing the problem that was identified in this study. This was followed by the design, implementation and refinement of various iterations of the TSCL PD. The semi-structured interviews with the participants as well as the researcher's own evaluation served as a means to reflect on the process and in so doing enhance the implementation of the TSCL PD.

5.5 CONCLUSION

In the foregoing chapter, the findings of the study on the basis of collected data from semi-structured interviews and follow-up interviews were discussed. Most of the categories and subcategories discussed were related to the literature study. The participants were free to express their own needs, views and experiences. It was evident that all participants demonstrated a high levels of ownership in terms of their learning during the TSCL PD. Participants also experienced a great deal of confidence and a strong desire to learn with each other**.** Self-reflection as a sign of readiness for SDL, was also noticed during the TSCL PD sessions. Participants in the current study acknowledged the importance of improving the quality of their own teaching and how this affects learners' understanding of Mathematics. They also commented on their willingness to improve their content knowledge and work together with other colleagues to form a community of practice as Mathematics teachers.

The last phase of the DBR requires the intervention to be evaluated in order to see if it addressed the problems and produced the desired outcomes (Herrington & Reeves, 2011:598). The results in this chapter indicate that the TSCL PD offered teachers a higher -level of ownership towards their learning, an opportunity to learn together, know each other, accept and respect each other. The following chapter will address the research questions, give a general overview of the study, the summary of the main findings together with the recommendations emanating from the major findings.

CHAPTER SIX

SUMMARY, RECOMMENDATIONS AND CONCLUSIONS

6.1 INTRODUCTION

The preceding chapter highlighted the analysis and interpretation of the findings gathered by means of the data collected. This final chapter brings the study to a close with a summary of the key literature and research data findings in an effort to respond to the research questions. Subsequently, in this chapter, the general overview of the preceding chapters, research questions and the significant limitations of this study are discussed. Finally, the recommendations and possibilities for future research are presented, followed by concluding remarks.

6.2 SUMMARY OF CHAPTERS

This thesis comprised six chapters, which were arranged in the following manner.

Chapter One: Introduction, problem statement and motivation for the study

This chapter explored the research problem, while providing the rationale for the study and stating the research problem. Herein, the researcher presented the research questions and the literature review concerning the main themes of the study. The researcher also provided an overview of the research design, methodology, population, participant selection and methods of data generation and analysis. A list of terminology for clarification of concepts and a review of the methodology of a qualitative design-based research (DBR) study was discussed.

Chapter Two: Mathematics education, Self-directed learning, cooperative learning and teacher professional development

Since the research topic referred to “enhancing Mathematics teachers’ self-directed learning through technology-supported cooperative learning”, it was very important to clarify what was meant by the topic in the context of the study. In this chapter, the literature on self-directed learning (SDL), cooperative learning (CL), professional development (PD), as well as technology-supported cooperative learning (TSCL) was examined. The literature review focused on the body of scholarship about TSCL PD for Mathematics teachers, teacher PD, and how PD can influence learners’ academic performance. The literature clearly depicted the value of technology use in Mathematics education. It was found that teachers’ PD that focuses on content knowledge contributes to a change in teaching methods, which subsequently affects learners’ results. Evidence from the literature suggests that, different technological tools and application software should be used in order to enhance teachers thinking as well as collaboration. It is important to note however, that, PD must become part of a teachers' daily life to address the challenges they are faced with. The literature review discussed in Chapter Two informed the development of the TSCL PD as well as the data gathering instruments used as part of the DBR process.

Chapter Three: Technology-supported cooperative learning professional development

To answer research sub-question 1, Chapter Three reported on the implementation of TSCL as a PD strategy, since it was established in Chapter Two that TSCL PD would be a viable option to meet teachers' PD needs and possibly develop their SDL skills. The chapter highlighted exactly what technology is, the technology initiatives, and the history of technology in South African education. The researcher explored the need for TSCL PD to enhance teachers' SDL, as well as the learning tools that can be used within TSCL PD and the technological barriers that can be encountered. The researcher concluded the chapter by proposing a new way for PD that would meet individual teachers' needs and different levels of content knowledge and skills (see 3.8).

Chapter Four: Research design and methodology

Chapter Four described how the study was planned and conducted. In this chapter, the researcher discussed the research paradigm, sample selection, data collection, data analysis, trustworthiness of the study and ethical considerations. DBR was conducted to design and implement iterations of the TSCL PD for Mathematics teachers. The process began with a literature review as well as a needs analysis to gain insight into the problem. This was followed by the design, implementation and refinement of the TSCL PD. Lastly, reflection took place by performing interviews with the participants to establish their experiences of the TSCL PD. Data on answering research sub-questions 2 and 3 were obtained by means of semi-structured individual interviews with the participants. The data were coded and analysed using ATLAS.ti™.

Chapter Five: Analysis and interpretation of findings

This chapter presented the analysed and interpreted data. The findings were presented, discussed and analysed, in order to answer the main research question and the subsequent research sub-questions. The chapter presented this data analysis under five themes. These themes were Mathematics education, SDL, CL, technology and PD. Codes were created as part of the data analyses and in turn were categorised and ultimately placed in themes

The first theme focused on Mathematics education. The discussion was presented as two sub-themes: Mathematics teaching, and teachers' content knowledge of Mathematics. The second theme that was discussed was SDL. Here, the researcher discussed two sub-themes that arose from the data, namely characteristics of SDL and SDL skills. The third theme was based on CL and it was divided into two sub-themes: the benefits of CL as a PD strategy, and the five elements of CL. The fourth theme that was discussed was technology, and this was divided into three sub-themes, namely teachers' experiences of using technology, the use of the Internet and the benefits of using technology during PD. The final theme of this chapter was that of PD. The two sub-themes that were explored were previous [experience of] PD and current [experience of] PD. From the research results, it seemed evident that all participants experienced a high level of ownership regarding their learning during the TSCL PD and that they have learnt how to complete a task to the best of their abilities. By establishing the participants' experiences of the TSCL PD, the study has been able to reflect on important aspects of the design thereof and enhance the implementation of the design process.

Chapter Six: Research objectives, main findings, limitations and recommendations

The final chapter presented the main findings of the study. In this chapter, the summary of conclusion was drawn, limitations of the study were identified and lastly, recommendations for further study were presented. The summary of the key findings are discussed in the section below.

6.3 SUMMARY OF KEY FINDINGS

This section presents findings in terms of the main question, namely: How can TSCL PD enhance Mathematics teachers' SDL? The summary of the findings are presented in terms of the following secondary questions of this study:

- What does the body of scholarship reveal about teacher PD with specific reference to Mathematics education and Self-directed learning?
- What are Mathematics teachers' needs in terms of TSCL PD and SDL development?
- How do Mathematics teachers experience TSCL PD?

Research sub-question 1: What does the body of scholarship reveal about teacher PD with specific reference to Mathematics education and Self-directed learning?

The literature emphasised that teachers need to update their knowledge and skills regularly (see 2.3.4). There is a need for teachers to enhance their SDL in order to meet the high expectations of the 21st century, and subsequently addressing the poor learner performance in Mathematics education. The body of scholarship revealed that PD that allows teachers to assist each other, exchange information and resources; give and receive reflections can help them develop into self-directed learners (Ekizoglu & Ozcinar, 2010:5882). The evolvement of different technological tools and application also make it possible for teachers to exploration different

Mathematics concepts and they also allow teachers to work collaboratively. The work of some researchers (Desimone, 2009:181; Mouton *et al.,* 2013:40; Opfer & Pedder 2011:184) has drawn attention to the fact that, teacher PD which addresses the teachers' needs also allows teachers to deepen their knowledge while becoming creative and adventurous in their teaching practices. One of the ways in which to address teachers' needs is to allow for collaboration between teachers.

Many benefits of CL were also reported in the literature study. The literature indicates that when CL is properly implemented with well-designed tasks, it has the potential to ensure that teachers gain confidence and develop to their full potential to become responsible in their learning (see 2.4). CL has also been shown to improve social and communication skills among teachers, by allowing individuals to communicate effectively, build trust amongst themselves, make better decisions and resolve conflicts (Mentz *et al.*, 2008:250). Additionally, it was evident from the literature that incorporating the five elements of CL encouraged teachers to become more engaged in their learning. The positive aspects of these five elements of CL match the values promoted by SDL learners, which refer to taking responsibility for own learning, linking new concepts with own current knowledge and learning to become a reflective thinker. Focusing a PD program on the development of SDL skills thus also holds promise.

The development of SDL skills, namely; decision making, finding relevant information and taking responsibility for own learning, creates an opportunity for teachers to become lifelong learners and this leads to a better understanding of one's own strengths and weaknesses (Louws *et al.*, 2017a:172). The realisation of the above-mentioned skills, as well as the expanded ability to use a variety of techniques to achieve learning goals, is a strong indication of self-directedness (Guglielmino, 2013:11–12). It is through such endeavours that teachers have the potential to reach a more comprehensive understanding of these environments and in so doing are then able to meet the demands of educational challenges for the 21st century.

The literature regarding technology use in PD rightly points out that technology provides teachers with the opportunity to become experts in their fields by allowing them to conduct their own independent research, during their own time, space and pace and this, according to Thornton (2010:161), is another aspect conducive to SDL development. Technology could act as an agent of change in teacher PD by increasing interaction amongst teachers, supplying limitless amount of information and providing flexibility to access learning anytime and anywhere.

From the investigation into the body of scholarship regarding teacher PD, CL, SDL and technology it became evident that TSCL PD holds a promise to be conducive to Mathematics teachers' SDL development. Teachers should therefore be exposed to TSCL strategies to prepare lessons, communicate with colleagues and access different sources of information available online in order to benefit from the advantages of these aspects.

Research sub-question 2: What are Mathematics teachers' needs in terms of TSCL PD and SDL development?

To answer this research question, the researcher was guided by the investigation into the body of scholarship as well as the informal discussions with teachers.

Teachers are burdened with a great responsibility to address learners' poor performance in Mathematics education. During the needs analysis of teachers, the participants indicated that in order to cope with the challenges with which they are faced in their teaching, they need PD opportunities that are engaging, flexible and ongoing. Most participants' responses pointed to the need for increasing their knowledge and skills, and changing their attitudes in order to enhance their teaching and learning in order to improve their learners' academic performance. The participants mentioned that they wanted to participate in a PD strategy which is enjoyable, which includes daily life experiences and in which they are actively involved. Supported by Darling-Hammond *et al.* (2009:48), teachers' PD should not be seen as an event, but a process.

There is a dire need for teachers to be evaluated after participating in PD in order to assess the impact of their learning (see 5.2). In this study, participants mentioned that they needed PD that allows time for reflection. The ability to reflect on learning is essential for the professional growth of teachers. One of the elements of CL (group processing) gives ample opportunity for teachers to reflect on their own PD (when CL is used) (see 2.4.2.5). From teachers' responses, it seemed evident that teachers need PD, which empowers them to assess their own learning and develop a deep understanding about their own teaching practices, resulting in them becoming more self-directed in their learning.

Research sub-question 3: How do Mathematics teachers experience TSCL PD?

To answer this question, the researcher drew on the findings of the semi-structured interviews conducted with the participants.

There was evidence from the results of this study that participants were completely satisfied with taking part in the TSCL PD. All participants in this study agreed that the TSCL PD helped them with solving new challenges they face in their classroom, gathering new information, developing Mathematics content knowledge and having control over their own learning.

The study revealed that teachers were influenced by the outcomes of the TSCL PD in that they were confident and could apply the content they had learnt in their Mathematics classrooms effectively. Teachers indicated that they were confident regarding their content knowledge and the new teaching practices they had learnt in the TSCL PD, and as a result, teachers felt that their learners would also benefit from the knowledge that the teachers acquired (see 5.4.5.2).

All participants experienced the TSCL PD positively. This was due to the fact that participants' needs, during the TSCL PD, were met. From the need analysis, participants mentioned that they would like to be involved in the process of PD strategy which is hands-on, content specific, flexible, collaborative. TSCL PD afforded participant a platform to voice their challenges, to share resources, screens and ideas through different technological applications and to work independently as well as to work cooperatively with colleagues, developing long-term, committed and caring relationships.

Participants appeared to understand the significance of taking responsibility for their own learning, which is a key aspect of SDL – this can also be an indication that teachers' SDL skills had been developed during the TSCL. For instance, during group activities, teachers would listen and build on the ideas of others or negotiate their ideas with others, which is a sign of making decisions on what is best for the benefit of the individual member and for the group (critical thinking). Teachers would also work independently on their computers to find relevant information, in order to complete the assigned task – another aspect of SDL (using appropriate human and material resources, see 1.2.2). The facilitator also allowed teachers to take risks and make mistakes during their use of technology, then gave them time to discuss on how they can fix the mistake as this helped teachers to be accountable for their own learning. Participants mentioned that the use of specific roles in the TSCL PD influenced them to take responsibility for managing their own learning.

In this study, teachers indicated that they had been given the chance to investigate and research on their own and as a result, they experienced a high level of ownership towards their learning during the TSCL PD (5.4.4.1). It was also evident that teachers created knowledge from experience (5.4.2.2), collectively learnt with and from one another (5.4.3.1) and created opportunities to construct their own knowledge (5.4.2.1), through collaboration and shared dialogue with their peers (5.4.3.2). Technology helped teachers to become more independent in their learning and more interconnected with other teachers. The main research question of the study was "How can TSCL PD enhance Mathematics teachers' SDL skills?". The study has shown the value of TSCL in the PD of Mathematics teachers. The teachers also experienced the TSCL PD positively as opposed to their previous experiences of PD. They also indicated the value of the TSCL PD in informing their classroom practices. By allowing collaboration between teachers and by using technology in the PD, the teachers assumed responsibility for their own learning.

6.4 CONTRIBUTION OF THE STUDY

This study contributes to the body of scholarship regarding the knowledge base of TSCL PD which aids teachers in becoming more self-directed in their learning, and has the potential to address the poor performance in Mathematics education, specifically in the context of this study. The findings of this study also provide insight into the PD needs of Mathematics teachers. It further has the potential to assist departmental officials involved in designing and presenting future teacher PD which will benefit teachers more than previous teacher PD endeavours.

The study also contributes to the research output of the Research Focus Area SDL at the North-West University (NWU) in the Faculty of Education as no other study of this specific nature has been performed at the time of this study.

6.5 LIMITATIONS OF THE STUDY

A possible limitation in the study was that the researcher employed a limited target population, which in essence could not be sufficient for generalisation in the district, North West or in South Africa; however, generalisation was not the aim of this qualitative study.

Another limitation in this study was that the period of the intervention was short. Ideally, the intervention should have taken place over a longer period, but due to the time constraints of the post-graduate study and teachers' time pressures, this was not possible – the findings of this study did however still provide valuable insights and a deep understanding of how these teachers (in a short period of time) experienced the TSCL PD.

6.6 RECOMMENDATIONS

The following recommendations are proposed for further and future research on enhancing mathematics teachers' self-directed learning through technology-supported cooperative learning.

6.6.1 Recommendations from this study

In light of the research and the findings, the following recommendations are put forward with regard to enhancing Mathematics teachers' SDL. The findings highlight the need for teachers to be engaged in PD that addresses teachers' needs for professional growth. The researcher therefore recommends that teachers should be exposed to PD that accommodates the following key processes: using technology for the exchange of information, ideas and research; allowing for cooperation amongst teachers; and allowing time for reflection and flexible learning. As lifelong learners, teachers should have an opportunity to participate in PD at a time and place that is convenient for them. Another recommendation from this study is that there is a dire need for teachers to be evaluated after participating in PD in order to assess their experience of the PD. The researcher therefore recommends that teachers need to be evaluated after participating in PD. From this study it thus became clear that TSCL PD holds the potential to cater to teachers' PD needs and possibly develop their SDL skills, especially in the light of the fact that teachers all experienced this proposed TSCL PD positively.

6.6.2 Recommendations for future research endeavours

Based on the above-mentioned findings, the following recommendations could be made for future research. The researcher recommends a teacher PD that focuses on pertinent 21^{st}-century skills, hence TSCL PD. It is also recommended that a similar study be conducted with more participants from different provinces. Lastly, it is recommended that the study should be expanded to other subject areas.

6.7 THE ROLE OF THE RESEARCHER

The role of the qualitative researcher is considered as an instrument of data collection (Vanderstoep & Johnston, 2009:91). It is important that the researcher maintains trust with all the participants (Creswell, 2009:175). In this study, the first role of the researcher was to do an in-depth literature study to propose how TSCL PD can enhance Mathematics teachers' SDL. This was then followed by a role of being an interviewer (during semi-structured interviews), a supporter (throughout the whole course of the research) and a primary instrument (for collecting and analysing data).

The researcher's main role was to be an instrument to give teachers, who participated in this study a voice to share their experiences of the TSCL PD and in doing so inform future teacher PD endeavours. As the researcher of the study, I myself also went on a journey of change, subsequently the 'journey of the researcher' – I myself – will be discussed.

6.8 REFLECTIONS ON MY RESEARCH JOURNEY

This journey started four years back after completing my honours degree in Mathematics education. My interest increased when I had the privilege of training Mathematics teachers within the Royal Bafokeng Nation (RBN) on how to use different computer application software to make Mathematics more fun and interesting. With the aim of bridging the gap between primary and secondary Mathematics education in the RBN, I conceptualised the idea of developing a Mathematics community of practice (CoP), where Mathematics teachers would meet to share ideas and discuss different approaches to tackling various topics. Through the CoP, I became interested in introducing teachers to technology integration as an alternative to traditional teaching strategies. Not only does the use of technology in classrooms accelerate the process of solving problems and learning, but it also makes Mathematics much more interesting and easier to learn as compared to more traditional methods. This is the reason I enrolled for the MEd degree in Mathematics Education with NWU.

This research study gave me the opportunity to become exposed to SDL and 21st-century skills. I was not equipping learners with the necessary skills before I became aware of lifelong learning, yet I was convinced that my teaching methods were interesting and effective. I would say, I have revisited my teaching practices and since SDL is a process, progress is yet to be made. Additionally, this research study gave me the opportunity to gain experience in conducting qualitative research and facilitating in-depth interviews. I also gained valuable knowledge of, and insight into the research topic. This two-year journey has enriched my life, many lessons were learnt and perseverance became my virtue.

6.9 CONCLUSION

The aim of this study was to enhance Mathematics teachers' SDL through TSCL PD. In this study, the potential of TSCL PD to enhance teachers' SDL was researched. The study was able to find that TSCL PD opens up new opportunities for better learning and teaching environments by allowing teachers to exchange information, discuss, encourage and facilitate each other's efforts. The preceding chapters referring to literature and reporting on data have highlighted that TSCL is a successful teaching strategy in which each member of a team is responsible not only for his or her own learning (see 3.5, 3.6, 5.4.1, 5.4.2, 5.4.3.1, 5.4.3.2, 5.4.4.1, 5.4.4.2 and 5.4.5.2) but also for the success of every individual group member. It is therefore clear that the provision of TSCL PD as a PD strategy fosters lifelong learning, as it provides for consistency of content delivery, provides training in remote settings, eliminates travelling costs and provides flexibility.

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LIST OF ADDENDA

ADDENDUM A: TASK 1: ALGEBRA – EQUATION OF A LINE: $y = mx + c$

Task 1: Algebra – Equation of a line: $y = mx + c$

Using GeoGebra design an activity in which you teach learners about straight line graphs (the role of m and c in the equation: $\boldsymbol{y = mx + c}$**;** the intersection of two straight lines and parallel lines).

Part A: Expert Groups get together **Task time:** 45min

Expert Group 1 (focused on the role of m and c in the equation: $= \boldsymbol{mx + c}$)

Each expert must report back on the focus of their investigation (eg. the role of m and c in the equation: $\boldsymbol{y = mx + c}$).

Expert group roles: Each group will consist of a "leader" (provides direction, instructions and guidance to a group), the "scribe" (records all the answers and ideas that the group generates) and the "presenter" (presents the *group's* finished *work* to the whole class).

Expert Group 2 (focused the intersection of two straight lines)

Each expert must report back on the focus of their investigation (eg. the intersection of two straight lines).

Expert group roles: Each group will consist of a "leader" (provides direction, instructions and guidance to a group), the "scribe" (records all the answers and ideas that the group generates) and the "presenter" (presents the *group's* finished *work* to the whole class).

Expert Group 3 (focused on parallel lines)

Each expert must report back on the focus of their investigation (e.g. parallel lines).

Expert group roles: Each group will consist of a "leader" (provides direction, instructions and guidance to a group), the "scribe" (records all the answers and ideas that the group generates) and the "presenter" (time keeping, presents task back to large group and facilitator).

Part B: Home Group (2 home groups) **Task time:** 45min

Each member has 15min to share his or her expertise with the group and complete the task given: Using GeoGebra design an activity in which you teach learners about straight line graphs (the role of m and c in the equation: $\boldsymbol{y = mx + c}$**;** the intersection of two straight lines and parallel lines).

Roles of the group members in the home group: 1. Group leader (asking critical questions, reflecting on task at all times), 2. Scribe (doing the task on the computer, preparing the presentation), 3. Presenter (time keeping, presents task back to large group and facilitator).

Part C: Presentation to large group **Task time:** 10min

Part D: Group processing **Task time:** 5min

Each member should also reflect on what worked and what did not work during group activities and complete the group members' rubric:

Expert group member's rubric				
	Exceeds expectations	**Meets Expectations**	**Nearly there**	**Ineffective**
Commitment to Goals	I consistently and actively helped my team achieve its goals.	I usually helped my team achieve its goals.	I sometimes helped my team achieve its goals.	I did very little to help my team achieve its goals.
Research and Communication	As an expert, I did my best to collect lots of accurate information for my team. In Jigsaw, I shared what I learnt with my team.	As an expert, I did my best to collect accurate information for my team. In Jigsaw, I shared what I learnt with my team.	As an expert, I collected some accurate information for my team. In Jigsaw, I generally shared with my team.	As an expert, I collected little accurate information for my team. In Jigsaw, I did not share, or had little to share with my team.
Leadership and Teamwork	I encouraged my team to work together and stay on task. I willingly accepted the duties of my role.	I encouraged my team to work together, and I accepted the duties of my role.	I was sometimes off task or reluctant to accept the duties of my role.	I was often off task and reluctant to accept the duties of my role.

ADDENDUM B: TASK 2: USING GOOGLE CLASSROOM AS A TEACHING RESOURCE

Task 2: Using Google Classroom as a teaching resource

Work cooperatively to design a grade 7 lesson on integers using Google Classroom. Members should use the stream tab for regular communication with other group members during the task.

Part A: Expert Groups get together **Task time:** 45min
Expert group members of the same segment will join together and help each other to begin with the same information and understand the nature of the task, then after they will return to complete the task (see part B) in their home groups.

Expert Group 1 (focused on lesson template)

Discuss and plan with a group member(s), a possible lesson plan template (and Google Classroom template) to use when designing a Grade 7 lesson plan on integers. You may select from a range of available templates online.

Expert group roles: Each group will consist of a “leader” (provides direction, instructions and guidance to a group), the “scribe” (records all the answers and ideas that the group generates) and the “presenter” (time keeping, presents task back to large group and facilitator).

Expert Group 2 (focused on mathematical content and interactive websites)

Collect more information that will help you later to compile lesson notes on integers. The lesson notes should include YouTube video link, explaining clear content of the lesson as well as interactive websites links relating to grade 7 lesson on integers.

Expert group roles: Each group will consist of a “leader” (provides direction, instructions and guidance to a group), the “scribe” (records all the answers and ideas that the group generates) and the “presenter” (time keeping, presents task back to large group and facilitator).

Expert Group 3 (focused on quizzes in Google Classroom)

Discuss and prepare multiple choice questions on Grade 7 integers, which will be used to create a quiz on Google Classroom.

Expert group roles: Each group will consist of a “leader” (provides direction, instructions and guidance to a group), the “scribe” (records all the answers and ideas that the group generates) and the “presenter” (time keeping, presents task back to large group and facilitator).

Part B: Home Group (2 home groups) **Task time:** 45min

Each member has 15min to share his or her expertise with the group and complete the task given: Work cooperatively to design a grade 7 lesson on integers using Google Classroom.

Roles of the group members in the home group: 1. Group leader (asking critical questions, reflecting on task at all times), 2. Scribe (doing the task on the computer, preparing the presentation), 3. Presenter (time keeping, presents task back to large group and facilitator).

Part C: Presentation to large group **Task time:** 10min

Part D: Group processing **Task time:** 5min

Each member should also reflect on what worked and what did not work during group activities and complete the group members' rubric:

Expert group member's rubric				
	Exceeds expectations	**Meets Expectations**	**Nearly there**	**Ineffective**
Commitment to Goals	I consistently and actively helped my team achieve its goals.	I usually helped my team achieve its goals.	I sometimes helped my team achieve its goals.	I did very little to help my team achieve its goals.
Research and Communication	As an expert, I did my best to collect lots of accurate information for my team. In Jigsaw, I shared what I learnt with my team.	As an expert, I did my best to collect accurate information for my team. In Jigsaw, I shared what I learnt with my team.	As an expert, I collected some accurate information for my team. In Jigsaw, I generally shared with my team.	As an expert, I collected little accurate information for my team. In Jigsaw, I did not share, or had little to share with my team.
Leadership and Teamwork	I encouraged my team to work together and stay on task. I willingly accepted the duties of my role.	I encouraged my team to work together, and I accepted the duties of my role.	I was sometimes off task or reluctant to accept the duties of my role.	I was often off task and reluctant to accept the duties of my role.

ADDENDUM C: TASK 3: USING GOOGLE DOCS AS A TEACHING RESOURCE

Task 3: Using Google Docs as a teaching resource

You are tasked to prepare a Grade 6 test on measurement, using real-time collaboration with Google Docs. Members should use the stream tab for regular communication with other group members during the task.

Part A: Expert Groups get together **Task time:** 45min
Expert group members of the same segment will join together and help each other to begin with the same information and understand the nature of the task, then after they will return to complete the task (see part B) in their home groups.

Expert Group 1 (focused on 2D shapes)

- Prepare a ± 10 Marks question, where learners are tested on how to use appropriate formulae to calculate perimeter and area of 2D shapes.

- Pictures of 2D shapes need to be included in the question.

Expert group roles: Each group will consist of a "leader" (provides direction, instructions and guidance to a group), the "scribe" (records all the answers and ideas that the group generates) and the "presenter" (time keeping, presents task back to large group and facilitator).

Expert Group 2 (focused on converting units)

- Prepare a ± 10 Marks question, where learners have to converting between appropriate units of measurement.

- The SI units should include:

$mm^2 \leftrightarrow cm^2$

$cm^2 \leftrightarrow m^2$

$mm^2 \leftrightarrow m^2$

Expert group roles: Each group will consist of a "leader" (provides direction, instructions and guidance to a group), the "scribe" (records all the answers and ideas that the group generates) and the "presenter" (time keeping, presents task back to large group and facilitator).

Expert Group 3 (focused on perimeter and area of 2D shapes)

- Prepare a ± 10 problem solving question that involves calculating perimeter and area of 2D shapes.

- The question should include a real-life application of perimeter and area.

Expert group roles: Each group will consist of a "leader" (provides direction, instructions and guidance to a group), the "scribe" (records all the answers and ideas that the group generates) and the "presenter" (time keeping, presents task back to large group and facilitator).

Part B: Home Group (2 home groups) **Task time:** 45min

Expert group members will return back to their home group using their codes, where they will compile a final version of a Grade 6 test on measurement, using real-time collaboration with Google Docs.

Roles of the group members in the home group: 1. Group leader (asking critical questions, reflecting on task at all times), 2. Scribe (doing the task on the computer, preparing the presentation), 3. Presenter (time keeping, presents task back to large group and facilitator).

Part C: Presentation to large group **Task time:** 10min

Part D: Group processing **Task time:** 5min

Each member should also reflect on what worked and what did not work during group activities and complete the group members' rubric:

Expert group member's rubric				
	Exceeds expectations	**Meets Expectations**	**Nearly there**	**Ineffective**
Commitment to Goals	I consistently and actively helped my team achieve its goals.	I usually helped my team achieve its goals.	I sometimes helped my team achieve its goals.	I did very little to help my team achieve its goals.
Research and Communication	As an expert, I did my best to collect lots of accurate information for my team. In Jigsaw, I shared what I learnt with my team.	As an expert, I did my best to collect accurate information for my team. In Jigsaw, I shared what I learnt with my team.	As an expert, I collected some accurate information for my team. In Jigsaw, I generally shared with my team.	As an expert, I collected little accurate information for my team. In Jigsaw, I did not share, or had little to share with my team.
Leadership and Teamwork	I encouraged my team to work together and stay on task. I willingly accepted the duties of my role.	I encouraged my team to work together, and I accepted the duties of my role.	I was sometimes off task or reluctant to accept the duties of my role.	I was often off task and reluctant to accept the duties of my role.

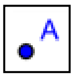
ADDENDUM D: RESOURCES FOR TASK 1 (GEOGEBRA)

Resources for Task 1

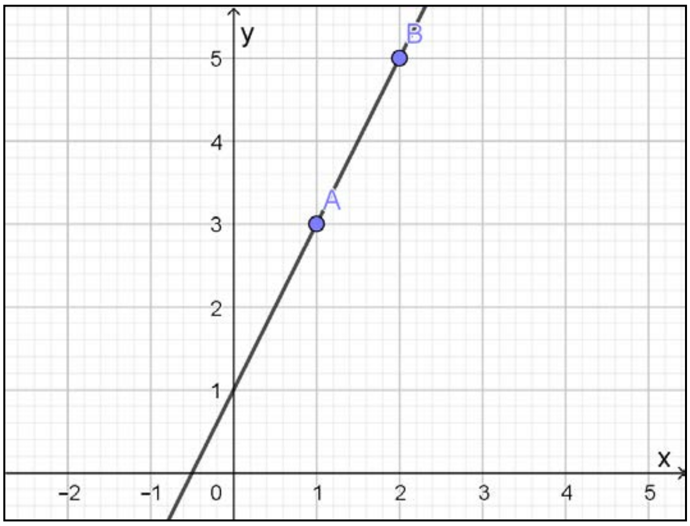
General resources about GeoGebra (refer to Guidelines to working with GeoGebra):

Task specific resource (Expert group 1):

The points should move along the line as you drag them

1. In the input bar enter: $\boldsymbol{mx} + \boldsymbol{c}$
   If prompted select *Create Sliders*.
2. Use the **Point** tool to add two points to the line, **A** and **B**. 

3. Vary the line with the sliders and the points by dragging them.



7 Questions for discussion

- How does changing c affect the line?
- How does changing m affect the line?

Try setting m and c to values such as 1, 2, 3…

What do you notice – what stays the same and

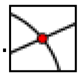
- Draw a few graphs with a positive gradient and a few with a negative gradient. What conclusion can you draw from this observations?
- Investigate the equations of vertical and horizontal lines.

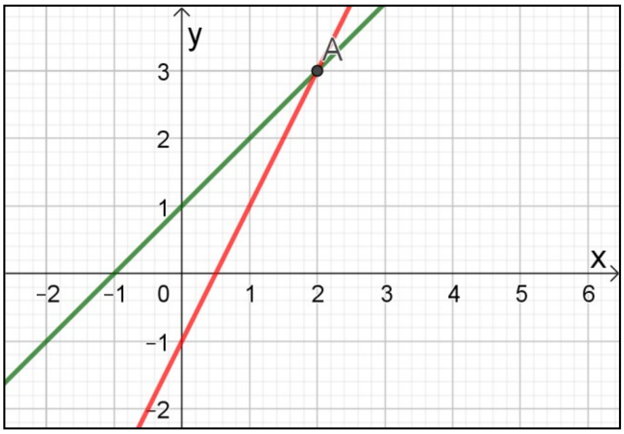
Task specific resource (Expert group 2):

1. In the input bar enter: $\boldsymbol{mx} + \boldsymbol{c}$
   If prompted select *Create Sliders*.

2. In the input bar enter: $\boldsymbol{nx} + \boldsymbol{d}$
   If prompted select *Create Sliders*.

3. Vary the line with the sliders so they are different.

4. Use the **Intersect** tool to find the point of intersection of the lines. 



8 Questions for discussion

- How could you find the point of intersection from the equations of the lines?

Find the point just using algebra and check it with your graphs. Try this for some different pairs of lines.

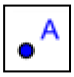
- When will the lines not have points of intersection?

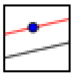
Will your lines ever intersect if you zoom out far enough?

Problem (Try the problem with pen and paper first then check it on your software) Find the coordinates of the point of intersection of the lines: $y = 3x - 2$ and $y = x + 4$

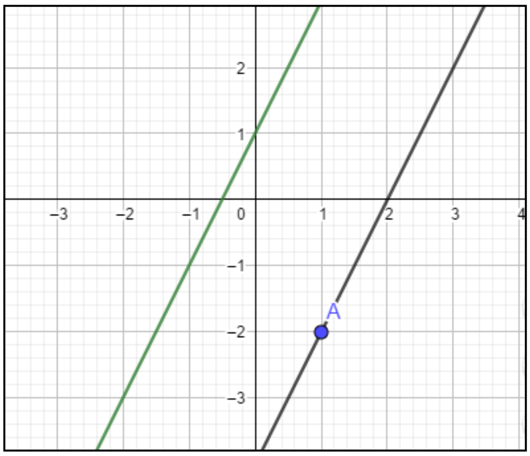
Task specific resource (Expert group 3):

1. In the input bar enter: $\boldsymbol{mx} + \boldsymbol{c}$
   If prompted select *Create Sliders*.

2. Use the **Point** tool to create a point, **A**.
   NB this point should not be on the line.
   

3. Use the **Parallel Line** tool to create a line parallel to the original line through the point.
   

4. Vary the line with the sliders and the point by dragging it .



9 Questions for discussion

- What is the link between the equations of parallel lines?
- How could you find the equation of a line if you knew a point on the line and the equation of a line parallel to it?

Try setting m and c to 1, 2, 3… What do you notice – what stays the same and what changes?

If you move A to a new point can you predict what the equation will be?

Problem (Try the problem with pen and paper first then check it on your software)
Find the equation of the line that passes through the point (2,1) and is parallel to $y = 3x + 2$.

ADDENDUM E: RESOURCES FOR TASK 2 (GOOGLE CLASSROOM)

Resources for Task 2

Google Classroom resources:

General guidelines to using Google Classroom (see videos etc.)

Creating and joining classroom

1. Navigate to https://classroom.google.com
2. Choose the "I am a Teacher" option
3. Click the "+" sign in the top right-hand corner next to your Google account
4. Select "Create Class", then give it a name and a section, and click "Create"
5. Click the Settings gear icon at the top of the page
6. Make a note of the class code and distribute this to home group members
7. Other home group members will then navigate to https://classroom.google.com, click the "+" sign in the top right-hand corner of the screen, and select **Join class**
8. Members have to enter the class code, and will instantly be added to the class
9. Confirm if they can access and create

Task specific resources (Expert group 1):

Designing lesson plan

1. Click on the created class
2. Click on the Classwork tab at the top of the page
3. Click the Create button and then choose Material
4. Add a title, description and any attachments you deem appropriate for the lesson plan
5. Click Topic and assign your materials to a new topic and name it “Grade 7-integers”
6. Click Post when you are done

Task specific resources (Expert group 2):

Compiling lesson notes

1. Open the created class
2. Click the Classwork tab at the top of the page
3. Click the Create button and choose to add an assignment
4. Give your assignment a title and add any additional instructions or a description in the box below

5. Choose the type of assignment you wish to create by clicking on one of the icons next to the word Assign. Your choices are to upload a file from your computer, attach a file from Google Drive, add a YouTube video, or add a link to a website.
6. Click **Assign** when you are done

Task specific resources (Expert group 3):

Creating quiz

1. Click on the created class
2. Click on the Classwork tab
3. Click Create and then choose quiz assignment
4. Click on Google Forms
5. Select question type (choose multiple-choice for the purpose of this task)
6. Create questions
7. Click Send when you are done

ADDENDUM F: RESOURCES FOR TASK 3 (GOOGLE DOCS)

Resources for Task 3

Google Docs resources:

General guidelines to using Google Docs (see videos etc.)

Creating and editing Google Docs.

1. Navigate to https://docs.google.com
2. In the top left, under "Start a new document," click "+" sign in the top upper-left corner of the screen to create new document.
3. Click untitled document in the upper-left corner to add a title to your document.
4. To share your documents with other people, click the blue *Share* button in the upper-right corner of the doc.
5. Invite other users by entering the appropriate email address in the resulting window.
6. People you share with can either edit, view, or comment on a document depending on what permissions you grant them.
7. By clicking the *Comments* button in the upper-right corner of your screen, you or anyone else who is in the document can start a discussion about your project.
8. To select a word, double-click it or use your cursor to select the text you want to change.
9. To undo or redo an action, at the top, click Undo or Redo .
10. If you're done with your current document, you can just simply close the window or tab. Everything is saved

Part A: Expert group task ***Time on task***: 40 minutes

You are tasked to prepare a Grade 6 test on measurements, using real-time collaboration with Google Docs. Expert group members of the same segment will join together and help each other to begin with the same information and understand the nature of the task, then after they will return to complete the task (see part B) in their home groups.

Task specific resources (Expert group 1):

- Prepare a ±10 Marks question, where learners are tested on how to use appropriate formulae to calculate perimeter and area of 2D shapes.

- Pictures of 2D shapes need to be included in the question.

Task specific resources (Expert group 2):

- Prepare a ±10 Marks question, where learners have to converting between appropriate units of measurement.

- The SI units should include:

$mm^2 \leftrightarrow cm^2$

$cm^2 \leftrightarrow m^2$

Task specific resources (Expert group 3):

- Prepare a ±10 problem solving question that involves calculating perimeter and area of 2D shapes.

- The question should include a real-life application of perimeter and area.

Part B: Home Group task **_Time on task_**: 20

- Compile a final version of a test for submission.
- The test should include Question 1-3, with mark allocations, grade and total.

Part C: Reflection **_Time on task_**: 30

- Share your experiences on the task.
- Reflect on what worked and what did not work during group activities.

ADDENDUM G: ROYAL BAFOKENG INSTITUDE APPROVAL LETTER

LETTER TO THE RBI MANAGER ASKING PERMISSION TO CONDUCT RESEARCH

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South Africa 2520

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Faculty of Education
Research Focus Area Self-directed learning
Tel: 018 111 1111
Email: Gordon.Sekano@nwu.ac.za

Gordon Sekano
81 Waterkloof Hills
Rustenburg
0299

Date: 01 June 2019

Dear Sir/Madam

PERMISSION TO DO RESEARCH IN ROYAL BAFOKENG INSTITUTE

I am requesting permission to conduct research in the Royal Bafokeng Institute (RBI). The research is part of my Master's degree in Mathematics Education at the North-West University, under the supervision of Dr. Dorothy Laubscher and Dr. Roxanne Bailey. The topic of my research is "Enhancing Mathematics teachers' Self-Directed Learning through technology-supported cooperative Learning." Primary school teachers from the LUKA MATHS FORUM (LMF) will be involved in the study and the research will be conducted from the 01st June 2019 to 01st July 2019.

The aim of this study is to enhance Mathematics teachers' Self-Directed Learning (SDL) through technology-supported cooperative learning (TSCL) as a professional development (PD) strategy. For teachers to benefit from using technology in everyday Mathematics teaching, it is important that they are adequately equipped with not only basic knowledge, but knowledge about new teaching techniques that are necessary in a technology-rich classroom and this can done through an on-going professional development (PD). The study therefore will develop teachers' SDL as teachers need to be equipped with skills to take responsibility for their own learning and in doing so keep up with the challenges posed in Mathematics education.

The findings of this study could assist the Royal Bafokeng Institute (RBI) and curriculum experts in the designing and adaptation of PD courses that are more relevant for teacher professional growth. This study will make contributions to Mathematics knowledge teachers by setting out to enhance teachers' SDL through TSCL. This will include introducing teachers to strategies and resources that can assist in their teaching of Mathematics. Furthermore participating in the interviews will give teachers the opportunity to reflect on their own professional growth and engage with the researcher regarding this.

The final report from the study will be sent to your office on completion. I foresee that the PD strategy will hold long-term benefits for teachers. If after reading the proposal you have any questions you wish to have clarified, please do not hesitate to contact either myself or my supervisors.

I trust that my request will be favourably received.

Sincerely yours,

Researcher: MR.K.G.Sekano

10/03/19

Date

I the undersigned, hereby give Mr.K.G.Sekano permission to conduct his research for her Master's degree, in this premises.

Name of the RBI manager

0836284311
tom.hamilton@bafokeng.com

Contact Number & Email

Signature of the Head of Research

Date

ROYAL BAFOKENG INSTITUTE
DATE:
SIGNATURE: 11/3/2019
P O BOX 315 PHOKENG 0335

ADDENDUM H: ETHICAL APPROVAL LETTER (NWU)

NORTH-WEST UNIVERSITY ®
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7 May 2019

To Whom It May Concern

I hereby confirm that the ethics application, as stated below, was approved at the Ethics Committee meeting of the Faculty of Education of 25 April 2019.

Ethics number: NWU-00138-19-A2

Project head: Dr DJ Laubscher

Project team: G Sekano, Dr R Bailey

Title: Enhancing Mathematics teachers' Self-Directed Learning through Technology-Supported Cooperative Learning

Period: 25 April 2019 – 25 April 2020

Clearance given for only one year. Extension can be requested after a year.

Risk level: Low

Should you have further enquiries in this regard, you are welcome to contact Prof Jako Olivier at 018 285 2078 or by email at Jako.Olivier@nwu.ac.za or Ms Erna Greyling at 018 299 4656 or by email at Erna.Greyling@nwu.ac.za .

Yours sincerely

Prof J Olivier
Chair Edu-REC

ADDENDUM I: INFORMED CONSENT FORM FOR PARTICIPANTS

Private Bag X6001, Potchefstroom
South Africa 2520

Tel: 018 299-1111/2222
Web: http://www.nwu.ac.za

Faculty of Education
Research Focus Area Self-directed learning
Tel: 018 111 1111
Email: Gordon.Sekano@nwu.ac.za

Gordon Sekano
81 Waterkloof Hills
Rustenburg
0299

Date: 23 October 2018

PARTICIPANT INFORMATION AND CONSENT FORM

I herewith wish to request your consent to participate in this research, which involves teachers from primary schools who are involved in the professional development sessions at the Royal Bafokeng Institute. Before you give consent, please acquaint yourself with the information below.

The details of the research are as follows:

TITLE OF THE RESEARCH PROJECT: Enhancing Mathematics teachers' Self-Directed Learning through Technology-Supported Cooperative Learning

PROJECT SUPERVISOR: Dr. Dorothy Laubscher
CO-SUPERVISOR: Dr. Roxanne Bailey
ADDRESS: Private Bag X6001
POTCHEFSTROOM, 2520
South Africa
CONTACT NUMBER: 018 299 4585
E-mail: Dorothy.laubsher@nwu.ac.za or Roxanne.bailey@nwu.ac.za

MEMBER OF PROJECT TEAM MEd-Student: Gordon Sekano
ADDRESS: House Number 81
Waterkloof Hills
Rustenburg
0299
CONTACT NUMBER: 078 766 8782
E-mail: Gordon.sekano@gmail,com

FACULTY OF EDUCATION RESEARCH ETHICS COMMITTEE
Contact person: Ms Erna Greyling, E-mail: Erna.Greyling@nwu.ac.za, Tel. (018) 299 4656

This study has been approved by the Ethics committee of the Faculty of Education of the North-West University and will be conducted according to the ethical guidelines of this committee. Permission was also asked from the Royal Bafokeng Institute as well.

What is this research about?

Feinman-Nemser (2001:1014) purports that teachers require access to serious and sustained learning opportunities at every stage in their career if they are to be able to teach in ways that meet the demanding new standards for student learning or to participate in the solution of educational problems. The study therefore will use technology-supported cooperative learning as a professional development strategy to provide teachers with necessary skills that move them to becoming more self-directed and in doing so take more responsibility for their own learning and needs.

Participants

The participants (n=7) in the study consist of Mathematics teachers who attend PD workshops once a week at the Royal Bafokeng Institute (RBI) premises in the Rustenburg area. The participants teach Mathematics in different grades in Primary Schools attended by low socio-economic status learners in the Royal Bafokeng schools.

What is expected of you as participant?

There will be different sessions presented during technology-supported cooperative learning professional development and participants are expected to work cooperatively by making use of technology. Teachers will be engaged in using computer and mobile technological applications, online discussion forums, learning management systems and social network sites. Prior to data collection, all participants will complete voluntary informed consent. Participants who opt to participate in the research, will be interviewed at the end of the four weeks professional development programme. The interviews will take less than 40 minutes and will be scheduled in a time and place convenient to the participant.

Benefits to you as participant

This study will make contributions to your knowledge as a Mathematics teachers by setting out to enhance your self-directed learning through technology-supported cooperative learning. This will include introducing you to strategies and resources that can assist in your teaching of Mathematics. Furthermore participating in the interviews will give you the opportunity to reflect on your own professional growth and engage with the researcher regarding this.

Risks involved for participants

Participants are only expected to participate cooperatively in the professional development, as such, there is no risk foreseen. There is no direct risk or discomfort anticipated with participation in the interviews. Should any participant at any time experience discomfort the interview can be terminated.

Confidentiality and protection of identity

Participation in this study is confidential. To ensure confidentiality, a random number is allocated to participants by the interviewer. Participants' identity will not be made public in the research report or the publication of the research results. The original interview recordings will be kept in a safe place by the researcher.

Dissemination of findings

The feedback of the study results will be available in the dissertation, and a summary will be available from the researcher should you be interested in the findings of the study. The researcher plans to publish a research article of the results.

If you have any further questions or enquiries regarding your participation in this research, please contact the researchers, project supervisors or NWU faculty of education research ethics committee on the contact details above.

DECLARATION BY PARTICIPANT:

By signing below, I …………………………………..…………. agree to take part in a research study entitled:

The relationship between the professional wellbeing of teachers and principals' leadership styles.

I declare that:

- I have read this information and consent form and understand what is expected of me in the research.
- I have had a chance to ask questions to the researcher and all my questions have been adequately answered.
- I understand that taking part in this study is voluntary and I have not been pressurised to take part.
- I may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- I may be asked to leave the research process before it has finished, if the researcher feels it is in my best interests, or if I do not follow the research procedures, as agreed to.

Signed at (place)___________________________on (date) ______/______/20____

______________________ ____________________

Signature of participant **Signature of witness**

ADDENDUM J: CERTIFICATE OF PROOF READING AND EDITING

Jackie Viljoen
Language Editor and Translator
16 Bergzicht Gardens
Fijnbos Close
STRAND 7140

Accredited member of the South African Translators' Institute No
APSTrans No. 1000017
Member of the Professional Editors' Group (PEG) No. VIL003
Member of Safrea No. SAF03316

☎ +27+21-854 5095 082 783 0263 086 585 3740
Postal address: 16 Bergzicht Gardens, Fijnbos Close, STRAND 7140 South Africa

DECLARATION

I hereby certify that the thesis by **GORDON SEKANO** was properly language edited but without viewing the final version.

The track changes function was used and the author was responsible for accepting the editor's changes and for finalising the reference list.

Title of thesis:

ENHANCING MATHEMATICS TEACHERS' SELF-DIRECTED LEARNING THROUGH TECHNOLOGY-SUPPORTED COOPERATIVE LEARNING

The editor did not write or rewrite any part of the thesis on behalf of the client, including passages that may have been plagiarised. The academic content is the sole responsibility of the client as author of the work. The editor could not and did not test definitively for plagiarism, nor is there any explicit or implicit guarantee that the content that was edited contained no material used without consent. The editor accepts no responsibility for any failure on examination of the thesis by the university.

JACKIE VILJOEN
Strand South
Africa
06 November 2019

ADDENDUM K: QUESTIONS FOR SEMI-STRUCTURED

1. Tell me about your experience of the TSCL PD.
2. Tell me about your favourite group work activity in the TSCL PD.
3. What have you learnt from working together in groups in the TSCL PD?
4. How did learning with other teachers or colleagues affect you and/or your teaching?
5. How did the TSCL PD support you in:
   - 5.1 Gathering relevant resources?
   - 5.2 Taking responsibility for your own professional development?
   - 5.3 Using appropriate learning styles to solve challenges you face in teaching?
   - 5.4 Reflecting on your own teaching practices?
6. How did you experience the use of specific roles in the TSCL PD?
7. What was the most difficult thing about working together in groups?
8. What role did the TSCL PD play in developing you in terms of:
   - 8.1 Mathematical content knowledge?
   - 8.2 Teaching strategies?
   - 8.3 Support?
   - 8.4 The use of technology?
   - 8.5 Collaborating with colleagues?
9. What would you do differently if we started with group work again in the TSCL PD?
10. Is there anything else you would like to add?