PROFESSIONAL DEVELOPMENT OF SECONDARY SCHOOL MATHEMATICS TEACHERS THROUGH COLLABORATIVE REFLECTION IN PRE-SERVICE AND IN-SERVICE LEARNING CONTEXTS

BY

LOVEMORE NYAUMWE

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Name of author: Nyaumwe Lovemore

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Signed …………………………………………..   **Date** …………….

ABSTRACT

Teacher professional development is the area of study of this thesis. The cursory post lesson reflective texts written by most student teachers on teaching practice that typically belonged to low reflection category (level one) motivated this study. The extent of effectiveness of a collaborative reflection with a peer (CRP) framework to facilitate student teachers' attainment of higher levels of reflection is documented. The study investigated the research question: *How can collaborative reflection with a peer enable secondary school mathematics student teachers to critically reflect on their practice and influence positively their cognition and decision making during instruction and post lesson reflective dialogues?*

Developmental research involving case studies of three pairs of pre-service and two pairs of in-service teachers was the model of inquiry used in this action research. Two sessions of field work were used to improve the validity and practicality of the CRP framework before final implementation in a third field work session. Data for the study were collected collaboratively by the researcher and a peer through (a) assessment of student teachers' reflective actions during teaching, (b) post lesson reflective dialogues, (c) assessment of post lesson reflective texts written by student teachers, and (d) group reflective interviews at the end of the teaching practice period.

The results from the data of interest were that a cognitive theory of collaborative reflection could explain the possible understanding of decision making processes that a student teacher might attain. The cognitive theory states six linear stages that discourse in typical post lesson reflective dialogues went through. A theory of student teachers' professional attitudes towards instructional practice theorises three phases that student teachers' priorities went through to attain higher order reflections. It is recommended that two student teachers be attached to one experienced teacher and share his/her teaching load. Such a deployment pattern may positively influence student teachers' cognitions and decision making during teaching and post lesson reflective dialogues. This deployment pattern may allow a student teacher and a peer to spend more time together during planning, teaching, and reflecting on each other's teaching.

DEDICATION

This thesis is dedicated to my late parents, Michael Njororo and Monica Nyaumwe.

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The people and organisations mentioned above made insightful suggestions to improve the process and product of this study. I remain responsible for any errors of interpretation or omissions that might be noticed in this thesis. Opinions expressed in the thesis are those of the author and do not necessarily reflect the opinions of the people and organisations that are mentioned.

PREFACE

Chapter One identifies the problem of the study that emanates from the tendency of student teachers to praise rather than critically reflect on their teaching in post lesson reflective texts. This tendency restricted their reflections to low order reflection categories of technical or practical reflection without achieving critical reflection level. The study is significant in that a CRP framework to guide student teachers' reflections may give them insight on how to develop reflective practice. The chapter describes the delimitations of the study, and provides definitions of commonly used words and the education system used in Zimbabwe that provides a route to teacher education.

Chapter Two surveys the literature on teacher professional development, conceptual meaning and usefulness of reflection in order to get a sense of available models of reflection and how they impact on this study. The chapter provides the evolution of reflection and the possible models used to develop reflective practice among teachers by some selected authors such as Dewey (1933), Kolb (1984), Smyth (1992) and Manen (1977). Weaknesses of current reflection and teaching practice models are discussed and the gap that CRP intends to fill is exposed. Ideas from this chapter informed the design and development of instruments that are discussed in Chapter Three.

Chapter Three describes three phases of development research that were used in this study. The chapter discusses case study designs, instruments for data collection, validity and reliability of instruments, procedures for data collection, and data analysis strategies. The instruments developed for the main study were piloted during the first phase of the study before implementation described in Chapters Four and Five.

Chapters Four and Five present the results from the main study for in-service and pre-service teachers respectively, using the chronological order of rounds of visits. The pre- and in-service teachers' reflective actions during teaching and post lesson reflections improved with length of school attachment and familiarity with using the CRP framework. Implementation of the CRP

framework resulted in the improvements of the student teachers' reflections at each of the four cyclic stages of conception, context, evaluation and development. This enhanced the observation that the CRP framework positively influenced the quality of the student teachers' reflections. Chapter Six discusses the results, conclusions, and some recommendations for the future of collaboration with peers.

Discussion of the results in Chapter Six produced two theories: (a) a cognitive theory of collaborative reflection, and (b) a theory of student teachers' affective goals for reflecting on their teaching. The two theories explain the cognitive and affective factors that influence secondary school mathematics student teachers' reflections on their teaching, and influence positively their cognitions and decision making during instruction and post lesson reflective dialogues. It was concluded that CRP is a viable framework that has potential to develop student teachers' reflective skills. More studies are necessary to understand the relationships and ways of conducting collaborative reflections in order to develop a comprehensive theory that can account for the effective implementation of the CRP framework in a variety of contexts. Deployment of two student teachers to one experienced teacher was recommended to be a possible strategy to enable student teachers and peers to spend a lot of their time together. This strategy might facilitate student teachers' development of openness to discuss their weak and strong teaching points with interpretations of learners' actions from a peer and an experienced teacher.

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CHAPTER 1: THE RESEARCH PROBLEM

1.1 Chapter overview

This chapter describes the background of the study. This is followed by current teacher professional development programmes used in Zimbabwe in order to provide an understanding of some aspects of teacher education in the country. Organising professional development programmes for teachers and weaknesses of current models used for developing professional competencies of student teachers are discussed in sections 1.4 and 1.5 respectively. Sections 1.6 and 1.7 present some expected outcomes of professional development and student teachers' programmes in Zimbabwe respectively. The research problem is presented in section 1.8 followed by the context that was used to collect data that answers the research question. The motivation, possible contributions, delimitations, and selected frequently used words are presented in later sections. A summary of levels of formal education in Zimbabwe is presented towards the end of the chapter in order to provide a common understanding of the entry qualifications of student teachers into teacher education programmes. The chapter ends with a summary of what was discussed and how this chapter links with Chapter Two.

1.2 Background of the study

There is a constant search for ways for improving mathematics education throughout the world (Grevholm, 2000; Julie, 2004; van der Sandt & Nieuwoudt, 2005). Issues surrounding learner achievement are receiving great attention because Mathematics is a critical filter for school leavers' employment opportunities and full participation in society (Brumbaugh & Rock, 2001). A school leaver's full participation in a community is determined in part by the extent to which goals for school mathematics are achieved. For instance, in mathematical discourses one hears references to mathematics for workplace, mathematics for scientific and technological development, mathematics for life and mathematics for cultural heritage, among others.

Societal expectations of secondary school mathematics school leavers are high but their performance in the subject has generally remained low. The Third International Mathematics and Science Study (TIMSS) results for learner assessment have indicated poor learner performance in

many countries (Cogan, Wang & Schmidt, 2001). The TIMSS results have prompted educators and policy makers to reconsider more carefully mathematics and science curricula in their countries and how they are taught in an effort to increase learner performance. Highest achieving countries have not sat back in celebration of their good performance, but continue to reflect and improve in order to maintain high standard of performance (Cogan, Wang & Schmidt, 2001). Although Zimbabwe was not among the 40 participating countries in TIMSS, neighbouring South Africa was ranked among the bottom five performing countries. South Africa's disappointing performance was perceived by educators and policy makers as reflecting performance of learners in Southern Africa. Such performance has prompted debates among educators and policy makers in the region to find possible ways of enhancing learner performance in mathematics. The Southern Africa Association for Research in Mathematics, Science and Technology Education (SAARMSTE) is the official body that promotes dialogue through a bi-annual journal and annual conferences in the region that discuss strategies for improving the quality of mathematics, science and technology education in southern Africa.

The effectiveness of teachers as catalysts for learner understanding has been scrutinized because teachers play a central role in the process of learning. No effort to improve learner achievement can succeed without parallel strategies for improving teacher instructional skills. This is so because teachers are crucial elements in efforts to build effective mathematical education systems (Fifteenth International Commission on Mathematical Instruction Study, 2004). For instance, the growing concerns regarding the effectiveness of transmission methods of learning Mathematics have necessitated design of strategies to equip teachers with instructional knowledge and skills to implement paradigm shift to learner-centred methods. A shift in teacher knowledge of pedagogical reform from teacher-centred to learner-centred methods entails changes in their views on teaching and learning. In learner-centred pedagogies, learning is conceived as a process of active engagement with experience leading to learner increase in knowledge structures. This leads to growth in conceptual understanding, increased understanding of mathematics teaching competencies and knowledge that lead to development and desire to learn more mathematics (Peressini, Borko, Romagnano, Knuth, & Willis, 2004; Siegle, 2006). Teacher roles in learner-centred classrooms shift from being dispensers of mathematical knowledge to coordinators, facilitators, guides, resource advisors, tutors or coaches. Teaching and learning cease to be

learner- and teacher-convergence on pre-existing truth, to divergence and broadening what is knowable, doable and viable (Breen, 2005).

There are raging debates on the unsatisfactory integration of theory and practice in teacher education and concerns about mathematics teachers as action researchers (Addler, 2004). Some teacher education programmes are sometimes pre-occupied with imparting content and pedagogical knowledge while giving minimal attention on how student teachers modify them to suit learner needs (Handal, 2003). This makes such programmes to have little effect on producing mathematics teachers who can effectively apply instructional theories they learn during training in their teaching. For instance, Marland (1994) established that some in-service teachers explained their classroom practices with reasons that were not related to what they learnt during their teacher education programmes. This evidence enabled Marland to conclude that teacher decision-making does not solely rely on pedagogical knowledge but also on their conceptions of the content and how learners understand it.

Instructional conceptions that teachers sometimes hold on how learners learn Mathematics sometimes come into conflict with educational reforms. These instructional conceptions are often difficult to change. To assist student teachers to constantly review their instructional conceptions and encourage them to implement teaching strategies that they learn during teacher education, it is useful to track how they marry pedagogical theories with teaching practice during their school attachment. Such tracking might provide an understanding of how teaching practice programmes may be improved, through suggestions for intervention strategies that influence student teacher conceptions on teaching. The tracking may also reveal how the student teachers utilize the contexts of the learning environments to implement pedagogical theories in their teaching. This study contributes to this debate by seeking theories on teacher professional development that might provide insight on how student teachers acquire knowledge and skills that enable them to positively influence their cognitions and decision-making during instruction.

The framing of the study is influenced by the nature of the professional development of mathematics teachers in Zimbabwe, problems and outcomes of professional development, and sources of the focal research problem posed for this study.

1.3 Professional development programmes for mathematics teachers in Zimbabwe

The enterprise of teaching and learning mathematics is so complex that pre-service education alone cannot provide life long teaching skills for teachers (Betoret & Artiga, 2004; Even, 2005). Constant review of mathematics teacher professional needs is necessary in order to increase knowledge and skills that facilitate resolving of the challenges of a host of issues that arise during teaching. For instance, reviewing teacher competencies to use hand-held technology might limit the relegation of calculators to the periphery of the mathematics classroom where they can be underutilized as computational gadgets (Nyaumwe, 2006). Early diagnosis of teacher professional weaknesses to implement technological reforms might lead to designing professionally enriching experiences that might help them to effectively use the technology during teaching to improve their classroom practice (Hea-Jin, 2001). Professional development for teachers can be organised through in-service programmes.

The distinction between continuing and in-service education is often blurred. Continuing education primarily refers to an acquisition or awareness of particular knowledge and skills for the purposes of enriching one's teaching. In-service education, on the other hand, is intended for staff development activities for a teacher to function more effectively in professional practice in which learners are the ultimate beneficiaries through improved learning.

Emphasis on professional development of teachers goes beyond a focus on new content and pedagogy to include strategies to influence teacher belief systems on teaching practices. Challenging teacher belief systems is necessary in order to convince them of the efficacy of professional skills that they are encouraged to adopt. When convinced of the importance and effectiveness of the new knowledge and skills that they are encouraged to develop, student teachers might successfully implement them in their teaching. For example, many Zimbabwean teachers hold the belief that graphing calculators in mathematics classrooms are not necessary. This belief is premised on the need for learners to develop graphing skills rather than watching graphs drawn by calculators. Such belief systems should be challenged through teacher conviction of what should be prioritized between learner explorations and technical skills of drawing graphs. When the teachers are convinced of skills that learners in a technological

developing country should posses, they may appreciate and successfully implement reform on technology usage in mathematics classrooms. When fully convinced that technology can be a catalyst in the learning of mathematics, the teachers may modify the myths and beliefs that they hold about technology in the mathematics curriculum. That understanding might challenge their existing ideas about doing, knowing, and teaching mathematics in ways that may increase their capacity to understand content, pedagogy and student learning technology rich classrooms. Consideration of some agents of professional development is necessary when designing programmes that facilitate changes in teacher attitudes toward the implementation of a desirable reform in the mathematics curriculum.

Hadi (2002) identified three agents of professional development that facilitate changes in teacher attitudes toward reforming the mathematics curriculum. The agents were identified as: (a) addressing teacher conceptions on teaching and learning mathematics, (b) situating learning of new professional knowledge and skills in classroom practice, and (c) expending time and support on the development of the repertory of intended professional skills. Each of these agents is elaborated below:

1.3.1 Addressing teacher conceptions of teaching and learning mathematics

Addressing teacher conceptions on the nature of mathematical knowledge during professional development is as complex as changing their teaching practices. Teachers hold complex webs of conceptions about the nature of mathematical knowledge and how to teach it. Davis and Hersh (1981) and Matthews (1994) generally agree on three broad conceptions of mathematics teaching and learning that influence teacher practices. They identified them as Platonism (static view), formalism (mechanistic view) and constructivism (contemporary view). In the Platonist conception of teaching and learning, mathematics is viewed as a universal and static subject whose concepts reside outside the human senses. Student teachers who hold formalist conceptions of teaching believe that sources of legitimate mathematical processes are axioms, definitions and theorems (Davis & Hersh, 1981). The products of mathematical activities in formalism arise from logical mechanistic use of accepted procedures that student teachers demonstrate to learners (Warren & Nisbet, 2000).

Teachers holding constructivist conceptions of teaching believe that mathematical knowledge is tentative, intuitive, subjective, and dynamic. They believe that mathematical concepts originate from observations, experimentation, and abstraction using senses (Davis, 1990). Such a conception regards teaching as equipping learners with conceptual understanding of the process skills that enable learners to individually or collectively develop a repertoire for constructing powerful constructions that concur with viable mathematical knowledge.

Teacher conceptions of the nature of mathematical knowledge influence their assumptions of methodology for, and presentation of, concepts of the subject in ways that they believe to be comprehensive to learners. The success of student teachers' teaching practice depends on the extent to which classroom practice influences their conceptions of mathematics instruction and ability to implement instructional strategies that they learn during the theoretical part of their training programme. For instance, teaching experience that facilitates student teacher reviewing their beliefs on how students learn and change their conceptions from formalist to constructivist orientation.

Teaching practice, therefore, is important for facilitating student teacher understanding of constructivist teaching approaches in ways that enable them to challenge their conceptions of transmission teaching methods, otherwise reform on learner-centred methods may not be implemented in Zimbabwean mathematics classrooms. Grounding professional development of mathematics teachers in classroom contexts enhances an evaluation of the efficacy of the new knowledge and skills that they are encouraged to develop and adjust their conceptions of them accordingly. Theoretical exposition of student teachers to new professional ideas and techniques only might be inadequate. It may not lead to significant implementation of the techniques learnt in the classroom as the student teachers may continue to use traditional teaching practices. Integration of theory and practice may enable student teachers to implement pedagogical strategies that are encouraged by curriculum reforms in mathematics instruction.

1.3.2 Situating learning of new professional knowledge and skills in classroom practice
What student teachers hope to achieve through professional development are concrete, specific, and practical approaches that directly relate to their daily teaching. Addressing student teacher pragmatic needs through situating professional development in real classroom practice provides

them with opportunities to reflect upon, and discuss their conceptions about mathematics teaching and learning in view of the new knowledge and skills they are encouraged to develop. Learning of new instructional knowledge and skills in the classroom situation with supportive materials that promote effective implementation of a curriculum reform can facilitate the development of teacher professional synergy.

Paradigm shifts in teacher professional development from off-site to on-site training, from theoretical presentation to distance learning materials, from pre-determined ideal curriculum to school determined agenda, and from knowledge acquisition to performance enhancement may be necessary to situate student teacher learning of reform needs if professional development programmes are to succeed. The paradigm shifts may emphasize learning new teaching knowledge and skills in the classroom contexts so they do not become just rhetoric. Situative teacher professional development programmes allow student teacher engagement with learners and meaningful tasks that may allow explorations on how to improve new teaching knowledge and skills that they are expected to develop (Peressini, Borko, Romagnano, Knuth & Willis, 2004). The success of student teacher situative learning requires time and support for them to engage in experiences that facilitate reviewing their instructional conceptions.

1.3.3 Expending time and support on the development of intended professional skills.

In circumstances where teacher professional development cannot be done in classroom situations, school attachment is an integral part of the programme. Provision of equal periods between teacher education theory and school attachment may provide teacher programmes with opportunities to develop teaching skills informed by both theory and practice. Such programmes may facilitate student teacher reviewing of instructional conceptions they hold. Student teachers go for school attachment with personalized conceptions of the nature of mathematics and its teaching and learning (Nyaumwe, 2004). These conceptions are influenced by teacher education courses, the way they mastered mathematical concepts as learners, and the way they were taught mathematics during their school days (Vacc & Bright, 1999).

School attachment facilitates student teacher experimentation and testing of the effectiveness of the conceptions on teaching and learning mathematics that they hold before accepting them as theory that guides their teaching. In coming to know teaching strategies that are effective and

those that are not, student teachers may make cognitive changes that are influenced by reflection on their professional practice. The outcomes of reflection on the student teacher experimentation with theory and personalized conceptions on teaching might lead to changes in their cognitive patterns. The conception and cognition changes that are influenced by improvements in teaching and learning mathematics might reveal a high degree of understanding professional practice, which is the essence of teaching practice.

Teaching practice exposes student teachers to actual classroom practice rather than theoretical descriptions of teaching. It offers opportunities for implementation, observation, critique, reflection, feedback and (re)construction of teaching practice in the light of instructional strategies extolled to be effective. For example, Loucks-Horsley, Hewson and Love (1998) concluded that successful professional development of student teachers occurred when they got opportunities to build personalized knowledge and skills from teaching practice. Teaching practice enables student teachers to test and develop the knowledge and skills of implementing pedagogical theories they are encouraged to use. Feedback on implementation from faculty members, peers and mentors facilitate provisions of opportunities for student teachers to reflect on their learning to teach. Reflection on how they learn to teach might act as lenses that show professional areas that need further development or consolidation. Short teaching practice durations designed to support implementation of new pedagogies that lack a coherent integration of theory and practice do not usually lead to professional development of student teachers (Loughran & Gunstone, 1997). Sustained time of teaching practice and support is necessary if student teachers are to learn how to teach and reflect on the effects of teaching practice on their professional development. This is possible with careful organisation of professional development programmes.

1.4 Organizing professional development programmes of teachers

Organizing teacher professional development programmes is not easy. It involves diagnosis of their needs and designing possible strategies to satisfy them. Professional developments that address teacher needs promote implementation of curriculum reform and encourage instruction that could contain the challenging and unpredictable learner behaviour in diverse learning contexts. For instance, professional development on implementing learner-centred teaching

methods might develop teacher understanding of local conditions that promote learner effective use of resources in their environments, to explore and model problematic situations. In designing teacher professional development programmes one usually encounters problems.

1.5 Problems in professional development of mathematics student teachers in Zimbabwe

The main goal of student teacher development programmes in Zimbabwe, as elsewhere, is to provide them with the opportunity, time, means and resources to improve their professional competencies in ways that lead to improved learner understanding. However, there are always challenges to overcome in pursuing this goal. Invarson (in Loughran & Gunstone, 1997) identified three challenges that are usually encountered in the professional development of student teachers on block-intervention or sustained professional growth initiative. The challenges are: (a) clarity of goals of professional development; (b) incentive system; and (c) weak professional controls by student teachers. Each of these challenges is elaborated in more detail below:

1.5.1 Clarity of goals of professional development

Goals of teacher education programmes are set on the basis of assisting student teachers to develop creative instructional approaches that inculcate in learners an enthusiasm and satisfaction to learn and apply mathematical knowledge. Teacher educators determine student teacher professional needs by choosing content and pedagogies that the student teachers are assumed to lack. Professional courses that are perceived vital to enable the student teachers to improve student learning are designed. The student teachers are not engaged in the negotiations and debates on what they should learn in order to acquire the skills that might make them more effective teachers. For instance, undergraduate teacher education programmes are usually designed on the assumption that student teachers need content and pedagogical knowledge to enable them to successfully teach mathematics up to 'A' Level.

The assumption that undergraduate student teachers need content and pedagogical knowledge is made without confirmation from the cohort classes of student teachers. Courses are designed on the basis of enrichment and adaptability to the 'A' Level curriculum. Some content courses are included in the undergraduate teacher education curriculum without a rationale for what student teachers should learn (Loughran & Gunstone, 1997). For instance, student teachers find no

immediate use and rationale for studying Abstract Algebra that is not included in the 'A' Level curriculum. Abstract Algebra is included in their courses for enrichment purposes. Some student teachers do not appreciate Abstract Algebra in their curriculum on the grounds that the course challenges their abilities and they spend a lot of time studying it yet they find it of no immediate relevance to their classroom needs. For student teachers to be studying Abstract Algebra without own justifications shows the extent to which they lack influence on the courses that they study in their teacher education programme.

1.5.2 Incentive system for student teachers

The lack of control on what they learn combined with a weak incentive structure to some extent, discourages practicing teachers to go for professional development through in-service programmes in Zimbabwe. After studying challenging courses and spending huge personal financial resources, student teachers expect some generous incentives on successful completion of teacher education programmes. The generous incentive structures are usually hard to come by because teaching is a generally low paying profession that does not offer competitive benefits that some professions offer, such as provision of soft loans to purchase capital assets. Low remunerations and lack of attractive incentives make some student teachers in Zimbabwe consider teaching as a stepping-stone for other professions (Nyaumwe, Brown & Dhliwayo, 2004). A weak incentive structure combined with a lack of autonomy to choose what they wish to learn, makes it difficult for some student teachers to appreciate some courses that they learn in the teacher education curriculum.

1.5.3 Weak professional control by student teachers

Lack of autonomy to practice their ideals of teaching Mathematics might inhibit student teacher construction of pedagogical practices that are different from those of teacher educators and their mentors at attachment schools. Student teachers can develop creative classroom practices when they are helped by mentors and peers to construct their own professional practice. Peer support might encourage student teachers to work in critical, questioning, and reflective modes that encourage their implementation of new pedagogical strategies while mentors guide them to use the context of attachment schools to implement pedagogical strategies they learn in teacher education theory. Teaching mathematics is a personal craft that requires student teachers to implement and discuss with peers and mentors a variety of teaching strategies they learn in

teacher education in a variety of classroom environments. Combined professional advice from mentors and peers on how to teach might allow student teachers to manage their learning through a social process of construction, negotiation, and evaluation of pedagogical decisions they make in their teaching (Papo, 1997). A collaboration of mentors and peers in guiding student teachers on how to teach, engages them in experimentations and discussions that might promote skilful teaching competencies that are informed by both theory and practice. Collegial peer and mentor support enhances favourable professional development outcomes of student teachers (Nyaumwe, Mtetwa & Brown, 2005) that meet the expected outcomes of teacher education.

1.6 Expected outcomes of professional development

An effective professional development programme aims to provide student teachers with knowledge and skills that enable them to meet a host of issues that arise during teaching with a goal of making learners achieve mathematics curricula. Abdal-Haqq (2000) argued that teaching practice allows student teachers to build their pedagogical knowledge and skills, work with a diverse range of learners, provide continuous examination and assessment of personal teaching, and generate a knowledge base that is effective for decision-making. This conclusion portrays teaching practice as a critical aspect in the development of professional knowledge and skills of student teachers. Thus, teaching practice emphasizes the development of pedagogical content knowledge through an evaluation of the basis upon which student teachers draw inferences when they make instructional decisions. Development of reflective skills in ways that provide insight to subsequent teaching practice is a problem that is often faced by some undergraduate student teachers on teaching practice. This problem limits their development of a complete repertory of professional skills to reflect on their teaching in ways that permit implementation of the results of reflection in subsequent teaching or attain critical reflection level. An understanding of this problem in the Zimbabwean context is provided in a review of student teacher programmes presented below.

1.7 Teacher development programmes in Zimbabwe

Diplomas are offered at teachers' colleges and undergraduate studies in initial secondary school teacher education are offered at some universities in Zimbabwe. At the diploma level, content and pedagogical courses are usually taught during the same residential period. The concurrent

offering of content and pedagogical courses during the first year of residential part of the diploma programme is assumed to adequately prepare pre-service teachers for a year-long teaching practice in the second year of the diploma programme. Another concurrent offering of content and pedagogy courses in the third year part of the residential course is assumed to provide pre-service teachers with an understanding of teaching theories that successful candidates graduate.

There are two models of undergraduate pre-service teacher education in Zimbabwe. In the most common model, pre-service teachers complete a Bachelor of Science (BSc) degree (three years after 'A' Level) in a Faculty of Science where they study content only. After graduating with BSc, graduates teach in schools for at least two years and come back for a full year to study pedagogical courses in a Faculty of Education. During the fourth year of their study, the pre-service teachers study professional courses only and go for twelve weeks of school attachment. Successful completion of the fourth year leads the pre-service teachers to graduate with a Post Graduate Diploma in Education (PGDE).

The second model of pre-service teacher education that is offered at one state university integrates content and professional courses during four years of undergraduate studies. In this model, pre-service teachers graduate with a Bachelor of Science Education degree (BScEd).

There are three models of in-service teacher programmes in Zimbabwe, namely, Better Schools Programme of Zimbabwe (BSPZ), Secondary Education In-service Teacher Training (SEITT) and Bachelor of Science Education (BScEd) or Bachelor of Education (B. Ed) degree. Each of these in-service programmes is briefly outlined below:

The BSPZ programme seeks to improve teacher quality in schools through the establishment of organizational structures that sustain continuous staff development and the provision of cost effective instructional materials. The BSPZ has permanent district resource centres that are coordinated by a provincial Education Officer where already certificated teachers access instructional resource materials. The district resource centres mount regular cluster and district workshops that address teacher professional needs in various subject areas.

The SEITT programme was initially introduced to enable peer graduate 'A' Level teachers in the same geographical confinements to staff develop each other in order to improve the quality of their teaching. The SEITT resource teachers who received two-year part time training at the University of Zimbabwe provide "in-service education of their peers through among other things organizing and running subject centred workshops for teachers" (Mtetwa, 2003: 77). In the BScEd/(B.Ed) programme teachers who posses Certificates or Diplomas in Education from initial teacher education at a teachers' college and who meet entry qualifications for undergraduate studies, are admitted at a university to upgrade their subject content and some professional areas on a full time basis to graduate level.

1.8 The research problem

Most student teachers from Bindura University of Science Education (BUSE) on school attachment show a tendency to praise rather than objectively reflect on their teaching practice. Similar to findings by Frid, Redden and Reading (1998), where the student teachers made criticisms on their teaching, they usually wrote superficial and unconstructive post-lesson reflective texts. The student teachers' interpretations of personal practice are usually not discussed in the post-lesson reflective text because they avoid exposing their teaching challenges. They feel vulnerable to expose their teaching challenges in a post-lesson reflective text when they perceive the locus of control to be with assessors who may blame them for any instructional challenges exposed through reflection (Hatton & Smith, 2006). For instance, a common post-lesson reflective text reads:

> The lesson was successful. Almost all the objectives on finding the solutions of simultaneous
> linear equations involving two variables were achieved. Time management was good since all
> work planned was covered. Classroom management was good because learners did not misbehave
> throughout the lesson (Post-lesson reflective text: Pre-service mathematics teacher, January 2004).

It can be deduced from the above post-lesson reflective text that the success of the lesson is based on covering the content that was planned. Achievement of objectives is simply construed as completing work planned and not learner understanding. Quietness of learners during instruction is portrayed as evidence of good classroom management. These conclusions are technically made without realizing that mere covering of content in a lesson may not guarantee learner

understanding or achievement of the lesson objectives. In a similar way, lessons in which learners are encouraged to argue amongst themselves might have a certain level of noise that is regarded as conducive to learning by those who value learner negotiations of mathematical knowledge. Those who believe that the teacher cannot teach without controlling everything that goes on in the class might consider such noise undesirable. In the absence of a critical analysis of the level of effectiveness of pedagogical preferences, decisions, actions, outcomes, and intervention measures designed to improve subsequent teaching; the post-lesson reflective text does not show professional and developmental insight that emerge from the lesson taught.

Reluctance to analyze and expose their instructional failures and making provisions for overcoming them, made some student teachers conceptualize reflection on their teaching as a kind of non-critical lay activity (Hobson, 2003). The non-critical lay activity was portrayed in some of the student teacher presentation of post-lesson reflective texts that were not critical, because they merely described what they thought or what they observed and failed to raise relevant issues that could help them utilize the experiences gained in lessons they taught to improve subsequent teaching (Ramasamy, 2002).

The post-lesson reflective texts that some student teachers wrote do not seem to go beyond remembering and narrating observable incidents noticed during teaching. Similar to observations by Hall (1997) in Australia, the texts written by some student teachers from BUSE lacked interpretations of learner behaviour that facilitated understanding of implementation strategies of theories learnt in teacher education. The post-lesson reflective texts that were written without reflecting on the effectiveness of the decisions and actions made during teaching and commenting on the learning contexts, cast doubts on the student teachers' ability to critically reflect on their teaching in ways that have potential to improve their subsequent teaching.

Reflection is critical when there is a conscious willingness by a student teacher to identify some strengths and weaknesses of their teaching practice and a desire to change some aspects of it (Daniels & Feltham, 2004 cited by Lillyman, 2006). Inability to critically reflect on their teaching was not peculiar to some student teachers at BUSE. In the United States, Hatton and Smith (2006), and Freed-Garrod and McNaughton (2005) also observed little evidence of student

teacher critical reflections on their teaching. Hoffman-Kipp (2003) also concluded that in the United States the majority of student teachers' reflections focused on conformity of instructional practice with learner achievement of predetermined lesson objectives. This resulted in reflections that were not critical of the student teachers' teaching practice.

A common conclusion that may be made from the post-lesson reflections written by some student teachers is that there is little evidence of critical reflection on their teaching. This is despite acknowledging that that learning to teach requires a critical analysis of events that occur during teaching and an understanding of the rationales for their occurrence. Furthermore, there are few researches that have investigated whether student teachers show evidence of reflection in their talk about their teaching (Williams & Watson, 2004).

A number of researches on student teacher post-lesson reflective discussions with supervisors after lesson assessment have shown little student teacher reflection because the reflective discussions are usually dominated by assessor talk (Nyaumwe, 2001; Williams & Watson, 2004). For student teachers to critically reflect on their teaching they need to engage in reflective dialogues in which nobody dominates the discussions. This study contributes to research on a strategy that provides equal opportunities to student teachers and their critique to reflect on each other's teaching. The study assesses the extent to which student teacher collaborative reflection of personal teaching practice with a peer enhances the development of professional skills to critically reflect on their teaching. The assessment is guided by the research question: *How can collaborative reflection with peers enable secondary school mathematics student teachers to critically reflect on their practice and positively influence their cognition and decision making during instruction and post-lesson reflective dialogues?*

1.9 Context of the study

The problem of the study was answered using the context of student teachers studying undergraduate mathematics in a BScEd degree programme at BUSE. The university, established in March 1996, aims at producing science teachers who can actively participate in the development and diffusion of scientific knowledge through inculcating science process skills in learners that enhances Zimbabwe's capacity to achieve scientific and technological development.

Students with two 'A' Level passes in science subjects are enrolled for a four-year concurrent professional and content pre-service BScEd degree programme. Teachers holding diplomas/certificates in education can enrol for a two-year full-time in-service course that upgrades their content and professional knowledge to teach at high school.

In the four-year BScEd degree programme, pre-service teachers study two science subjects in the first two years and proceed with one major subject in the third and fourth years. An integrative approach of content, pedagogy and school attachment throughout the four years of study enables pre-service teachers from BUSE to combine the technicalities and complexities of teaching theory and practice. The pre-service teachers go for one-month school attachment during vacations of each of the first three academic years of the programme. In the fourth year, they go for twelve weeks of school attachment during the first semester. During the fulltime part of their programme, in-service teachers enrolled at BUSE attend the same content courses with pre-service teachers. The in-service and pre-service student teachers attend different professional courses. This set up was based on the assumption that the student teachers have the same requirements for content but different needs on professional knowledge. The in-service teachers go for four weeks of teaching practice during the long vacation in the second year.

During the theoretical part of their teacher education programmes, the student teachers were acquainted to the collaborative reflection with peers (CRP) framework that is described in section 2.6.0. They practiced implementation of the CRP framework in miniature classrooms during peer teaching before they went out on full-time teaching practice.

1.10 Motivation of the study

Teaching mathematics increasingly requires teachers to go beyond technical competence to include responding to a host of issues emanating from the ecology of education that change from teacher-centred to learner-centred teaching methods. Teaching mathematics is a complicated enterprise that requires wise choice of resources, suitable pacing and sequencing of content, creating classroom environments that promote learner participation, challenging and extending learner thinking (Even, 2005). To adequately prepare teachers who can meet the challenges created by the complexity of classroom environments, teacher education programmes should

produce mathematics teachers who are self rejuvenated through learning from self-practice and that of others. This is the essence of this study. The study was motivated by a need to: (a) reform the current teaching practice model at BUSE, (b) develop and test the effectiveness of the CRP framework to guide collaborative reflections of student teachers and their peers. The extent to which the framework enabled secondary school mathematics student teachers to critically reflect on their teaching and influence positively their cognition and decision making during instruction and post-lesson reflective dialogues was also analysed. Each of these motivations is briefly described below:

1.10.1 Reforming teaching practice model

Reforming the current school attachment model used by BUSE where experienced teachers coach student teachers the craft of teaching is necessary if the teacher education programme offered by the university is to "adequately prepare mathematics teachers for the present and future conditions and needs of learners" (Hea-Jim, 2001:1). Student teacher learning to teach requires analysis of events that occur during teaching and understanding of the rationales for their occurrence. This understanding increases reinforcement of favourable instructional outcomes, avoidance of undesirable instructional outcomes, and designing intervention measures that facilitate improvements in future teaching.

Teaching practice reforms that inculcate in student teachers a sense of self-assessment that can lead to better teaching practice are appropriate to produce effective teachers. A teaching practice model that emphasizes teacher self-assessment is influenced by research that suggests that reflection enhances teacher effectiveness (Loughran & Russell, 1997; Monyatsi & Nleya, 2004; Ramsey, 2000). Development of self-assessment skills entails equipping student teachers with professional knowledge and skills to reflect on their decisions and actions during teaching when they decide to deviate from the practices of experienced teachers. Student teachers need assistance to reflect on their implementation of pedagogical theories in the classroom.

1.10.2 Development of a framework to guide student teacher reflections

A possible strategy to enable student teachers to critically reflect on their teaching might be to encourage them to use a CRP framework to guide their post-lesson reflections. A CRP framework might guide student teachers to reach deeper and more critical levels of reflection.

Golvez-Martin (2003) revealed that student teachers reached higher levels of understanding how to implement pedagogical strategies when addressing issues related to teaching and learning with guidance from peers. A CRP framework might enable student teachers to analyse aspects of their teaching that they usually ignore and provide them with opportunities that might promote the development of critical reflection on their teaching. Critical reflection might enable student teachers to adapt mathematical concepts and pedagogical strategies that suit learner cognitive needs and interests rather than learners adapting to mathematical concepts and teaching strategies used by student teachers. A framework that guides student teacher reflective actions on their teaching is necessary if they are to reach higher levels of reflection that they can possibly reach.

A framework for guiding student teachers to critically reflect on their teaching without canvassing for good grades cannot be realized on the drawing table alone. The drawing table cannot determine and address the diverse contexts of schools, problems student teachers encounter when using the framework to reflect on classroom incidents and the broad intricate issues that they face when they implement it. Interactive cyclic development and implementation of a CRP framework might provide approximations for successive ideal situations for evaluating the extent to which reflection with peers helps student teachers to critically examine the efficacy of their assumptions of the nature of mathematical knowledge, how they teach, and how students learn mathematics in a manner that facilitates learning from personal and peer practice. The above motivations of this study have potential to make contributions to the improvement of teaching practice models used at BUSE and elsewhere.

1.11 Expected contributions of the study

Knowledge of the extent to which the CRP framework can guide student teachers to reflect on their teaching might provide insight into how they develop pedagogical reasoning, and change their conceptions of mathematics teaching. The knowledge might also provide insight into how student teachers implement teaching plans made collaboratively and appreciate that teaching is a continual professional learning process that improves with each lesson taught through critical reflection.

The use of a CRP framework to guide student teacher reflections may minimize the possibility of liability of inexperience in several domains of teaching knowledge that some of them hold such as pedagogical content knowledge, knowledge of learners, and knowledge of the teaching milieu (Shulman, 1986). The availability of such a framework might make significant contributions to attempts that seek to improve student teacher teaching practice programmes. A teaching practice model that involves post-lesson reflective dialogues with peers may significantly increase the capacity of student teacher experimentation with new pedagogical strategies and make critical reflections that can improve implementation of learner-centred pedagogical strategies. This is possible because peers have the potential to help each other to make reflections on their teaching problematic in non-threatening and non-judgmental ways. Such atmospheres might enable student teachers to learn from their own teaching and that of their peers.

1.12 Delimitations of the study

This study was confined to the development, implementation, and evaluation of a CRP framework to guide student teachers to reflect on their teaching using the context of BUSE student teachers. Case studies of student teachers that practice teaching in natural school settings offer empirical evidence, theoretical articulation and contexts in which an assessment of the effectiveness of the CRP framework was made. The case studies were limited to mathematics student teachers who attended formal undergraduate courses in mathematics content and pedagogy at BUSE. This conclusion was made after realizing that it was difficult to organize sporadic, short-term staff development activities in skills that in-service teachers lacked in order to perform their professional duties effectively in specific school settings. The difficulties arose in identifying professional weaknesses of teachers' practices and attracting them for staff development programmes that were followed by formative evaluations of the degree to which they mastered the new intended skills in natural school contexts.

The influence of experienced teachers on the development of professional skills of student teachers on teaching practice is recognized but does not form part of the present study. In order to provide a common understanding of the terminologies used in the study, the contexts in which some words were commonly used are explained below:

1.13 Frequently used words

A **peer** is a fellow student teacher practicing to teach at the same time as they are helping a colleague to improve their teaching practice.

Cognitions are the mental processes involved in acquiring new knowledge

Cognitive needs are the knowledge that are required by individual learners to perform specific mathematical operations

Collaborative reflection with peers (CRP) is a confidential relationship between at least two student teachers who collectively reflect on their teaching and share ideas on how to improve it.

Conceptions are the personalised ideas and imaginations that are held by a teacher or learners about the nature of mathematical knowledge and how it is mastered.

Constructivism is a theory of knowledge acquisition with roots in philosophy, psychology and cybernetics that view mathematical knowledge and reality as having no objective or absolute value.

Instrumentalism is the belief that mathematics is a fixed and sequential body of knowledge that is effectively learned by rote, algorithmic and repetitive procedures.

Open assessment is the freedom of at least two people observing the same lesson to use their personal understanding of instructional practice in order to capture a wide range of instructional abilities viewed from different angles without using a standard assessment instrument.

Openness is the willingness to submit oneself to self-criticism and criticism by others

Pedagogical reasoning is figuring out possible learner misconceptions, their possible sources, and deciding on how to help learners to overcome cognitive obstacles associated with the learning of a concept.

Post-lesson reflective text is a post-lesson audit that depicts the extent to which a lesson was conducted with the aim of improving the instructional skills of a student teacher.

Professional development is the acquisition of "interrelated whole of knowledge, insights, attitudes, and repertory of teacher needs that is required for the day to day adequate practice of teaching in a given school environment" (Vonk & Schras, 1987: 97).

Reflection is the active, persistent and careful consideration, speculation and contemplation of teacher beliefs and knowledge systems that lead to professional development, growth and greater understanding of the self and the profession (Opitz, 2003).

Student teacher is a collective name for pre and in-service teachers on school attachment.

Tacit skills are the professional skills that teachers acquire through practical experience in the classroom that ensues from the complex dimensions of teaching.

The **formal educational system** in Zimbabwe is summarized below with emphasis on how two different groups of teachers are trained.

Table 1: Levels of formal education in Zimbabwe

Age	3 4 5	6 7 8 9 10 11 12	13 14 15 16 17 18			19 20 21 22^{+}
Education level	Pre-school	7 - year primary school	6 - year secondary school			Tertiary education
Sub-levels			2 – year ZJC	2 - year 'O' Level	2 - year 'A' Level	Higher Education. Universities.
Prospective careers					Vocational. Diploma in teaching	Polytechnics. Vocational. Diploma in teaching.

ZJC- Zimbabwe Junior Certificate; 'O' Level- Ordinary Level and 'A' Level- Advanced Level

Learners may study for a diploma in teaching after successfully completing 'O' or 'A' Level.

1.14 Summary

Chapter One discussed teacher professional development as the area of study of this investigation. The chapter discussed the research problem, some teacher professional development programmes, student teacher programmes in Zimbabwe, the research problem, the context, motivation, expected contributions, delimitations and frequently used terminologies in the study. Chapter Two surveys the literature on teacher professional development, conceptual meaning and usefulness of reflection in order to draw insight for designing the collaborative reflection with peers (CRP) framework from available models of reflection.

CHAPTER 2: LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Chapter overview

The purpose of this chapter is to expose the literature that informed this study and develop the theoretical framework that guides it. The chapter begins with analysis of literature which shows the complex activity of teaching, showing that it is a profession with continually changing knowledge bases. Two strategies of teacher professional development of learning communities and mentoring are examined. Their weaknesses as approaches to teacher professional development in the context of Zimbabwe are highlighted. These weaknesses are amplified by case studies conducted before the main study. The importance of the notion of reflection-in-action with continually challenging knowledge and reflection-on-action in the overall development of reflective practice of student teachers are discussed. The theoretical framework shows the evolution of the collaborative reflection with peers (CRP) framework from previous models of reflection. The CRP framework is presented as a viable model to augment current professional development models of student teachers. The chapter ends with a review of the important characteristics of the CRP framework.

2.2 Complexity of teaching

Teaching mathematics is a complex enterprise (Even, 2005; Freed-Garrod & McNaughton, 2005). To reduce the complexity student teachers need a specific type of knowledge that Shulman (1986) called pedagogical content knowledge (PCK). PCK enables student teachers to reduce mathematical content to levels that are comprehensive to learners. PCK also helps teachers to identify and correct learner alternative conceptions, be skilful in posing challenging questions, listen carefully to learner ideas, rephrase learner explanations in cognitive mathematical language, decide appropriate times when to provide information, let learners struggle or orchestrate learner discussions (Peressini, Borko, Romagnano, Knuth & Willis, 2004). Beyond procedural and conceptual understanding of mathematical knowledge student teachers need wisdom to carefully choose learning materials, design learning environments, determine

appropriate paces of instruction, challenge and extend learner thinking, and choose pedagogical strategies that suit student learning styles (Even, 2005).

Teaching is therefore not just a technical craft where teachers use predetermined sets of rules to apply to any given classroom situation. It requires professional artistry that depends on the nature of the content, context of learning and learner needs (Bryan, Abell & Anderson, 1996). Learners in mathematics classrooms possess varied combinations of cultural and socio-economic backgrounds, prior knowledge, experiences, motivations, interests, cognitive and social development, among others. Teaching them effectively requires more than teacher competencies in systematically performing a series of standard classroom practice skills such as pedagogical, management, planning, assessment and communication skills. It requires wise choice of resources, designing appropriate learning environments, adapting suitable paces to cover content, determining logical sequence of concepts, and setting challenging questions, conducting discussions, and designing appropriate activities that extend learner thinking (Even, 2005). In addition to a good mastery of content and knowledge of the curriculum, teachers need abilities and dispositions to utilize diverse but related sources of knowledge through inquiry and reflection in order to effectively conduct the enterprise of teaching (Steele, 2005). Effective teaching demands from teachers, a myriad of knowledge and skills for continually reflecting on their instructional practice.

2.3 Reflection

Dewey (1910) first noted reflection as a means of knowing from experience. Dewey recognized that learners need to be involved, not only in doing but also in considering knowledge for doing (Birkenhead & Stevens, 2004). Reflection is the means through which student teachers can understand their instructional practice through a critical analysis of what happens, why it happens, and what they could do differently to improve their teaching performance (Galvez-Martin, 2003). It involves the analysis, questioning, theorizing, critiquing and formulating instructional practice that enhances understanding of various pedagogical theories and a commitment to personal and professional development. Further, reflection enables student teachers to become both scholars and artists who can inspire in learners a passion for learning.

Being a scholar and artist involves active inquiry, imagination and discovery, use of intellect, creativity, interpretation, judgment, self awareness and awareness of learner needs. Reflection provides lenses that portray instructional knowledge as tentative, contextual, and eclectic, and is constructed from multiple points of views (Ovens, 2004). This necessitates a shift from a traditional position where scientifically derived knowledge was perceived as correct and unquestionable, to accepting that artistic and intuitively generated knowledge has a claim to being equally appropriate (Smyth, 1989). The acceptance of artistic and intuitively derived knowledge as legitimate, nurtures intuition, creativity, improvisation and expressiveness. It also involves judgment, insightfulness, and sensitivity that integrate understanding, knowledge, teaching, learning and their relationships. This integration is never complete because reflective inquiry oriented student teachers engage in life long learning to continuously invent their instructional practice. Through reflection, student teachers make conscious ethical and pedagogical decisions that are grounded in their instructional experiences and that of others.

Schon (1987) portrayed reflection that is embedded in action. He holds that teachers frame and reframe their teaching, test various interpretations that they get from the context of teaching and modify their actions accordingly. Reflection on one's teaching cultivates a thoughtful and evaluative analysis of the many factors that affect teaching, learning, and schooling. For the life long professional development of student teachers, teaching practice should offer an opportunity for them to develop and nurture their reflective practice skills so that they can continuously evaluate their teaching throughout their teaching years. Learning from one's practice through reflection in the light of learner needs improves student teacher instructional practice with each lesson taught rather than the number of teaching years (Mtetwa & Kwari, 2003). Schon (1987) perceived teacher reflections as taking place during and after teaching, calling them reflection-in-action and reflection-on-action respectively. Each of these reflections is briefly explained below.

2.3.1 Reflection-in-action
Reflection-in-action refers to the process of interpreting, analyzing and providing solutions to teaching problems at the time they are happening (Schon, 1987). It involves looking at a teaching experience as it unfolds, assessing the level to which it is effective in terms of learner understanding and attending to theories-in-use. Theories-in-use are the theories that are implicit in what teachers do as practitioners, that is, the knowledge-in-use or mental maps with regard to

how to act during teaching (Smith, 2001). Argyis and Schon (cited by Smith, 2001) argued that teaching actions are determined by mental maps or knowledge-in-action and not by pedagogical theories. During reflection-in-action student teachers use mental maps to consciously think about a teaching action or learner outcome at the time it is happening, make sense of what is taking place, and shape successive instructional steps using multiple viewpoints as appropriate. It entails building new understanding to inform actions in the situation that is unfolding. Reflection-in-action is an epistemological perspective of seeing possibilities for teaching actions in order to enhance learner understanding. It consists of experimenting with pedagogical theories to discover their practical consequences and implications. The experimenting allows student teachers to create teaching problems to be solved and instructional opportunities to be exploited in order to understand pedagogical strategies (Schon, 1983).

Learning of student teachers to teach is usually a trial and error process that involves the detection and correction of errors in judgment, strategies, or implementation of pedagogical approaches. When an error is detected during teaching, a starting point for most student teachers is to use their knowledge-in-action to choose another strategy that appears appropriate to address the error within the learning context. Implementation of the new strategy consciously generates new understanding that informs student teacher actions in the instructional context unfolding. This facilitates reflection-in-action to get directed toward making the implementation of a pedagogical approach more effective. After teaching a lesson student teachers retrospectively look at their teaching practice through reflection-on-action to review the extent to which their teaching was successful.

2.3.2 Reflection-on-action

Reflection-on-action involves thinking in retrospect on what a student teacher has done during an instructional episode to assess how knowing-in-action produced intended or unintended learner outcomes. It takes place when a student teacher has left an instructional arena and mentally reconstructs that arena to analyze actions and outcomes. It involves analyzing, questioning, theorizing, critiquing and (re)formulating or (re)constructing instructional actions. The insight derived from reflection-on-action makes it possible to evaluate the effectiveness of instructional theories, decisions, or activities organised for a lesson. During reflection-on-action student teachers spend some time exploring the rationales for their actions and learner responses to the

actions. This provides student teachers with insight on choices for decisions, pedagogical strategies, and activities that provide an understanding of their teaching practice through a commitment to personal and professional growth. The commitment is expressed through an ongoing examination of their judgments, pedagogical knowledge, beliefs, and sensitivity to interweave theory with practice necessitating one to become a reflective practitioner.

2.3.3 Reflective practice

Basically, reflective practice combines reflection-in-action and reflection-on-action. It requires a student teacher to interrogate instructional encounters with a goal of being self-critical in order to encourage self-growth on an on-going basis. It involves a student teacher's self-understanding of their teaching practice through a commitment to personal and professional growth. The commitment is expressed through a continual examination of pedagogical knowledge, beliefs, and classroom practice and the purpose of education within school and national contexts.

2.3.4 Levels of reflection

Teachers reflect on their teaching practice but differ on the levels of their reflections. Three levels of reflection are often used to monitor the progression and growth of student teacher reflections (Hall, 1997; Hatton & Smith, 2006; van Manen, 1977). In order of hierarchy of sophistication, van Manen (1977) called the levels of reflection; technical, practical and critical reflections. Hall (1997) named them fleeting, deliberate and systematic reflection whilst Hatton and Smith (2006) called them descriptive, dialogic and critical reflections.

Van Manen (1977) developed a three level framework for monitoring the progression of student teacher reflections. At the lowest level is technical rationality, followed by practical action. Critical reflection is the most sophisticated reflection level. At the technical rationality level student teachers consider the technical applications of pedagogical approaches and basic curriculum goals for the purpose of attaining some predetermined lesson objectives (Hatton & Smith, 2006). For instance, typical reflections at the technical level point out that "using discovery method in group work for learners to calculate the point of intersection of a line [$\mathbf{r} = 5\mathbf{i} + 5\mathbf{k} + \lambda(2\mathbf{i} + \mathbf{j})$] and a plane [$\mathbf{r}.(\mathbf{i} + 2\mathbf{j} + 2\mathbf{k}) = 11$"] (post-lesson reflective text: In-service teacher; February 2004). If some groups successfully find the point of intersection as required, a

conclusion to the effect that the objectives of the lesson were achieved is made without reflecting on the efficacy of the pedagogical approaches used.

At the practical action level a student teacher is concerned with clarifying assumptions underlying competing pedagogical goals while assessing the educational consequences of a teaching action. An example is a text statement: "allocation of more time could have enabled learners to debate whether two is a prime number so that learners could help each other to clarify their alternative conceptions of prime numbers rather than given a definition" (Post-lesson reflective text: In-service teacher; January, 2004). In this reflective statement, social construction of the concept of prime numbers is competing with formalist and constructivist conceptions of how learners comprehend mathematical concepts. The student teacher's formalist conception of providing formal definitions to learners competes with the constructivist conception that it helps learners to expose and debate their misconceptions on the concept of prime numbers.

At the highest level of critical reflection student teachers are non-defensive, are open minded to moral and ethical considerations of educational processes. To achieve critical reflection level student teachers assess the strengths and weaknesses of a lesson, effect possible changes, provide possible reasons for the way the lesson went, think of unanticipated learning that occurred, provide suggestions for alternative pedagogical approaches, and consider the value of content covered to learners and moral and ethical concerns that occurred in the lesson (Pultorak, 1993 cited by Hatton & Smith, 2006). By highlighting weaknesses of a lesson and considering moral and ethical grounds for giving learners a problem, a student teacher can be viewed as reflecting at critical reflection level although some aspects of the characteristics to critical reflection identified by Pultorak (1993) may be missing. For instance, consider the following reflective text:

> The use of weather patterns in the introduction was effective in providing learners with a concrete picture of chances in their environment. The practical example helped learners to link chances and the concept of probability. From the set {1, 2, 3, 4, 5, 6} I should have asked learners to list the subsets of prime factors, odd and even numbers, and multiples of 3 as well as the probabilities of getting each subset. My demonstrations trivialized the examples because they were too easy for "A" Level learners. Where learners asked questions I should have thrown back the questions for them to answer (Post-lesson reflective text, Pre-service teacher: October 2004).

This post-lesson reflective text shows a critical analysis of pedagogy and interests of learners. The post-lesson reflective text highlights pedagogical errors such as providing learners with answers instead of throwing back questions to learners to answer. Throwing back questions to learners had potential to encourage learner debates.

Hatton and Smith (2006) characterized the levels of reflection in a manner similar to van Manen (1977). They named the three levels of reflection; descriptive, dialogic and critical. At the descriptive reflection level student teachers describe the events of a lesson and provide some justifications for events and actions in a descriptive way. For instance, part of a student teacher's reflective text reads "allowed learners to conduct some experiments with a deck of playing cards in order for them to answer questions on probability in an active manner" (Post-lesson reflective text: In-service teacher, February, 2004).

Characteristic of dialogic reflection is discourse with self in exploring the experience, events and actions that occurred in a lesson using qualities of judgment and possible alternatives for explaining and hypothesizing them. This is illustrated in this extract; "use of problem-solving strategies made me aware that learners experience difficulties to understand the language. I ended up explaining the problem to learners in ways that removed the block and made the solution strategy obvious" (Post-lesson reflective text: Pre-service teacher, October 2004).

Hatton and Smith (2006) viewed critical reflection as showing awareness that action and events are located and influenced by multiple historical and socio-cultural contexts. For instance, an extract from a student teacher's post-lesson reflective text stated; "learners failed to conceptualize a shear operation because of their lack of familiarity with the concept in its everyday settings. Using rubber bends on a geometer's pad could help learners to view shear operation that might help them to determine a shear factor and the invariant line" (Post-lesson reflective text: Pre-service teacher; March 2005). This type of post-lesson reflective text is typical from pre-service teachers who fail to provide appropriate activities or examples of the shear transformation using learners' environments.

Hall (1997) identified three levels of "reflectiveness" that she named fleeting, committed or programmatic reflection. A synopsis of each of these levels follows. At the lowest level of reflection of Hall's characterization is fleeting. Fleeting reflection does not go deeper than thinking, remembering or narrating what happened during instructional practice. For instance, as illustrated in the following extract: "the objectives of the lesson on the two methods of substitution and matrix method for solving simultaneous linear equations were not achieved. The learners were slow on using the matrix method resulting in them not attempting solutions by substitution" (Post-lesson reflective text: Pre-service teacher; September 2004). The post-lesson reflective text narrates what happened in the lesson without attempting to reflect on why learners were slow on using the matrix method to solve simultaneous linear equations.

Following fleeting is committed reflection. Committed reflection is centred on or about action and it may or may not contribute to development in instructional practice (Hall, 1997). The following extract illustrates this point; "the learners were encouraged to draw neat graphs using a sharp pencil in order for them to accurately read solutions of quadratic equations from the graphs they draw" (Post-lesson reflective text: Pre-service teacher; October 2004).

The highest level of reflection in Hall's characterization is systematic reflection. Systematic reflection takes place through action in projects that require a considerable amount of time and careful design such as action research projects.

The first two levels of reflection have the same conceptual characteristics for Hall (1997), Hatton and Smith (2006), and van Manen (1977), but use different names. While different names are used for level one reflection category (technical, fleeting, descriptive), they are in nature narrations or descriptive of the events encountered during teaching. Level two reflection category (practical, deliberate, dialogic) are predominantly on the learning experience and the consequences of instructional practices. Whilst van Manen, and Hatton and Smith concur on using the term critical reflection to denote the third level of reflection, Hall calls it systematic reflection. Critical reflection and systematic reflection are conceptually different. Critical reflection involves multiple perspectives that are located in, and influenced by, multiple historical

and socio-political contexts; while systematic reflection could be appropriate for funded large-scale projects such as action research projects.

Reflection of student teachers is conceptualized here as reaching three levels of sophistication. In the lowest category of technical or everyday reflection student teachers present their post-lesson reflective texts through narration of events that occurred during teaching. At the technical level, post-lesson reflective texts prematurely point out successes of lessons without justifications or evidences from teaching episodes. Several issues ranging from classroom management, learner achievement of objectives, pedagogical approaches, and lesson conclusion are mentioned without analyzing them in detail. Generally, the post-lesson reflective texts belonging to the technical reflection category are short but comment on almost all the stages in the detailed lesson plan. The student teachers do so using short sentences without providing evidence to support the conclusions proffered.

In the second category of reflection, practical reflection, the post-lesson reflective texts are deliberate in that student teachers reflect on the strengths and weaknesses of teaching episodes. The strengths and weaknesses of lessons are presented at uncritical level because there is lack of interpretive skills to explain learner behaviour or outcome in response to student teacher actions during teaching. The reflections at this level reveal student teacher desire to learn from personal teaching, but lack the openness to lay bare the weaknesses of a lesson in ways that can enhance the designing of intervention strategies that can improve teaching.

The highest category of reflection that can possibly be attained is systematic or critical reflection. In critical reflection student teachers are open to personal teaching that they expose the strengths and weaknesses of lessons taught. The sources of the strengths and weaknesses are interpreted in ways that permit the designing of strategies to improve subsequent teaching. Reflection at this level enables student teachers to identify critical incidences in a teaching episode and evaluate them with well-illustrated examples. In critical reflection suggestions to improve future teaching are made after considering their applicability, and implementation strategies are carefully described showing how teaching can be improved.

Power, Clarke and Hine (2002) reported that student teacher repeated exposure to reflection does not guarantee their achieving critical reflection category. This is so because they are usually pre-occupied with the processes of teaching that they often overlook the process of learning to teach. To facilitate student teachers' attainment of the critical reflection category, they need encouragement, support and challenges to develop their personal worldviews of teaching and learning to teach. Current models of professional development are analysed next with a view to showing the extent to which they enhance student teacher skills to reflect on their teaching.

2.4 Models for developing reflective skills in student teachers

Kirner and Lebrun-Griffin (2005) identified various models of professional development of teachers that include cohort/cadre, instructional planning, distance learning, mentoring, networking, peer coaching and reflective journaling. These models involve two major themes. First, professional development is enacted through dissemination of appropriate teaching skills from experienced teachers (mentoring), use of modules (instructional planning) or use of internet and other technologies (distance learning) to assist student teachers to acquire a variety of instructional knowledge and skills through human and written material. Second, the models propose student teacher development of instructional knowledge and skills through learning with their peers in cohort groups, networking groups and peer coaching communities. Two models of teacher professional development that Kirner and Lebrun-Griffin (2005) identified that are relevant to this study are mentoring and peer communities. These two models are discussed in detail below in order to evaluate their relevance to Zimbabwe.

2.4.1 Peer Communities of practice

The peer-coaching model involves a continuous growth process in which student teachers purposefully discuss, observe, and share experiences in communities of practice. Peer communities of practice facilitate student teacher development of professional knowledge and skills to reflect on each other's teaching and produce instructional practices that promote learner achievement of curriculum goals. Student teacher development of repertoire of instructional skills through communities of practice enable them to examine, explain their pedagogical reasoning to others, learn from peer experiences, and reflect on unexpected outcomes (Even, 2005).

Vygotsky's (1978) co-construction theory asserts that knowledge is internalized, appropriated, or transmitted in formal and informal settings. In extending the thesis of co-construction theory Wenger and Snyder (2005) developed a community of practice model. Wenger and Snyder argued that in life people do not only learn from individual experiences but also from the experiences of others. Experiences from others are transmitted through relationships and assimilations in social interactions that are enhanced by affiliation and membership to groups that accept and guide what members bring and willingly share. Learning occurs consciously or unconsciously in social contexts. For instance, acquisition of the first language at infancy occurs through membership of a family to a particular society that speaks a specific language. While parents teach an infant to speak their native language, most of the words an infant learns are mastered through playing with peers in the vicinity of the infant. Learner participation in group activities is more powerful than individual learning of specific skills. This argument reinforces the fact that communities of practice are more powerful to develop knowledge and skills to their members than learning the knowledge and skills in formal settings. Analogously, the valuable knowledge and skills of teaching as an artistic and tacit profession cannot be only learnt in teacher education programmes, codified in documents or explained in formal settings, but can best be acquired in communities of practice.

A community of practice is a group of people who are willing to share their experiences and passions about a topical issue of interest and voluntarily interact on a regular basis to further develop their understanding of the issue (Gomez, 2000; Wenger, 1998). In learning communities student teachers can help and support each other to improve understanding of content and pedagogical theories and how to apply them in practice. For instance, in Zimbabwe, the Science Education In-service Teacher Training (SEITT) programme creates communities of practice of teachers in the same province to work in clusters, districts and at provincial level to help each other to improve the quality of their teaching. The Science and Mathematics Centres (SMCs) are housed at centrally accessible provincial cities in order to provide venues for teachers in a province to discuss professional areas of need. The SMCs keep various educational resources that are used during workshops that are regularly organised to address teacher-identified content and pedagogical areas of instructional weaknesses.

A community of practice like the SEITT programme is capable of serving a number of valuable purposes. Among the services of a community of practice are provisions of support and friendship, helping each other to locate materials to implement specific pedagogical strategies or reform, learning vicariously from one another's experience and collaboratively planning for lessons. The goal of engagement in a community of practice is the production and dissemination of professional knowledge of value to peers and building understanding of the knowledge among each other, rather than demonstrations of individual member achievements or competency. Typically, members in a community of practice solve instructional problems, discuss insights for handling classroom situations, reflect together on lessons taught, coach each other and develop resource materials and frameworks that become common knowledge of the community (Wenger & Snyder, 2005).

Membership to a community of practice is voluntary and members are attracted to the community by the professional activities and benefits they collaboratively gain together. A community of practice defines itself along three dimensions of mutual engagement, joint enterprise, and shared repertoire (Gomez, 2000; Wenger, 1998). Engagement involves the functions of the community through continual negotiation of meaning, formation of trajectories and unfolding of histories of practice. Enterprise involves the continual negotiations of the purposes of the community by members and shared repertoire is the communal resources produced by a community over time.

A community of practice does not emerge spontaneously and exist forever. It develops through some five phases that can form a normal curve (Wenger, 1998). At the formation stage is the Potential phase. At the Potential phase student teachers face similar school situations. Activities in this phase are that of identifying each other and discovering commonalities. At the Coalescing phase student teachers come together and identify their potential. Their activities at this phase are those of exploring connectedness and purposes for forming a community. At the climax, is the Active phase where student teachers engage in developing their professional repertoire. They engage in joint activities, adapt to changing circumstances by renewing interest, commitment and relationships.

The anticlimax starts with the Dispersed phase where the student teachers in a community of practice no longer engage actively but the community still exists as a force and source of knowledge. The student teachers remain in touch, communicate, and call for advice. In the last phase of Memorable, the community is no longer a central source of advice. Members still remember it as a significant part of their professional identities. They tell stories and preserve artefacts from the community of practice.

Mathematics student teacher active participation in communities of practice was hypothesised to be an effective strategy for their professional development (Gomez, 2000). Teacher communities of practice facilitate the development and sharing of a body of knowledge gleaned from their experience in ways that enhance innovative teaching practice that can improve learner performance. Communities of practice help to remove the insecurity towards change that some student teachers sometimes experience, making them willing to change their practice in light of reform demands and their teaching, and developing potential to become generative.

The numerous benefits inherent in student teacher communities of practice may be reduced by the weaknesses that are possible in the orientation. Development of communities of practice may not occur in the linear form delineated by Wenger (1998) above. Identifying each other and discovering commonalities at the Potential phase may not be easy to achieve if student teachers are not free to expose their instructional needs, or lack the willingness to help each other. Unwillingness to help each other to identify potential strategies that might reduce identified student teacher areas of weaknesses may render the activities of a community of practice ineffective. The nature of relationships that develops between student teachers in a community of practice also influences the successes at the Potential phase. Communities of practice where student teachers and peers are willing to expose their teaching weaknesses have potential to improve reflection on pedagogical strategies in ways that enhance development of rich and powerful understanding of instructional practice.

A community of practice of student teachers and their peers involved in the development of reflective skills is influenced by social constructivist theories that advance the learning process of how to teach as an active phenomenon in social settings characterized by debates and

negotiations. For instance, Vygotsky's (1978) co-construction theory emphasised co-participation, cooperative learning and joint discovery in which student teachers and their peers co-construct pedagogical knowledge together. Student teacher and peer social construction of teaching strategies in communities of practice can allow them to learn from, and value the existence of each other. This might enable them to construct their own teaching styles in active ways that may facilitate the development of talents and competencies in teaching. Peer assistance in communities of collaborative reflection can provide student teachers with support and insight that are necessary to creatively solve instructional problems in non-threatening ways. Effective student teacher and peer communities of practice can facilitate the development of pedagogical content knowledge through discourses that stimulate critical and creative thinking of classroom situations and how learners learn mathematics in ways that may promote continuous social construction of teaching knowledge. A community of practice that engages experienced teachers and neophytes in typical school situations is mentoring.

2.4.2 Mentoring

Effective mentoring programmes pair an experienced teacher with a student teacher so that the former can provide the latter with regular coaching and feedback that are essential for student teachers to know areas they are doing well in or need to improve on. In such programmes, mentors provide a dynamic reciprocal relationship with student teachers that promote the career development of student teachers by reflecting on their pedagogical approaches in efforts that seek to improve their teaching practice (Vonk, 1993). Successful mentors possess instructional competencies, commitment to the profession, and relational skills (Chen, 1993). Such mentors use their tried and tested teaching experience to handle different classroom contexts that they use to guide student teachers to turn mathematical content into teachable units that are comprehensive to learners. The mentors act as model teachers who demonstrate to student teachers how to teach certain concepts or how to implement certain pedagogical strategies using the contexts of schools. They offer constructive criticisms in non-threatening ways on how well student teachers are coping with teaching.

In efforts to develop reflective practice of student teachers, an eclectic mentoring model that utilizes the merits from other models is used (Hayward, 1997; Nyaumwe, 2001). The use of an eclectic mentoring model is a strategy to nurture open-ended inquiry that makes student teachers

reflect on their teaching in ways that make learning to teach a life long process that forms an integral part of their continual professional development. An eclectic mentoring model allows student teachers to imitate the skills and artistry of reflection through observing mentor teaching. It also allows student teachers to reflect on their decisions and actions with other teachers in a school, as well as challenging the conceptions they hold concerning mathematics teaching and learning after testing them during teaching. But mentoring in the context of Zimbabwe has some implementation weaknesses.

2. 4. 3 Weaknesses of the mentoring orientation in Zimbabwe

Mentoring at secondary schools in Zimbabwe suffers from several weaknesses. It is sometimes not effective to develop the professional skills of student teachers to reflect on their teaching because mentors are not trained or supplied with a blue print on how to conduct their professional duties (Mavhunga, 2004). As in Botswana, (Monyatsi & Nleya, 2004), mentoring in Zimbabwe is sometimes not effective to equip student teachers with effective teaching skills because some mentors were merely experienced classroom teachers without the capacity for training other teachers. The mentors figured out on their own how to guide student teachers attached to them.

Some of the mentoring implementation challenges in Zimbabwe emanate from attachment schools not clearly understanding the concept of mentoring, mentors not aware of their roles and lack of coherence between attachment schools and teacher education institutions (Nyaumwe, 2001). Lack of coherence between training institutions and attachment schools makes mentors not aware of the pedagogical theories that student teachers are encouraged to implement in their teaching. These implementation problems make some mentors unable to coach student teachers some professional skills such as reflective teaching. Reflective teaching is a tacit skill that is usually difficult for mentors to coach alone because it involves a critical evaluation of the implementation and applicability of pedagogical strategies that student teachers are encouraged to implement, rationales for decisions, and actions mentees make during instruction (Nyaumwe, Mtetwa & Brown, 2005). Furthermore, some mentors and lecturers do not hold a common understanding of the standard of professional practice that student teachers should attain resulting in variations in assessment of teaching (Nyaumwe & Mavhunga, 2005).

Some criticisms levelled against mentoring arise from selection of appropriate mentors who are capable of enhancing student teacher reflection and learning how to teach through experimentation with pedagogical theories (Loughran, Brown & Doecke, 2001). For instance, some of the mentoring implementation flaws in Zimbabwe are difficult to reduce because teacher-training institutions have no influence on choosing mentors. This often results in some of the mentors to possess degrees in mathematics without teaching qualifications. Such mentors do not usually command respect from their mentees because the mentees feel that they posses stronger pedagogical base than the mentors (Nyaumwe, 2001). For example, mentors without teaching qualifications assiduously reflect with student teachers on observable issues of classroom management, differentiation, and management. They neglect critical issues of interpreting student teacher actions in the light of learner outcomes (Rodd, 1995). Such mentors would typically not analyze pacing and balance of content or reflecting on alternative mathematics teaching methods that might improve instructional practice. The mentors without adequate pedagogical backgrounds do not use educational theories from which to draw insights for rationales of decisions and actions, and interpreting their outcomes. An inability to link theory and practice by some mentors without adequate professional qualifications in teaching may curtail student teacher development to reach critical reflection category.

The mentoring model of developing reflective practice of BUSE student teachers in its present form needs revision in order to minimize weaknesses in it. Similar to findings by Zuzovsky, Feiman-Nemser and Kremer-Hayon (1998: 9) the mentoring model in Zimbabwe is criticized for conflating "institutional expectations with developmental assumptions and ignores the student teacher influence on the mentor action". Institutional expectations such as the need to complete the syllabus on time influence mentors to adopt quick demonstration methods in order to prepare learners for summative examinations when the content can be covered more conceptually using learner constructions. The need to prepare learners for summative examinations often make some mentors discourage student teachers from deviating from their patterns of classroom practice. For instance, some mentors encouraged student teachers to employ teacher-centred methods which tend to emphasize procedural learning of mathematical concepts. The student teachers who employed learner-centred methods were not "forbidden but met with little support, discouragement or even opposition" (Vonk & Schras 1987:107). Such moves curtail the

implementation of a variety of pedagogical approaches that student teachers could possibly trial test and reflect on their effectiveness to implement them. In such circumstances it is difficult for student teachers to implement and reflect on teaching practices that differ from those encouraged by their mentors.

Different views on the nature of mathematical knowledge that student teachers and their mentors sometimes hold "can be a source of resonance or dissonance" (Rodd, 1995: 234). This is possible because reflective discussions on instructional practice by teachers with different conceptions of teaching and learning mathematics have different focus on processes and outcomes of instructional practice. For example, student teachers with learner-centred views of teaching attached to mentors with teacher-centred views of learning are likely to come into conflict on reflection involving instructional decisions.

Some case studies are used to amplify the weaknesses of the current mentoring model of teaching practice used by BUSE. The three case studies were conducted during the first phase of the study in line with principles of development research that was used in this study.

2.5 Case studies on BUSE mentoring implementation strategies

Three case studies that are presented in this section were conducted by the author and colleagues to expose the gaps that are inherent in the teaching practice model used at BUSE. The case studies show student teacher perceptions of the mentoring model of teaching practice that they experienced (Nyaumwe, 2001), the impact of fulltime student teaching on pre-service teacher conceptions of mathematics teaching and learning (Nyaumwe, 2004) and mentor and lecturer assessment variations of pre-service teacher classroom practice (Nyaumwe & Mavhunga, 2005). Each of these case studies is briefly described below.

2.5.1 Pre-service teachers' perceptions of a mentoring model of teaching practice (Nyaumwe, 2001)

This study investigated BUSE pre-service teachers' perceptions of the mentoring model of teaching practice that they went through. The study focused on pre-service teachers' perceptions of the guidance that they received from their mentors to develop some professional skills. Forty-

four (44) final year pre-service teachers attending undergraduate studies at BUSE and 24 mentors provided data for this study. Questionnaire and reflective interviews showed that pre- and post-lesson reflective conferences with mentors enabled pre-service teachers to develop new insights into their lessons that improved their teaching practices. In the post-lesson reflective dialogues some mentors were hesitant to give as much professional guidance as they were capable of giving because they avoided contradicting teaching practices that the pre-service teachers were encouraged to adopt by their tutors. Some mentors were reluctant to have pre-service teachers sit in lessons that they were teaching. The study concluded that mentoring was a satisfactory way of coaching pre-service teachers into school practice, improved coherence between the university and schools, and pre-service teachers should be allowed to sit in lessons that mentors were teaching.

This case study showed that some pre-service teachers were not getting much professional guidance from their mentors because some of the mentors feared to contradict with the theoretical knowledge of the pre-service teachers. Failure by some mentors to use theoretical knowledge to interpret pre-service teachers' teaching during reflection had potential to reduce the opportunities of the pre-service teachers to critically reflect on their practice and influence positively their cognitions.

2.5.2 The impact of full-time student teaching on pre-service teacher conceptions of mathematics teaching and learning (Nyaumwe, 2004)

This study investigated the changes in conceptions of mathematics teaching and learning of BUSE undergraduate pre-service teachers after twelve weeks of full-time teaching practice. Written responses to open-ended questions administered at the beginning and end of full-time teaching practice were triangulated with interviews. The pre-service teachers exhibited more differences in conceptions of teaching than on learning mathematics. Learners' ages, class level, the nature of mathematical content and the need to match learner discursive skills with their achievement in written work influenced the pre-service teachers' pedagogical and epistemological beliefs. The pre-service teachers' changes in conceptions of teaching and learning resulted from needs to model pedagogical strategies and relate them to learners' mathematical understanding and dovetail their prior knowledge with content under review.

Some pre-service teachers used procedural assessment methods to defend their continued use of teacher-centred methods, when in fact self-doubts about their capacity to implement learner-centred pedagogical strategies could have been a stumbling block. On the other hand, pre-service teachers who taught 'A' Level classes preferred to use transmission methods because of the abstract nature of concepts at this level. Despite being attached to mentors, some pre-service teachers found it difficult to relate some 'A' Level concepts to activities in learners' environments. The limited link of some 'A' Level concepts with learner realities promoted the dominance of teacher-centred strategies and limiting learner explorations to construct them.

2.5.3 Mentor and lecturer assessments of pre-service teachers on teaching practice (Nyaumwe & Mavhunga, 2005).

The third case study investigated reasons for different mentor and lecturer assessments of BUSE mathematics and science pre-service teachers on teaching practice. The pre-service teachers' raw marks from mentors, lecturers, and the external examiner were triangulated with interviews in order to explore the variations in the assessments. A one-way Analysis of Variance (ANOVA) established a significant difference ($p < .01$) between mentors' and lecturers' marks but no significant difference between lecturers' and the external examiner's marks. Mentors and lecturers emphasizing different teaching methods and professional skills, having different relationships with the pre-service teachers, and having different standards for pre-service teachers' professional practice, caused the differences. These results can inform debate on strategies for assisting pre-service teachers to marry theory with practice whilst on teaching practice in ways that may allow the development of a synergy of professional skills.

Findings from this case study showed that lecturers and mentors encouraged pre-service teachers to implement different pedagogical strategies because they held different standards for student teaching. Differences between lecturers and mentors on professional standards and emphases on teaching strategies was used to conclude that the current teaching practice models used at BUSE are not effective in making pre-service teachers to combine theory with practice during school attachment

The professional weaknesses exposed by the case studies presented above may be reduced by allowing pre-service teachers and their peers to reflect on each other's teaching. Involvement of

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student teachers in collaborative reflection on lessons taught may reduce the theory-practice gap that currently exists in the teaching practice models used by BUSE. CRP has the potential to reduce the theory-practice gap because pre-service teachers and their peers posses similar pedagogical theories that they use to help each other to experiment with in their teaching. They also use similar standards of teaching to evaluate the effectiveness of their implementation strategies.

The weaknesses in the mentoring model of teaching practice can limit the full potential of student teacher achievement of a repertoire of professional skills. Using mentors alone to coach student teachers may make it difficult for some student teachers to build a flexible repertory of reflection on their teaching. This is possible because some student teachers do not receive sufficient assistance from mentors to order and structure their teaching experiences in the light of pedagogical theories they hold (Nyaumwe, 2001). Broadening the chances for student teachers to experiment with a variety of pedagogical strategies may facilitate reflection on their decisions, actions, and conceptions on mathematics teaching and learning. Student teacher experimentation with a variety of pedagogical strategies might bring new possibilities for seeing classroom practice from different angles making instruction in mathematics dynamic rather than static. To meet the multiplicity of demands that student teachers face when reflecting on their teaching necessitates that teaching practice undergo reform (Hapanyengwi, 2003; Ramsey, 2000) in order to fill the gaps in the present school attachment models.

Reforming the BUSE teaching practice model is one of the goals of this study. This reform utilizes student teachers and their peers in the development of each other's pedagogical knowledge and skills. This strategy is assumed to reduce the theory-practice gap currently in the mentoring model of school attachment used by BUSE. The literature review and the case studies discussed above provided insight that informed the theoretical framework that was used to reduce the weaknesses inherent in the mentoring model of teaching practice used by BUSE.

2.6 Towards addressing the gap

An open professional development model that encourages peers to augment mentor coaching of student teachers to plan, implement pedagogical strategies and reflect on teaching provided

insight that was used to help them to develop professional skills. An open professional model might provide student teachers and their peers with insight into reflecting on their teaching and how these reflections are conducted in atmospheres that facilitate experimentation with pedagogical strategies (Vonk, 1993). Such a model recognizes student teachers as self improving and innovative practitioners, who are capable of reflecting on their teaching with mentors and peers, react to learner needs and evaluate the outcomes of their interventions (Feiter, Vonk & van den Akker, 1995). Evaluations of outcomes of interventions suggested by peers might provide a learning exercise that makes student teachers analyze the grounds for success or failure of their intervention strategies so that reasons to act more appropriately in comparable situations are sought. Reflections on the reasons for successes or failures of lessons may lead to problematizing and problem-solving in which teaching experiences are translated into problems that can be solved. The problematizing and problem-solving that can lead to meaningful ways of learning how to reflect on teaching can best be done with peers who face the same dilemmas. Involvement of mentors and peers in the development of student teacher professional skills is illustrated in the next case study.

2.7 Involvement of student teachers and their peers in each other's professional development

The case study presented below was conducted during the first phase of this study to assess the extent to which student teacher and peer coaching of one another to acquire some teaching skills was effective.

2.7.1 Bridging the theory-practice gap of pre-service teachers using collegial peer and mentor coaching (Nyaumwe, Mtetwa & Brown, 2005)

This study was conducted to identify the professional skills that mentors and peers respectively coached 115 BUSE mathematics and science pre-service teachers on twelve weeks of teaching practice. Eight mentors and their mentees were interviewed for the purpose of cross method triangulation. Findings showed that collegial peer and mentor coaching can promote the integration of theory and practice of pre-service teachers by anchoring their teaching on a theoretical and practical framework. Despite their lack of teaching experience, peers shared common theoretical teaching perspectives with pre-service teachers that enabled them to be more effective than mentors on coaching covert skills involving planning, reflection and teaching

strategies. The wealth of teaching experience that some mentors possessed made them effective to coach overt skills in line with school contexts and expectations such as classroom management, learner assessment and location of resources in the school among others. This study concluded that peer and mentor collegial mentoring of student teachers was effective in narrowing the theory-practice gap of pre-service teachers in ways that enhanced their development of instructional skills.

Reflections with peers required a framework to guide post-lesson reflective dialogues between student teachers and their peers. A framework that guides student teachers to reflect on their teaching is necessary because they have a liability of experience in knowledge, pedagogical skills, and learners that may hinder their reflections. Without a framework to guide their reflections, student teachers may get preoccupied with the process of teaching and overlook the process of learning how to teach through reflection (Power, Clarke & Hine, 2002). The CRP framework is proposed with the hope that it might solve the ambiguity of purpose that reduces student teacher guesses about what to reflect on by providing guidance on the aspects that reflection on teaching could focus on.

2.8 Theoretical framework of the study

A framework that guides student teacher reflections is necessary if they are to critically reflect on their teaching experiences. The art of cultivating student teacher reflective skills requires specific guidelines that provide them with useful insights on the direction of reflective discussions about teaching and learning (Mueller, 2003). Guidance that facilitates student teacher attainment of critical reflection enhances their attaining deep understanding of the relationships between teaching and learning and how they interact.

Striving for a model that guides student teachers to achieve critical reflection on their teaching is a journey that requires continual improvements and sense making that should never be viewed as fixed, static or prescribed. Interactive cyclic development and implementation in the evolution of such a framework is necessary in order to determine the theoretical and empirically ideal situations where it is effective to guide student teacher reflections. The development and testing of the framework for its effectiveness and practicality allows the provision of approximations for

successive ideal situations in which the framework guides student teacher reflection on their teaching. Attempts to refine and trial test the framework are an on going process. For instance, several scholars have refined Dewey's (1933) model of reflective thought in order to improve teacher reflection on their teaching. Among the plethora of models that emerged from Dewey's model, three of them by Kolb (1984), Smyth (1992) and van Manen (1977) will be used as illustrative ongoing efforts to improve teacher reflective practice. A presentation of some of the models on reflection that provided insight in developing the CRP framework is shown below:

2.8.1 Dewey's model of reflection

Dewey (1933), the pioneer on reflective practice, proposed five phases of suggestions, problem, hypothesis, reasoning, and testing in the reflective thought model as shown below:
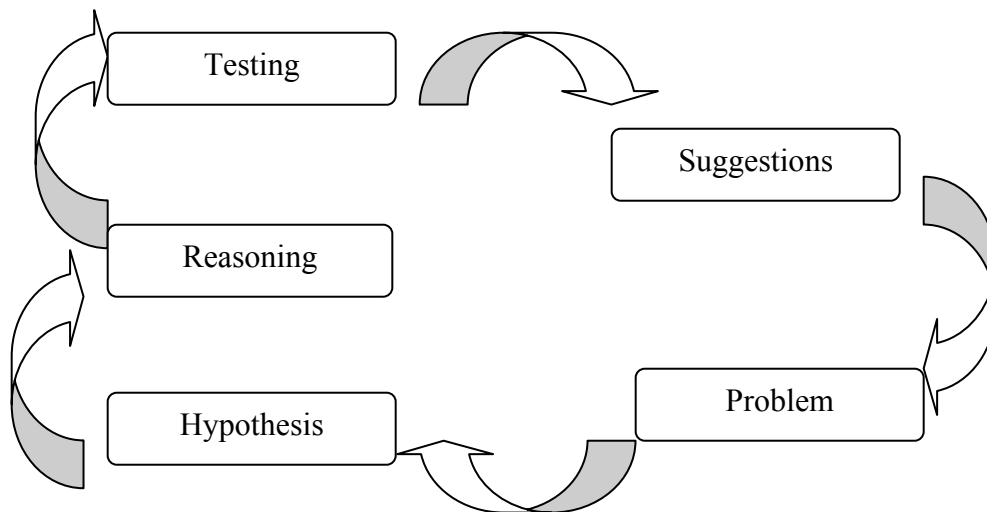
Figure 1: Dewey's (1933: 204) model of reflection

The starting point in Dewey's model of reflective thought is suggestions. In the phase of suggestions the mind searches for possible solutions to a problem (critical situation) that was encountered during teaching. Suggestions are followed by a problem phase in which strategies to solve a problem encountered during teaching are explored. The hypothesis phase initiates and guides the solution of the identified problem in the third stage of the model. In the fourth phase is reasoning in which there is elaboration of ideas. Testing the reasoning and the hypothesis in order to determine the viability of the solution obtained from the reflection is done in the fifth phase of the model.

Smith (2001) criticized Dewey's reflection model for portraying reflection as an individual process in which teachers learn to reflect on their teaching experience rather than an interactive or dialogical process. According to Cinnamond and Zimpher (1990) cited by Smith (2001), Dewey's work on reflective thought is premised on the conception that individual teachers can learn to reflect on their teaching practice alone. Improvements to make the model interactive can be made if the model followed a sequence beginning with problem, hypothesis, reasoning, testing and suggestions. This sequence facilitates finding solutions of instructional problems that a teacher encounters during teaching. After identifying specific problems that were encountered during teaching, some teaching solutions can be sought. Suggestions to improve teaching through reduction of the problems encountered in a lesson taught are hypothesized with insight drawn from pedagogical theories. The classroom contexts generate hypotheses that form the focal point of reflection using reasoning based on conditions existing in the classroom, learner interest, skills and resources. The hypotheses are later tested in the classroom in order to determine their effectiveness and applicability in the light of the learning context.

Dewey advocated that his model can be used as a linear plan for action in which some phases may be "passed over" (Dewey, 1933: 207). Following Dewey's suggestion of omitting some phases, van Manen (1977) suggested a three-phase model of reflection as an improvement.

2.8.2 Van Manen's model of reflection

Van Manen (1977) described reflection as going through three phases of: questioning, analysis, and assumptions as shown below.
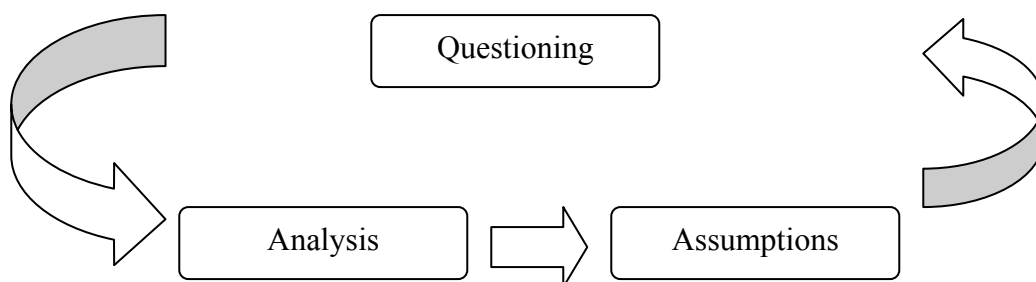
Figure 2: Van Manen's (1977: 212) model of reflection

In van Manen's model, reflection is conducted in a cyclic order of questioning, analysis, and assumptions. The use of broad terms in the model such as analysis, assumptions, and questioning is open to wide interpretations that concern teaching. For instance, assumptions may include learner skills, pedagogical strategies, or depth of content among other things. This renders a student teacher to choose what their reflections may focus on. The use of broad terms such as questioning may provide a wide view of being critical to events of the lesson not specifically implying evaluation. Inclusion of evaluation as a phase in the model may provide an analysis of the grounds for actions made during teaching in the light of learner outcomes. Like Dewey's reflective thought model, van Manen's model lacks grasp of reflection as an interactive process in which student teachers can reflect with peers. The model does not give room for integration of theoretical and practical pedagogical knowledge through reconstruction of teaching after implementation of pedagogical strategies in a classroom situation. Improvements of van Manen's model by Kolb (1984) saw the inclusion of some critical elements of reflection that provide a more refined model.

2.8.3 Kolb's model of reflection

Kolb (1984) included reflection as one of the components in a four-phase cycle of experiential learning that includes experiencing, reflection, conceptualization, and planning.
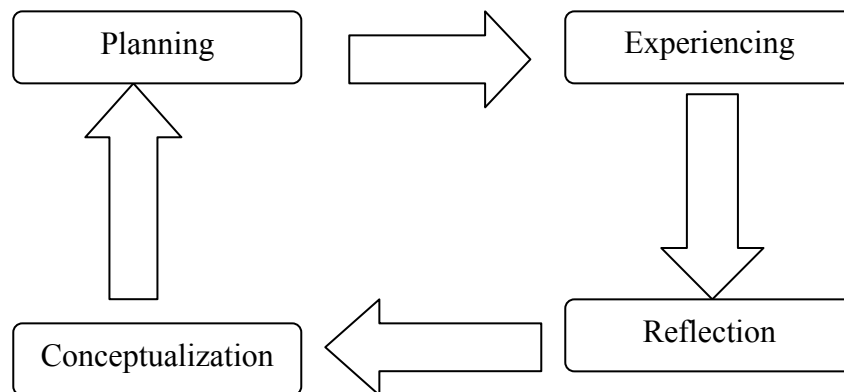
Figure 3: Kolb's model (1984: paragraph 3) of reflection

Experiencing in Kolb's model indicates immersion in the teaching experience. At this stage a student teacher implements pedagogical strategies they think are appropriate for the content at

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hand. The experiencing stage provides a synopsis of the insights gained through teaching a lesson. The reflection stage involves looking back at an instructional episode and reviewing events that occurred during teaching. The effectiveness of instructional strategies is determined by learner responses to the instruction given. The conceptualization stage involves the reviewing of strategies implemented in the lesson that promoted understanding of the relationship between theory and practice. Conceptualization of the various variables that influence teaching prepares student teachers for the planning stage. In the planning stage, new understanding of instructional practice attained is translated into action by planning the subsequent lesson. The planning incorporates the understanding gained from the previous phases of experiencing, reflection, and conceptualization in order to reduce weaknesses of the lesson to be taught next.

Improvement of Kolb's experiential learning model can be made by including a (re)construction phase before planning. Student teachers need to (re)construct their theoretical and practical knowledge and develop new understanding that might enable them to plan for a subsequent instructional action. Planning subsequent lessons without reconstructing theoretical and practical understanding of teaching strategies may allow repetitions of teaching weaknesses from one lesson to the next. By including a (re)construction phase in a model of reflection, Smyth (1992) refined the model of reflection to include understanding that a student teacher is capable of developing after reflection.

2.8.4 Smyth's model of reflection

Smyth (1992) suggested a four step cyclic model comprising description, information, confrontation and (re)construction as shown below:
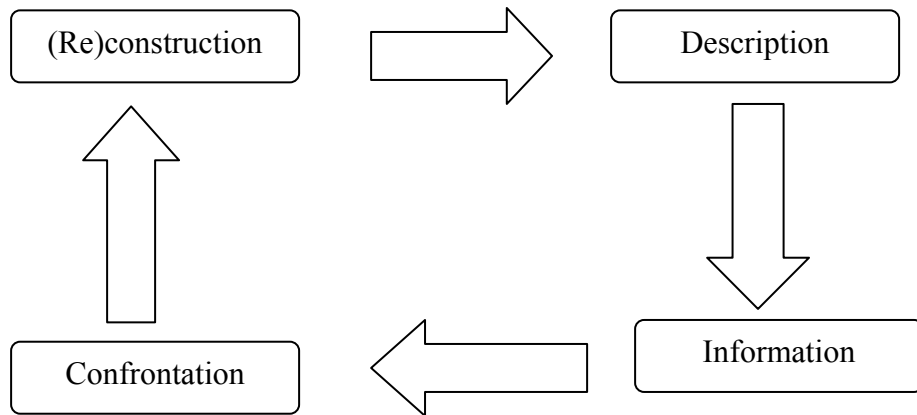
Figure 4: Smyth's (1992: paragraph 15) model of reflection

Smyth's cyclic reflection model starts with description of the instructional enterprise just completed. A description of the teaching environment provides an understanding of the content, pedagogical approaches and the teaching context. The description stage is followed by the information stage which provides insight into teaching experiences that were effective and those that were ineffective. Information on the lesson makes provision for analyzing and discussing the reasons for events turning the way they did during teaching. The analysis may provide insight into why successes or failures were experienced. It also allows explorations of other situations the teaching decisions are likely to be effective in, or what went wrong in the lesson and what refinements are possible to make the instructional decisions effective. After the information stage, reflection can "confront" the appropriateness of student teacher choice of variables that influenced teaching such as pedagogy, resources, and actions, among others. After confrontation of student teacher decisions it is now possible to (re)construct the instructional understanding in order to improve subsequent teaching.

Smyth's reflection model uses general and broad terms that may be problematic for student teachers to interpret. Description is a wide term that does not enable student teachers to focus on specific classroom situations during reflection. For instance, student teacher description can focus on learner prior knowledge, content, resources and a multiple of other variables that influence the learning process. In a similar way information is too broad for student teachers to be able to provide the information that Smyth anticipates. The use of the term confrontation in the third phase appears to be militant. Milder words such as review, interrogation or evaluation may be appropriate terminologies to refer to the confrontation of instructional incidents that is implied by Smyth. The use of the term evaluation as a replacement of confrontation may enable student teachers to assess how and why they teach the way they do and facilitate determination of instructional areas that need consolidation or refinements. The fourth stage of (re)construction is appropriate as it implies the implementation of professional insights developed from teaching a lesson. The weaknesses inherent in the three models of reflection discussed above are highlighted below:

2.8.5 Weaknesses of the available reflection models

The models discussed above have been used with different levels of success but in most cases they did not facilitate student teacher development of critical reflection skills (Power, Clarke & Hine, 2002). Use of the above reflection models was not successful in guiding some student teachers towards attaining critical reflection level, because some of the student teachers who held instrumental views of teaching mathematics did not go beyond descriptive reflection level (Hatton & Smith, 2006). Lack of a conception phase in the models does not make it mandatory for student teachers to review the conceptions they hold on the nature of mathematical knowledge taught in a lesson and how learners acquire it. The absence of the conception phase did not make it compulsory for student teachers to review the deeply held beliefs about teaching and learning mathematics that they held in the light of learner understanding. The models, furthermore, presented reflection as an individual activity rather than an interactive and dialogical process (Smith, 2001). In a community of practice of peers it is important that student teacher reflections on teaching can become an interactive process where student teachers and their peers can collaboratively reflect on each other's teaching. The notion of collaborative reflection necessitates a model that promotes dialogue during student teacher reflections. The present study conflates the models discussed above in designing a reflection model that facilitates student teachers to collaboratively reflect on their teaching.

2.8.6 The proposed CRP framework

The proposed reflection model that facilitates student teacher interactive reflection with peers was developed with insight from the reflection models described above. The proposed CRP model avoided the use of general terminologies and presents the model using specific and comprehensive words that are easy for student teachers to understand. The proposed framework also includes a conception phase at the beginning of the four cyclic phases in order to allow student teachers to constantly expose and review their deeply held beliefs on the nature of mathematical knowledge and how learners acquire it. Review of student teacher conceptions of teaching and learning mathematics may facilitate transformation of their teaching from teacher-centred to learner-centred or vice versa, with reasoned arguments based on teaching experiences.

The summarized four cyclic phases in the proposed CRP framework are conceptions, context, evaluation and development. In the conception phase student teachers describe personal beliefs

on teaching and learning of the concepts of a lesson, learner prior knowledge and skills that are hoped to facilitate attainment of objectives of the lesson. In the context phase student teachers analyse the learning environment created by learners, critical incidents emerging during instruction, and consequences of reflective actions during teaching on learner understanding. The evaluation phase identifies strengths, weaknesses of a lesson and interpretations of learner actions and their causes. The development phase involves analysis of instructional decisions, (re)construction of theoretical and practical knowledge and designing alternative strategies that might improve subsequent teaching. After the (re)construction of instructional practice in the light of new understanding of pedagogical strategies and learner needs, planning of the subsequent lesson that incorporates new understanding that is held is possible. The phases of the proposed CRP framework are shown diagrammatically below:
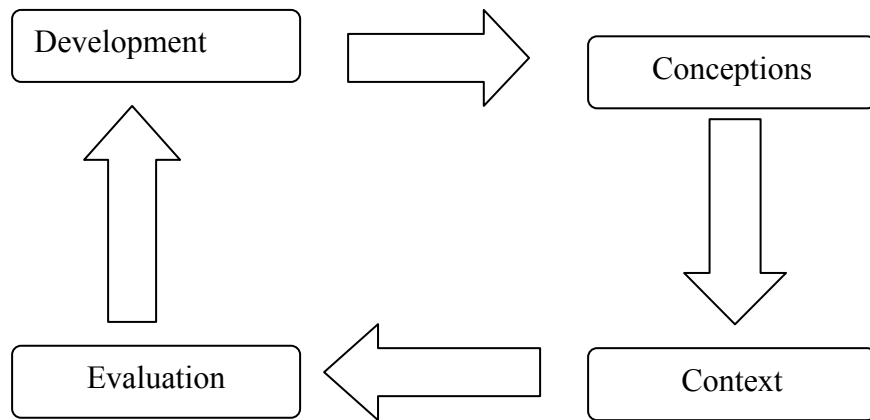
Figure 5: The proposed CRP framework

2.9 Essential features of the CRP framework

The proposed CRP framework contains some new concepts that were not covered in the models of reflection discussed earlier. For instance, conceptions, context, and evaluation are three terminologies commonly used in educational circles that were not highlighted in the previous reflection models. The development phase is not unique to the proposed CRP framework because it is equivalent to the broad terms of reconstruction (Smyth, 1992) and suggestions (Dewey, 1933). The development phase specifically requires student teachers to highlight the insights they develop from teaching a lesson that shows how their understanding of pedagogical strategies, how learners learn and the nature of mathematical concepts have changed as a result of

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teaching a lesson. Below is the rationale for the new concepts and the order of the cyclic phases in the proposed CRP framework.

2.9.1 The order of cyclic phases

The four phases of conceptions, context, evaluation and development in the proposed CRP framework are cyclic. Whilst it is acknowledged that each phase cannot be written in a post-lesson reflective text separately, but that concepts from different phases can proliferate throughout the text, the logical order of phases depicted in the CRP framework enhances coherent discussions. The order of phases allows alternative views on how students learn; assessment of pedagogical strategies, and new insights that can possibly be drawn from teaching a lesson. A discussion of the rationale for each stage in the CRP framework is presented below.

2.9.2 The conception phase

Student teachers do not act as gateways to mathematical knowledge. They go for teaching practice with theories and pedagogical knowledge that they already posses. They should test them for effectiveness in their teaching. Student teachers convey their conceptions of the nature of mathematical knowledge in their instruction. Conceptions mould the assumptions, methodology and style of presenting mathematical knowledge in ways that student teachers believe will make learners understand concepts under review. Conceptions of how to teach or learn mathematics in turn influence implementation of pedagogical strategies in a lesson. It is necessary, therefore, for student teachers to expose the rationale and effectiveness of their conceptions of teaching and learning in the light of learner outcomes during instruction. As cited in Section 1.2.1 the three broad conceptions of teaching and learning mathematics that student teachers can hold are Platonism (static view), formalism (mechanistic view) and constructivism (contemporary view).

Student teachers describe their views on teaching and learning mathematics in order to expose their philosophy of knowledge acquisition. This helps to guide the direction of the dialogue because instructional conceptions strongly influence the roles of a student teacher in a lesson, planning, and decision-making processes during instruction (Tobin, Tippins & Gallard, 1994 cited by Lee & Lin, 2005; Handal, 2003). Exposing personalized conceptions on teaching mathematics also provides insight into the choice of pedagogical strategies used in a lesson that facilitate an understanding of the learning context that learners can possibly create.

2.9.3 The context phase

After exposing student teacher conceptions of teaching and learning and the nature of mathematical content under review, additional information on the context of the learning environment is necessary in order to interpret learner behaviour. In the context phase, student teachers describe how they implemented pedagogical strategies, interpret learner responses to instruction and identify critical incidents of a lesson. Learner interest, prior knowledge and outcomes during instruction are also discussed. Student teacher decisions and actions during instruction and learner responses to them are also discussed in this phase. Describing the context of the learning context gives a peer some background information that might provide insight into interpreting the teaching and learning atmosphere using teaching theories. This allows an assessment of the effectiveness of a student teacher's instruction.

2.9.4 The evaluation phase

A peer, who is aware of conceptions of learner acquisition of mathematical knowledge that a student teacher holds on teaching certain concepts and the learning context, may be ready to evaluate the effectiveness of the teaching that occurred. The evaluation phase involves analysis of strengths and weaknesses of a lesson, learner behaviour, effectiveness of decisions and actions as well as appropriateness of pedagogical strategies implemented in a lesson, among other teaching variables. Using pedagogical theories to interpret the outcomes of a lesson in the light of learner responses helps to assess anticipated and unanticipated outcomes of a lesson, importance of the content to learners, and the moral and ethical concerns that occurred in the lesson. Discussions on the implementation and effectiveness of alternative viable pedagogical approaches used are also debated and negotiated in the evaluation stage. The debates in this phase of the framework culminate in the designing of intervention measures that are anticipated to improve subsequent teaching.

Due to the numerous aspects that compete for attention in the evaluation phase, not all the aspects that appear on the detailed lesson plan such as appropriateness of resources, learner prior knowledge, teaching strategies, objectives, and classroom management, among others, can be evaluated. Student teachers have a tendency to superficially evaluate the extent to which all the aspects on a detailed lesson plan, especially that learner objectives were achieved.   Such evaluations centred on too many aspects have often resulted in superficial comments that lack

interpretation and evidence. It is therefore, prudent for student teachers to concentrate on critical incidents or memorable events of a lesson and supply concrete examples from a lesson taught in their evaluations. Concentrating evaluations on a few critical events of a lesson allows detailed account of the incidents. This facilitates interpretations of the causes and outcomes of the incidents. Correct interpretations of the causes and outcomes of incidents of a lesson provide insight to design viable intervention measures in the developmental phase, to replicate them if they were favourable, or to reduce them if they hindered learner understanding.

2.9.5 The development phase

Effective development phases show instructional skills that student teachers mastered and those that require refinements. When consecutive post-lesson reflective texts are put together, the accumulated teaching skills acquired by a student teacher can be determined. In the development phase, suggestions for changing some aspects of a lesson taught are explored through examination of important conditions that influenced the course of the lesson. The development phase also provides discussion on alternative pedagogical strategies for teaching the lesson that might improve the learning process. The understanding that is developed in the development phase can be used to plan a subsequent lesson.

The CRP framework can guide student teachers to reflect on their teaching in a community of peers to attain critical reflection category. This is possible because examination and explanation of student teacher reasoning with peers, learning from feedback that peers provide and reflecting with peers on unexpected outcomes of a lesson, may provide insight to carefully consider the choice, designs and moral and ethical concerns for teaching a lesson (Even, 2005). The importance of the proposed CRP framework to guide student teacher reflections on their teaching is discussed next.

2.10 Importance of the CRP framework

Implementation of the CRP framework has several potential benefits in the development of teaching knowledge and skills of student teachers. For instance, implementation of the CRP framework has potential to: (a) improve student teacher reflections to critical levels, (b) develop student teacher autonomy to develop professional knowledge and skills, and (c) promote dialogue in a non-threatening environment. Each of these CRP benefits is briefly outlined below.

2.10.1 CRP potential to improve student teacher reflections

Power, Clarke and Hine (2002) reported that student teacher reflections using the current school attachment models remained at superficial level at the end of full-time teaching practice. A possible strategy to enhance student teacher reflections to attain higher than the superficial level is to introduce the CRP framework to guide their post-lesson reflections. The CRP framework may enhance student teachers' ability to focus reflection on relevant aspects that examine learner understanding in the light of teaching proffered. Reflection guided by the framework has potential to enable student teachers to construct tentative and problematic pedagogy that may improve their teaching practice.

The establishment of learning communities through CRP promises to be a positive way to reconceptualise teacher education in a manner that impediments faced during teaching practice are collaboratively addressed with peer assistance. A model of teaching practice that uses the principles of CRP has potential to enable student teachers to collaboratively develop professional skills in communities that are interdependent and focused on better learner achievement. Student teachers using the CRP framework to guide their reflections have the potential to develop teaching knowledge and skills that is guided by curriculum goals that are negotiated with peers. Student teacher and peer collaborative reflections might improve their teaching practices through collaborative review of strategies to enable learners to achieve curriculum goals, instructional methods, decisions, and actions leading to the development of instructional strategies that enhance effective teaching in the light of learner outcomes. Collaboration in analyzing classroom incidents with peers, who are partners in learning how to teach, has high possibilities of promoting collegiality among student teachers that is paramount for reducing teacher isolation. Reflection on a student teacher's teaching that is conducted in an environment that encourages free expression of opinions and debating of different points of view constitutes a vital step in the process of constructing a critical and analytical discourse on teaching mathematics.

2.10.2 Development of student teacher autonomy to develop professional knowledge and skills

CRP deserved trial testing as a reflection model to augment existing teaching practice models in order to assess the extent to which it enhances student teacher development of professional skills to overcome problems that can be encountered during interactive teaching. Trial testing CRP in typical classroom situations facilitated exploration of long held student teacher conceptions of

mathematics teaching and learning that can minimize the challenges of professional development that were raised by Ingvarson in Loughran and Gunstone (1997). Possible incentive systems that exist in CRP are that a collaboratively developed repertoire of professional skills is intrinsically motivating in that improved reflection improves instructional practice. CRP is expected to enhance student teacher control of their professional growth in that peers assist each other to design, implement and evaluate the efficacy of suggested teaching strategies to improve learner understanding and achievement. Furthermore, CRP recognizes student teacher mathematical knowledge, understanding, skills and experiences as assets in professional development in an analytical and reflective learning environment.

2.10.3 Promotion of dialogue in a non-threatening environment

Dialogue with peers is a critical element in enhancing learning from personal and peers' teaching practice. Dialogue has the potential to encourage student teachers and peers to seek understanding of each other's instructional views and challenge deeply held assumptions, create mechanisms to alter each other's perspectives and influence changes in each other's practice. For instance, dialogue with peers might help to dispel the Platonist belief that some student teachers sometimes hold regarding learner inability to teach each other mathematical concepts in groups unless they are revising work already covered in class (Nyaumwe, 2004). The issue of learner ability to construct mathematical knowledge influences student teacher choice of teaching methods or integration of pedagogical strategies in the teacher-centred and learner-centred paradigms. Choice of teaching methods has implication on classroom management. For example, some student teachers may have a tendency to avoid learner-centred methods because they fear that they may fail to control learner movements during a lesson. Reflection with peers may help to dispel such fears.

Reflections with peers are held in a freer environment than with experienced teachers. Experienced teachers and student teachers have no equivalent freedom to express teaching perspectives during reflection. Experienced teachers usually dominate the reflective dialogues because they have tried and tested teaching knowledge and skills, which they can use to defend their opinions that are not held by student teachers (Chen, 1993). The experienced teacher dominance sometimes renders reflections ineffective to challenge student teacher deeply held perspectives on teaching because development of reflective skills should not be done by coercion

through experienced teacher coaching (Bryan, Abel & Anderson, 1996), but can be voluntarily developed through interactions with peers.

The discourse of student teachers and their peers in CRP are different from arguments based on Toulmin's model of argument (Toulmin, 1958). Toulmin believed that reasoning in an argument is less an activity of inference involving the discovery of new ideas but more a process of justifying a conclusion. An example of a practical argument based on Toulmin's model is one in a court of law. Such an argument consists of a fact, warrant, backing or rebuttal and conclusion. A warrant is used to support a fact in order to make a conclusion. A warrant in turn may need backing in order to make a conclusion plausible or a rebuttal to refute a claim. Toulmin's argument pattern has been used as a tool for understanding actions in science classrooms. For instance, Duschl (2007) used Toulmin's model to analyse science education policy and decision makers' goals and priorities for the design of curricula, instruction and assessment models.

The literature review and theoretical framework provided insight that may contribute to the development of a theory on student teacher and peer involvement in reflecting on lessons they teach. The insight will help to make an assessment of the extent to which CRP can enable secondary school student teachers to critically reflect on their teaching and influence positively their cognition and decision making during instruction and post-lesson reflective dialogues.

2.11 Summary
The literature review and theoretical framework presented in this chapter provided insight for proceeding to the next phase of the study. The literature review exposed the complexity of teaching and the weaknesses in current teacher professional models. The theoretical framework showed the types of reflection models and their weaknesses to develop reflective practice of student teachers. The weaknesses prompted the development of the CRP framework to augment them. The methodology and instruments of the study to assess the influence of the CRP framework to guide student teachers to reflect on their teaching practice is discussed in the next chapter, Chapter Three.

CHAPTER 3: METHODOLOGY

3.1 Chapter overview

This chapter outlines the methodology, development of instruments and procedures used to generate and analyse data that answers the research question. Based on the CRP framework presented in the preceding chapter, a case study design is discussed at the beginning of the chapter. Discussion of development research, nature of data, sources of data, instruments, and procedures followed during data collection respectively follow this. Scoring system adopted using reflection indicators in the CRP framework and examples of typical texts is presented later. A result of piloting of an instrument for assessing student teachers' reflection-in-action is presented towards the end of the chapter. The chapter ends by summarizing the main aspects discussed and linking them to the nature of professional skills that in-service teachers developed from collaborative reflection with peers presented in Chapter Four.

3.2 Case study design

The models of inquiry adopted for this study were action research and case study design. Action research is perceived here as self-reflective inquiry undertaken by a teacher educator in real classroom situations in order to improve the rationality and practice of the teacher education programmes they teach, and understand student teacher practices in the situations in which teaching is conducted. Action research, as a process through which a teacher educator can gain experiential understanding of the effectiveness of the CRP framework to develop student teacher reflective skills, was conducted in natural classroom environments where student teachers were practicing to teach.

Studies on the professional development of student teachers are usually conducted in case study designs that involve small sample sizes (Chen, 1993; Crawford, 1998; Ensor, 2000; van Tulder, van der Vegt & Veenman, 1993). Case study designs are often used to investigate the impact of reflective practice of student teachers in natural school settings (Mackinnon, 1993; Spalding & Wilson, 2002). A case study design was suitable for this study because it allowed the provision of following and documenting the classroom practice of student teachers on teaching practice. It

also allowed interval assessments of the development of reflective skills of the pairs of student teachers who participated in this study during full-time teaching practice of their programme.

The case study approach was also appropriate for allowing investigations of student teacher teaching activities in real classroom contexts (Ferguson, 2005). Conducting the research in real classrooms enhanced observations of meaningful characteristics of actual teaching practices of student teachers. A small sample size of five pairs of student teachers in this case study design permitted collection of large corpus of data that not only allowed for methodological soundness but also facilitated the generalizations that could lead to the emergence of a theory that explains the quality of reflections of student teachers reflecting with peers (Perressini, *et al*, 2005). Data from multiple sources of post-lesson reflective text, assessment critiques of reflective actions during teaching, and interviews can be used to answer the research question without violating assumptions for using case study design. Data generated from case studies of student teacher instructional practices permitted identification of typical exemplars of different reflection levels.

Case study designs provided the additional advantage of freedom to use varieties of data collection and analysis methods. For instance, assessments of student teacher reflective actions during teaching generated data collection, interpretation, and analysis methods different from those for assessing reflection-on-action. Reflective actions during teaching data were collected through classroom assessment of student teacher teaching, whilst reflection-on-action was assessed through post-lesson reflective texts that were written after collaborative reflection with a peer using a CRP framework. The CRP framework was itself located within the tradition of development research.

3.3 Development Research

Development research is a pragmatic process in which a researcher gets insight from literature and personal experience to create a product by designing, testing and revising several prototypes. The development of prototypes is an instrumental process that starts with the formulation of specific goals and the expected outcomes of the product. Principally, development research goes through three stages, namely, designing of prototypes, formative evaluation of the prototypes, and summative evaluation of the final product when it is implemented in practice. Van den

Akker (1999) viewed development research as a systematic study of the design, development and evaluation of the processes and products of an educational innovation that meets the criteria of validity, practicability and effectiveness. This view presents development research as an evolutionary process that is guided by formative evaluation in the development, trial testing and implementation of prototypes, and the worthiness of the product for national implementation assessed during summative evaluation.

Development research was appropriate to investigate the impact of CRP framework to guide student teacher reflection. It provided formative evaluation at each of the development, trial, and implementation stages of the CRP framework. This information provided prompt feedback seeking to improve the framework at the stage where loopholes were noticed. Results of the summative evaluation depended on how the CRP framework enhanced student teacher reflections to attain critical reflection levels.

A detailed account of how each of the three key stages of development research (development, trial test and implementation) was used in the development of the CRP framework now follows. At the development stage, literature on professional development of mathematics teachers, reflection, and tentative frameworks on experiential learning were analysed (see section 2.5.0). The tentative frameworks from literature were modified to suit the context of the present study. Criteria for evaluating the effectiveness of the CRP framework were the extent to which it enabled student teachers to make critical reflections of their teaching and influence positively their cognitions and decision-making during instruction and post-lesson reflective dialogues. The goals of the study that guided the refinements of the CRP framework from the trial tests were two fold. First, there was analysis of ways that student teachers applied the framework to guide and nurture their reflective practice. Second, there was evaluation of the changes in perceptions on mathematics teaching and learning that accrued as a result of CRP and whether these changes in perceptions enabled student teachers to attain critical reflection levels.

The CRP framework was trial tested in the field to provide formative evaluation (Nyaumwe, 2005). The suitability of draft instruments used to measure student teacher reflections were also trial tested before the main study (Nyaumwe, 2006a). Trial tests of the framework and

instruments were necessary in order to provide revisions and improvements that suggested refinements and adjustments of the CRP framework and indicators of reflection. The indicators were then related to levels of reflection that were attained by the student teachers.

3.4 The link of development research to the research question

To answer the research question stated in section 1.7, the situation indicators for measuring reflection were improved after the first trial test of the CRP framework. For instance, after realizing that the content objectives stated on the detailed lesson plan were used as the basis for student teacher reflections, a section for pedagogical objectives was introduced on the lesson plan format (Table 2. The inclusion of pedagogical objectives on the lesson plan facilitated student teachers' reflections on both learner achievements of content objectives and teacher development of specified instructional strategies that they implemented in a lesson.

To help student teachers to construct pedagogical objectives, the researcher and student teacher pairs collaboratively compiled samples of pedagogical objectives shown in Appendix A. Each collaborative pair had a copy of Appendix A before the first round of data collection visits. Reflections on the extent to which student teachers achieved pedagogical objectives facilitated an assessment of the level to which the CRP framework influenced their cognition and decision-making during instruction and post-lesson reflective dialogues.

Table 2: Original and revised lesson plan formats used by student teachers

Original lesson plan format				Revised lesson plan format			
1.Name of student:　　2.School 3. Date(s):　　　4.Time(s): 5. Class(es):　　　6.No. of pupils: 7. Topic:　　　8. Lesson Topic: 9. Content objectives: 10. Lesson's assumed knowledge: 11. Anticipated difficulties: 12.Media: 13. References: 14. Lesson structure:				1. Name of student:　　2. School: 3. Date(s):　　　4.Time(s): 5. Class(es):　　　6. No. of pupils: 7. Topic:　　　8. Lesson Topic: 9. Content objectives: 10. Pedagogical objectives: 11. Lesson's assumed knowledge: 12. Anticipated difficulties: 13. Media 14. References: 15. Lesson structure:			
Stage	**Content**	**L. Act**	**T. act**	**Stage**	**Content**	**L. act**	**T. act**
Introduction				Introduction			
Step 1				Step 1			
Step 2 etc				Step 2 etc			
Conclusion				Conclusion			
15. **Post-lesson reflections**:				16. **Post-lesson reflections**:			

　　　　Key: L. act – Learner activities　　　　T. act – Teacher activities

Inclusion of pedagogical objectives after content objectives enabled student teachers to reflect on their personal conceptions of teaching and learning mathematical concepts planned for a lesson, effectiveness of their implementation of pedagogical strategies, and commenting on the instructional insight they developed as a result of teaching a lesson. The inclusion also facilitated achievement of a balanced basis on which student teachers could reflect on the extent to which they acquired teaching skills to implement instructional strategies they trial tested in a lesson. The effectiveness of implementation strategies could be related to learner achievement of content objectives. The manner in which development research was used in the development of the CRP framework is outlined below.

3.5 Development research strategies used in the study

The CRP framework underwent two cycles of revisions and refinements until it was deemed satisfactory enough to guide student teachers' reflections that met the criteria stipulated at the development stage. The cycles of developmental stages that were adopted are chronicled below:

In the first cycle the CRP framework was designed using insight derived from literature (Section 2.5.0) and researcher experience. The initial phases of the framework were: teaching beliefs, learning environment, evaluation, and development, as shown below:
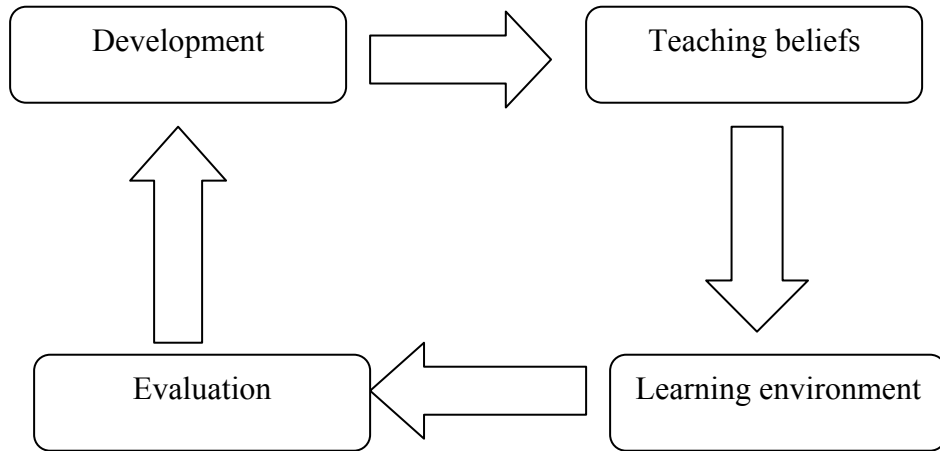
Figure 6: The initial CRP framework

The initial CRP framework was implemented in the field to assess its validity. The emphasis in this cycle was on the student teacher interpretations of the four cyclic phases of the CRP framework (Nyaumwe, 2005) as described in a study conducted during the first phase of this longitudinal study presented below.

The field test in the first cycle of the study sought to establish the extent to which a CRP framework was practical to guide BUSE pre-service mathematics teachers to reflect on their teaching. Case studies of two pairs of pre-service teachers attached at different high schools formed the sample. The last post-lesson reflective texts written on the previous days of the three rounds of visits made by the researcher were the source of data. Interviews were conducted on the two pairs of pre-service teachers to establish the extent to which the CRP framework was practical in guiding them to reflect on their teaching.

The pre-service teachers faced difficulties in identifying what to write in the teaching beliefs and learning environment phases. Lack of knowledge of specific aspects to write in these two phases

influenced the contents of the evaluation and development phases. After realizing that the caption *teaching beliefs* in the first stage limited student teachers to analysing learner prior knowledge, a broader term of conception was adopted to capture the assumptions and beliefs that student teachers held about teaching and learning during planning. The term c*onception* is a broader word that could enable student teachers to reflect with peers on the effectiveness of their belief systems on how learners acquire mathematical concepts. The reflection on personalized conceptions about mathematics teaching and learning could facilitate an exchange of views on how pedagogical strategies that were chosen to teach the concepts of a lesson could be improved in order to optimize learner understanding. Such reflections allowed an assessment of the extent to which the CRP framework can possibly guide student teacher reflections and influence their cognitions positively.

The phrase *learning environment* in the second phase of the initial CRP framework confined student teachers to the learning atmosphere created during instruction. In the post-lesson reflective texts, the student teachers commonly wrote phrases such as "learners solved problems quietly or noisily and interactions during the lesson were good", among others, to describe the learning environment phase. Learner actions in response to instructional events were the basis of the student teacher reflections. Issues on teacher decisions in response to learner behaviour were silent on the post-lesson reflective texts. The phrase *learning environment* was replaced by *context* in order to capture both student teacher and learner behaviours and actions during instruction. The findings from the first cycle helped to refine the terminologies, teaching beliefs and learning environment to conceptions and context in the CRP framework (Figure 5).

3.5.2 The second cycle

The CRP framework designed in the first cycle was field tested in order to determine its practicality. Presentations of post-lesson reflective texts were problematic. Writing post-lesson reflective texts following the headings of the CRP framework phases was not feasible because some of the contents overlapped into the other phases. For instance, a post-lesson reflective text such as "the groups were too large that some learners were passive during discussions*"* is both contextual and evaluative. *Too large* is a student teacher evaluative opinion while *passive learners* describes the learning context of learners. Statements such as these made it difficult for the post-lesson reflective text to be written separately in a specific phase of the CRP framework.

To minimize the above problem and allow student teachers to write logical and well-reasoned post-lesson reflective texts, subheadings were avoided so that phases of the CRP framework could spread throughout the post-lesson reflective text.

The student teachers used the CRP framework to guide their post-lesson reflective dialogues with peers in order for the discussions to be balanced on the determinants of effective teaching of conceptions, context, evaluation and development. The four cyclic phases in the CRP framework were revised and linked to the stages of a typical lesson in the initial visit. For instance, a student teacher's conceptions manifest in the introduction and proliferate in the choice of instructional strategies. The context is evident during the learning process when learners react to student teacher instructional decisions and actions. Interpretations of the learning context gave rise to judgmental decisions that evaluated the appropriateness and effectiveness of instructional decisions and strategies used leading to the identification of the strengths and weaknesses of a lesson. Once the evaluation of a lesson was made, suggestions to overcome the weaknesses and strengthen the strong points of the lesson were made in order for a student teacher to professionally develop and improve their future teaching practice. The discourse that was possible in the post-lesson reflective dialogue at each of the four cyclic stages was assumed to promote critical reflection in student teachers.

3.5.3 The third cycle

The third cycle was the full implementation of the CRP framework that is discussed in chapters four and five. When satisfied that the CRP framework sufficiently met the predetermined goals of the study it was implemented in the intended field. Summative evaluation of the effectiveness of the CRP framework on instructional practice of student teachers was to answer the research question: *How can collaborative reflection with peers enable secondary school mathematics student teachers to critically reflect on their instructional practice and influence positively their cognition and decision making during instruction and post-lesson reflective dialogues?* Data that lead to answering the research question determined the effectiveness of the CRP framework to guide student teachers and their peers to reflect on each other's teaching practice. A table that summarizes the development research that was adopted for the study is shown below:

Table 3: Summary of stages of development research conducted on the CRP framework

Purpose	Focus	Preliminary design	First field work	Second field work	Third field work
Validity	CRP frame work	Literature adaptations	a) Reflective text. b) Lesson observations c) Réflective interviews		
Practicality	Student teachers		CRP trials	a) Reflective text. b) Lesson observations c) Reflective Interviews	
Effectiveness	Student teachers				Implémentation

The nature of the data collected during the implementation stage of the CRP framework and how they were analysed were determined by the research question.

3.6 Nature of data

Answering the research question required data that allowed an assessment of the extent to which the CRP framework could guide student teachers to attain specific levels of reflections. The research problem, *how can a CRP framework enable secondary school student teachers to look objectively at their practice and influence positively their cognition and decision making during instruction*, can best be answered by qualitative data. Qualitative data is useful to determine the validity, practicality and effectiveness of the CRP framework in guiding student teachers' reflections on their teaching and allows an assessment of the level to which their conceptions of the nature of mathematics and how learners master it is made.

The effectiveness of CRP is determined by the extent to which reflective discussions with peers facilitated student teacher building of knowledge on their current practice, and revision of their understanding through reflection in order to improve their teaching and enhance learner understanding. For instance, a detailed lesson plan that showed a broad understanding of learner-centred pedagogical methods that incorporated learner needs led to improve teaching. This

included ability to suggest exact process skills and how they could be used to develop some named mathematical concepts and generalizations, as opposed to suggesting improvements without showing exact implementation logistics.

3.7 Sources of data

The main data for the study were collected from student teachers attending undergraduate Bachelor of Science Education (Honours) degree at BUSE studying mathematics as their major or minor subject. The pre-service teachers were on twelve weeks of full-time teaching practice between January and April 2006. They were doing teaching practice at high schools in four provinces located in central and northern parts of Zimbabwe. The pre-service teachers were on teaching practice during the first semester of the final year of their four-year degree programme. The in-service teachers were on four weeks of full time teaching practice during the vacation between January and February 2006. They were deployed in the same provinces as the pre-service teachers.

3.7.1 The population

Pre-service teachers with mathematics as their major or minor subject who were teaching the subject during the teaching practice period formed the population of this study. The whole cohort comprised of 14 pre-service teachers majoring in mathematics and five having mathematics as their minor subject. The population for the in-service teachers was 20 undergraduate students studying one content subject of mathematics.

3.7.2 The sample

A purposive sample of student teachers was used for data collection. The criteria for sampling were: (a) deployment of at least two student teachers at the same high school, and (b) teaching mathematics. A combined five pairs of student teachers meeting these two criteria were located in rural and urban settings that represented a mixture of co-educational government and private independent secondary schools (see tables 4 and 5 for deployment patterns).

The school attachment deployment system at BUSE in which student teachers independently chose schools they wished to do teaching practice at influenced the number of pairs that participated in this study. Furthermore, some student teachers were deployed at the same schools

but failed to meet the criterion of teaching mathematics as they taught their minor or major subject that was not mathematics. Initially, two sets of in-service teachers and three of pre-service teachers met the two criteria of doing teaching practice at the same school in pairs and teaching mathematics. Attrition of one pre-service teacher, Munashe, who withdrew from school attachment at the beginning of March due to family commitments, reduced the number of pre-service teacher pairs from three to two.

3.7.3 The characteristics of sample participants

The in-service teachers had an average teaching experience of twelve years with a range of teaching years of four to twenty two years. They received initial training at one of the secondary school teacher training colleges of Belvedere, Gweru, Mutare, and Hillside. Teacher education from any of these four colleges permitted a variety of knowledge and skills that could provide different teaching perspectives during peer discussions. One of the in-service teachers was not actively involved in mathematics teaching because he was a school head. As a requirement of their degree programme, in-service teachers on school attachment teach 'A' Level classes only. They were assumed to have acquired sufficient teaching skills during initial training to teach at lower levels of the secondary school.

At most there were two 'A' Level mathematics classes at a school. In one class learners combined mathematics and commercial subjects and in the other they combined mathematics and natural science subjects. Due to the fewer classes at 'A' Level than lower levels, there was no "hot seating" for 'A' Level learners. Large enrolments in some urban government schools necessitated schools to operate on a two tier system in which half the Form level classes attend lessons during the first half of a school day and the other half attends lessons during the second half. This arrangement is called "hot seating".

The average age of the pre-service teachers was twenty-two years of age. They were teaching for the first time on an extended period of twelve weeks. One of the pre-service teachers, Mavis taught both the major subject (geography) and the minor subject (mathematics). Munashe and Mavis taught 'O' Level classes in different sessions. This made constraints on their meeting times because one had to come early and the other had to stay late at school in order for them to sit in each other's lessons or reflect on the lessons they taught together.

Student teachers deployed in urban schools faced time constraints to meet after a teaching session because they lived far from the school and usually some long distance apart. The constraints of time reduced the length of post-lesson reflective dialogues. Afternoon co-curricular activities in which the student teachers participated in different sporting activities on different days of the week further reduced the chances of the student teachers' meeting durations after teaching sessions.

The pre-service teachers, Michael and Cynthia, who were deployed at the same rural boarding school, potentially had ample time to meet because they were housed at the school but their different genders limited their meeting times. School social and religious norms of a male meeting a female dictated that they reflected on the lessons they taught during normal working hours in the staffroom. They faced problems to reflect together on the lessons they taught towards the end of a working day.

Typically 'A' Level mathematics lessons are offered on a daily basis. Each lesson is a double period of 70 minutes for urban schools and 80 minutes for rural schools. Lower class lessons usually have six 35 or 40 minute periods of mathematics per week depending on whether a school is located in an urban or rural area. Urban schools have shorter lesson periods than rural schools in order to cover the equivalent number of periods per day during a half-day session.

3.8 Instruments used for data collection

The instruments used to detect student teacher reflections need to be carefully defined if objective, valid, and reliable assessments of reflective actions are to be made. The character of the problem necessitated the analysis of student teacher reflections to determine whether they are critical of their teaching, learn from it, and perpetually seek strategies to improve it. The instruments for data collection that are informed by literature as effective to evaluate student teacher reflections are written texts in journals (Maloney & Campbell-Evans, 2000; Spalding & Wilson 2002), lesson assessments (Clarke & Chamber, 1999), and post-lesson reflective interviews (Freed-Garrod & McNaughton, 2005). Reflection detected through either of these strategies enabled student teachers to develop self inquiry and critical thinking that helped them

to move from one level where their teaching was guided by impulse and routine, to a level where their teaching was guided by intuition, reflection and critical thinking.

Following insight from literature, the instruments that were used to collect data that answered the research question were (a) post-lesson reflective texts (written at the end of each detailed lesson plan to detect reflection-on-action), (b) assessment critiques of live lessons separately written by the researcher and a peer illuminating reflective actions during teaching, (c) post-lesson reflective interviews to understand the basis of student teacher decisions during instruction, and (d) reflective group interviews at the end of the teaching practice period. The validity, effectiveness and practicability of the CRP framework was determined by the extent to which it influenced student teachers' reflections that led to changes in pedagogical cognitive patterns and decision making during lesson delivery and post-lesson dialogues. The level to which teacher-centred and learner-centred strategies were integrated during teaching to enhance learner understanding through improved instructional practice determined a student teacher's reflective actions during teaching. Post-lesson reflective text portrayed content that depicted student teacher ability to reflect on their teaching to attain a reflection category. The post-lesson reflective texts were evaluated using the reflection categories shown in Table 7 (presented in section 3.10.2). Each of these data collection instruments is briefly described below:

3.8.1 Post-lesson reflective texts

Journals that involve explicitly written reflective texts that are made available to inform action are gaining prominence for detecting student teacher levels of reflections. Post-lesson reflective texts and journals permitted assessment of the development of reflective skills and the integration of student teacher learning experiences with their teaching (Clarke & Hine, 2002; Johns, 2006). Journals were used to investigate whether student teachers understood the process of learning to teach through reflective practice, in the manner that Spalding and Wilson (2002) used them to identify pedagogical strategies that help student teachers to improve their reflective thinking.

Post-lesson reflective texts written at the end of detailed lesson plans were used as data collection instruments in this study due to their merits. Post-lesson reflective texts are useful as data sources because they provided concrete representations of the reflections that student teachers were capable of achieving. Self-written post-lesson reflective texts were suitable for capturing

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the documented reflection of student teachers in ways that facilitated the placement of the reflective text to appropriate reflection categories without researcher idiosyncratic tendencies to add personal opinions. In writing post-lesson reflective texts, student teachers organized their teaching experiences and the insights they developed from it, thus allowed combinations of personal and professional knowledge. Writing post-lesson reflective texts promoted student teachers' abilities to communicate and reflect on how they thought through the logical presentations of their texts. Post-lesson reflective texts produced accounts of how student teacher reflections during teaching were coherent with their personal and professional conceptions.

3.8.2 Assessment text of reflective actions during teaching

Learning to teach is a situated practice because it takes place in a particular location shaped by a unique set of personal, institutional, and social factors. Contextual factors such as learner prior knowledge can affect a student teacher's teaching and reflective actions during teaching. Mathematical concepts are developed in a cumulative manner such that failures to understand lower order concepts may result in a lack of understanding of higher order ones. Student teacher ability to respond to these learning variables required effective reflective actions during teaching. Reflective actions during teaching can enable student teachers to gain professional focus on teaching issues that can enhance learner understanding. Reflection on significant events as they unfold during one's teaching can enable student teachers to use various frames to look at and interpret learner actions and outcomes, and respond to them in ways that can promote learner understanding. Student teachers' ability to respond to learner needs while teaching a lesson were detected through assessment of a lesson that produced assessment texts of the student teacher responses to learner actions and needs as well as illustrative episodes from a lesson.

3.8.3 Post-lesson reflective interviews

Teaching is a complex profession that varies from time to time and involves wise choice of decisions in order to appropriately respond to the learning contexts created by learners. The complexity of teaching allowed numerous interpretations of learner and teacher behaviour giving rise to diversified opinions on the interpretations of instructional dilemmas and how they were resolved. Strategies for implementing pedagogical theories were elaborated when assessors discussed the rationales for decisions made during instruction in post-lesson reflective interviews with a student teacher.

Post-lesson reflective interviews provided a forum for analyzing how assessors and student teachers coordinated and integrated their theoretical pedagogical knowledge bases. They also enabled assessors to understand a student teacher's reflective actions during teaching, after discussing the practical learning situations created by learners and the effectiveness of pedagogical strategies used. Engaging in an assessor and student teacher post-lesson reflective interview facilitated listening to the rationales for instructional decisions, thinking about assessment, student teacher conceptions of teaching and learning, and for understanding decisions made during instruction, and what was seen, heard, and felt about a lesson. Assessor, peer, and student teacher post-lesson reflective interviews also enhanced the formulation and evaluation of the effectiveness of pedagogical strategies, explanations, and purposes of decisions, examples, and arguments that were used to defend actions made during teaching. Such post-lesson reflective interviews facilitated inquiry and models of teaching in which an assessor and a student teacher attitude, conceptions of teaching and learning, and values could be modified, extended, or verified.

3.8.4 Reflective interviews at the end of school attachment

Reflective interviews with student teachers at the end of teaching practice period were useful to assess changes in their teaching cognitions and evidence of reflection in their practice. Clarke and Chamber (1999: 294) applauded such interviews as enabling student teachers to defend "the extent they self improved their reflections by articulating and defending their own purposes and relating them to their personal and professional opinions". Group reflective interviews gave student teachers opportunities to elaborate the decisions and actions that they made during instruction and exposed their attitudes towards CRP. A discussion of the validity and reliability of the instruments used for detecting reflection relating to this study is provided next.

3.9 Validity and reliability of instruments

Validity and reliability are two key concepts that are critical in research in order for findings to be genuine and of value. Validity is the extent to which a research instrument measures what it is designed to measure, while reliability is the extent to which a research instrument consistently measures variables that influence the answers to a research question. This section considers the

validity and reliability of the instruments used to measure student teacher post-lesson reflective texts, reflective actions during teaching, post-lesson reflective dialogues and group interviews.

3.9.1 Validity of assessments of reflective actions during teaching

The validity of assessment instruments for measuring reflective actions during teaching of student teachers is clearly contestable, and this has ramifications for reliability of researcher and peer assessment agreement. Validity of lesson assessment instrument is difficult to achieve because there are no standard classroom practices that permit replication of teaching skills. Teaching practices that are effective in one setting may be viewed differently in another setting where there are different instructional variables, constraints and circumstances (Munro, 2005). This implies that success in teaching is determined by the unique classroom contexts that are created by learners. This observation necessitates the view that a single best teaching method that guarantees learner understanding does not exist, but varieties and experimentations with teaching techniques characterize the art of teaching (Huang & Leung, 2005). Successful teaching, therefore, entails effective reflection-in-action that enhances student teacher identification of, and responses to, a host of challenges that are possible during a learning context.

The validity of the level of effective reflection-in-action is also difficult to achieve because there is no consensus on good teaching (Nyaumwe & Mavhunga, 2005). Open student classroom observation instruments (Ensor & Hoadley, 2004), in which peers and the researcher agreed on the precise ways in which reflective actions during teaching data were to be collected, provided common understanding of areas of assessment focus. Insight from pilot studies facilitated the use of open researcher and peer assessments of student teacher reflective actions during teaching based on the intentions of the collaborative assessments (Nyaumwe & Mtetwa, 2006).

The intention of the researcher and peer collaborative assessment was to promote student teacher learning to teach from personal experience viewed from different vantage points of a researcher and a peer. The researcher and peer provided formative assessments that were used to interpret student teacher competencies to teach, how they were implementing pedagogical strategies, and their responsiveness to learner needs. The closed instrument used by university lecturers at BUSE to assess student teacher teaching competencies was restrictive in that it assumed that

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student teachers can show standard teaching competencies that can be uniformly assessed on a five point Likert scale ranging from 0 (absolutely no competence) to 4 (excellent competence) (Nyaumwe & Mavhunga, 2005). Using that instrument, a subtotal of the ticked levels on the 25 item instrument indicated the percentage competency of a student teacher.

Recognition that the learning landscape is influenced by many variables necessitated that the researcher and a peer assessing the same lesson taught by a student teacher based their assessments on their understanding of learner-centred instructional strategies in vogue at the university. The researcher and peer assessors were expected to provide evidence from a classroom episode of conclusions that they made about the level of instructional competency achieved by a student teacher. Open assessments allowed a peer and the researcher to capture professional information and skills that student teachers were capable of performing that could fall outside the realm of skills specified in closed assessments (Ensor & Hoadley, 2004). The strategy of using open assessments was meant to generate multiple perspectives on interpreting instructional practice of a student teacher in a way that facilitated generalizations of implementation strategies of teaching methods to new situations. This enhanced promotion of self-assessment, awareness of strengths and weaknesses of a lesson, and critical reflection. Assessments based on a peer and researcher interpretation of the unfolding instructional context recognize the pervasive changes that can be noticed in mathematics classes that disregard standard classroom practices as the trick to achieve excellence in teaching and learning. Researcher and peer open assessments recognize that there are no best teaching strategies because teaching is an interpretive, tacit skill that depends on experimentations in fluid learning environments that are influenced by learner skills, local constraints, other limitations, circumstances, and the nature of the content.

Ultimate decisions on the level of reflective actions during teaching that student teachers could achieve, were based on good or bad teaching that influenced learner understanding. Incontestable peer and researcher attributes of good teaching were; clarity of questions that challenge learner thinking, listening carefully to learner contributions, deciding on when to provide information, when to let learners struggle and when to orchestrate whole class discussions, and ensuring that all learners actively participate in class activities (Peressini *et al,* 2004). Learner active

participation in classroom activities recognizes that learning mathematical concepts is both an individual and social activity.

In contrast to good teaching, bad teaching was typically characterized by student teacher poor relationships with learners, lack of classroom management, ineffective decisions and actions, and lack of content mastery (Younger, Brindley, Pedder & Hagger, 2004). Common understanding of good and bad teaching practices entailed agreement on the area of focus to make valid assessments of student teacher reflective actions during teaching. The purpose of peer and researcher assessment was formative (student teacher reflection-in-action to identify learner needs and modifying their teaching to meet the needs). Some possible common areas on which peer and researcher assessments focused on were; identified skills on pace of lesson, logical sequence of content, choice of resources, classroom management, pedagogical approaches, content mastery, use of learner prior knowledge, and link of content to learner everyday experiences, among others.

As advised by Ensor and Hoadley (2004), the validity of open assessments arises largely at the analysis stage. In this case, at the analysis stage care was made to increase validity and reliability of interpretations of assessment texts made by peers and the researcher of the lessons to interpret the relationships between teaching practices, pedagogical strategies, and decisions on the effectiveness of reflective actions during teaching. To increase the validity and reliability of interpreting peer and researcher assessment reports, video tapes of lessons taught by student teachers were taken in the first and last assessment rounds of visits in order to provide concrete evidence to verify teaching contexts and peer and researcher interpretations during post-lesson reflective dialogues (Younder *et al*, 2004).

After assessing a lesson, a post-lesson reflective dialogue was conducted between the researcher, peer, and a student teacher who taught a lesson assessed. During the post-lesson reflective dialogue the researcher and the peer discussed the lesson vicariously while a student teacher elaborated on the decisions and reflective actions they enacted during instruction in retrospect. The post-lesson reflective dialogues were expected to generate multiple perspectives that could help the student teacher, peer, and the researcher bring their pedagogical theories to the fore and

use them to interpret an instructional episode. This was meant to assist the student teacher who taught the lesson, and was at the centre of the reflective dialogue, to learn from personal teaching experiences and express their new understanding on implementing pedagogical strategies and interpreting classroom contexts in the post-lesson reflective text.

3.9.2 Validity of post-lesson reflective text assessments

Post-lesson reflective texts express student teachers' teaching experiences through thinking deeply to replay, revise, and transform instructional experiences into teaching and learning tools. They narrate teaching experiences of student teachers, which portray how one understands personal teaching. Student teachers' use of the CRP framework to guide their reflection increased the validity of the post-lesson reflective text because the framework enhanced reviewing of critical issues that influenced their teaching practices. The validity and reliability of post-lesson reflective texts arose largely at the analysis stage when interpreting the texts and placing them in the appropriate levels of reflection (Ensor & Hoadley, 2004).

A possible limitation posed by narratives that could compromise the validity of the post-lesson reflective texts written by student teachers in this study is that they presented their narratives in a second language. It was possible that the choice of words in writing the narratives could compromise their sense making leading to distorted reflective narrations. For instance, the quality of the reflections could influenced a pre-service teacher's ability to express reflections in written form, making skilful writers produce texts that achieved higher reflection categories than their counterparts with a lesser vocabulary.

3.9.3 Reflective interviews

Reflective group interviews were conducted at the end of the teaching practice period of the student teachers. Student teachers were asked to elaborate their rapport with guidance, and views on the professional skills that they developed as a result of CRP on their teaching and that of their peers. The interviews were transcribed verbatim in order to facilitate interpretation of responses. All the instruments discussed above were piloted and practiced on before the main fieldwork. The piloting also increased validity and reliability of the instruments.

3.10 Procedures for data collection

This section discusses how the instruments discussed above were used to collect data from the field. Ethical considerations and logical sequence that optimized time and the implementation of the instruments for collecting data were the major considerations made in order to collect valid and reliable data.

During the researcher's initial visit to schools, the student teachers who met the sampling criteria (see section 3.6.2) were identified. For ethical reasons, permission was sought from the identified student teachers to participate in this study. The sampled student teachers were made aware that assessments made by the researcher for this study were not contributing to their summative evaluation grades. Assessments to grade their teaching competencies were to be made by other lecturers in the university department. It was also made clear that participation in the study entailed more assessment visits to participants by the researcher than the rest of the student teachers on school attachment. The student teachers viewed more assessments as an advantage to them because participation in the study increased feedback on how well they were teaching which in turn increased their preparedness when their lecturers visited them for the purposes of summative evaluations. For this reason, the student teachers viewed participation in the study as increasing their chances of passing teaching practice which they were willing to accept.

After identifying the pairs of student teachers who were willing to participate in the study, the logistics were discussed with the participants in order to establish a common understanding of what was to be expected in the study. A common understanding of the peer and lecturer collaborative assessment, the post-lesson reflective interviews, and the stages in the CRP framework were reviewed. Characteristics of learner-centred pedagogies in vogue at the university were reviewed to enable participants' recall of the teaching methods they were encouraged to use. The purpose of the collaborative lecturer and peer assessments was agreed on as a formative evaluation exercise to determine the trajectory that student teachers go through to achieve reflection levels that they can attain.

The researcher, a peer, and sometimes a technician in the Department of Education at BUSE collected data from student teachers' live teaching sessions. Triangulation of data from post-lesson reflective texts, lesson assessments, post-lesson reflective dialogues and reflective group interviews allowed an assessment of the level of consistency of the CRP framework to guide student teachers' reflections on their teaching and depiction of possible changes in their cognitions emanating from CRP and teaching experience.

Five of the first lessons taught by each of the student teachers were video taped by the technician in the Department of Education and transcribed. Post-lesson reflective dialogues were conducted on the same day the lessons were taught and videoed in order to interpret them when the events of the lessons were still vivid. After assessing a lesson, post-lesson reflective interviews between a peer, student teacher, and the researcher were conducted in order to assess the reflective actions during teaching achieved by the student teacher who taught the lesson. The video tapes were played back during post-lesson reflective dialogues so that the conclusions written on the assessment critiques could be elaborated by an episode from a lesson and interpretations of the acts collaboratively made. The play back of the video taped lessons also standardised lecturer and peer assessments of student teacher reflective actions during teaching.

Data were collected during three and two rounds of visits from pre-service teachers on twelve weeks, and in-service teachers on four weeks of teaching practice respectively at their attachment schools. The initial rounds of visits for in-service teachers were made during the week ending 20 January 2006. The first and second data collection rounds of visits were made during the weeks ending Friday 27 January and 3 February 2006 respectively.

The rounds of visits for pre-service teachers were made between week ending January and March 2006. On average three hours were spent with each student teacher pair per visit. This makes a total of six hours at a school per each round of visits on a typical day. Of this time about half an hour was spent studying the post-lesson reflective text of a lesson previously taught and detailed lesson plan for the lesson to be assessed respectively. At most 70 minutes were spent on lesson observation and the remainder of the time was spent on conducting post-lesson reflective dialogues. The period at an attachment school and the number of visits permitted valid and

reliable assessments of the level of reflection category attained by a student teacher. Summaries of deployment patterns and topics taught during the rounds of visits are shown in Tables 4 and 5. For ethical reasons pseudonyms are used for student teachers to protect their identities.

Table 4: Deployment patterns for in-service teachers and topics they taught

Pair	Name	School type	Topics taught
1	Peter	Urban Government	Sequences and series Expansion of combined series
	Charles		Summing series Series expansion
2	Christopher	Urban Private	Division of complex numbers Mean and variance
	Nyasha		Introductory complex numbers Standard deviation and variance of grouped data

Pre-service teachers were mostly attached to non-examination classes to teach. The pre-service teachers were also given some selected lessons to teach in examination classes (Forms Four and Six) as a requirement of their programme to get familiar with teaching of all classes in the secondary school. Topics that some pre-service teachers were found teaching were different from the previous day's topics when they were found teaching a new topic or a class they do not normally teach. Mathematics has a spiral curriculum in which some topics are presented repeatedly in textbooks at different or the same class level covering different content depths. The student teachers were found teaching content in the order presented in the main textbook that was usually the only textbook available to learners.

Table 5: Deployment patterns of pre-service teachers, subject combinations, classes, and topics taught

Pair	Name	School type	Major subject	Minor subject	Topics taught
1	Tendai	Urban government	Mathematics	Chemistry	Laws of indices Similarity of plane shapes Linear fractional equations
	Richard		Mathematics	Biology	Sets Prime factors Equivalent fractions
2	Munashe	Urban government	Mathematics	Geography	Linear equations Simultaneous linear equations Not available on 3rd visit
	Mavis		Geography	Mathematics	Linear equations Simultaneous linear equations Not assessed on 3rd visit
3	Michael	Rural government	Mathematics	Chemistry	Venn diagrams Frequency curves and histograms Probability outcome tables
	Cynthia		Mathematics	Geography	Conditional probability Circle geometry Arc length and sector area of a circle

The rounds of visits to schools were made on a day when lessons taught by a peer and a student teacher were spaced out to allow time for collaborative researcher and peer assessments of a lesson taught by a student teacher. After assessing a lesson, the researcher and a student teacher assessed a peer teaching on the same day. Days for data collection from pre-service teachers were different from those for in-service teachers even when student teachers were deployed at the same school. Different days for assessing pre and in-service teachers were set because of the duration it took to assess a lesson and conduct post-lesson reflective interviews. Sometimes it was possible to conduct post-lesson reflective dialogues for one student teacher before assessing a peer's lesson but at other times the timetable did not permit that. In such instances, the post-lesson reflective dialogues were conducted one after the other after assessing a peer's teaching. As noted by Williams and Watson (2004), time lapses between a lesson observation and post-lesson reflective dialogue (immediate and delayed debriefing) did not pose any threat to validity and reliability of a debriefing session results.

Post-lesson reflective texts of the last lessons taught on the previous day of the visits were studied in order to determine the extent to which the strategies designed during the developmental stage of the previous lesson were implemented in the teaching plans of subsequent lessons. This was possible only in circumstances when there was continuity between concepts of the previous lesson and those of the lesson to be assessed. Plans for lessons to be assessed were also studied in order to understand how they were to be conducted. Equipped with an understanding of how a lesson was going to be conducted, the researcher and a peer sat in a lesson that a student teacher was teaching in order to assess the student teacher's reflective actions during teaching. Typical procedures for each of the data sources of post-lesson reflective texts, assessment of reflective actions during teaching, post-lesson reflective dialogues and group interviews are discussed in the next section.

3.10.1 Post-lesson reflective text
At the end of each detailed lesson plan used by student teachers there is a section for reflection on the lesson taught where they write post-lesson reflective text. Detailed lesson plans that are made by student teachers are kept in the teaching practice file. On the day of an assessment visit the researcher got a teaching practice file and selected the lesson plan of the previous day to study the post-lesson reflective text.

3.10.2 Researcher and peer assessments of student teacher reflective actions during teaching
The researcher and a peer assessed the reflective actions of student teachers during teaching at the same time and produced separate assessment critiques as described by Nyaumwe and Mtetwa (2006). Recognition that the learning landscape is influenced by many variables necessitated that the researcher and a peer assessing the same lesson taught by a student teacher base their assessments on their understanding of learner-centred instructional strategies in vogue at the university (see section 3.8.1). The inter-assessor reliability for the lesson assessments was addressed through the following process. A peer, a student teacher, and the researcher met to discuss and standardize the modalities for lesson assessment and established a common understanding of the tenets of learner-centred and teacher-centred instructional practices.

3.10.3 Post-lesson reflective dialogues

Post-lesson reflective dialogues were conducted as soon as possible after lesson assessments. In the post-lesson reflective dialogues student teachers explained rationales for their decisions and actions during instruction.

3.10.4 Reflective interviews

Group interviews with the pairs of student teachers were conducted at the end of the school attachment period to determine the professional benefits that they gained from collaborative reflections. The focus of the group interviews is shown in Appendix B. Transcriptions of group interview audios were played back on the day they were taken to facilitate interpretations when some episodes from the interviews were still vivid in the researcher's mind. Audio taping of the group interviews allowed replays that permitted (re)categorizing responses in appropriate themes emerging from the interviews. The data collected using the procedures described above necessitated systematic analysis.

3.11.0 Data analyses

Data from different instruments were analyzed by interpretative and analytic induction (Bogdan & Biklen, 1992 cited by Morrison, Mcduffi & Akerson, 2005) in this way: (a) reflective actions during teaching text, (b) post-lesson reflective texts, and (c) group interviews. How the data from each of these sources was analysed is shown below:

3.11.1 Analyzing reflective actions during lesson delivery text

As explained in section 3.8.1 assessment of student teachers' reflective actions during teaching is a difficult task. A common understanding of good and bad teaching practices provided insight on the extreme ends of a continuum on which reflective actions during teaching could be scored. Realization that typical teaching practices combine both good and bad aspects gave rise to satisfactory reflective actions during teaching as falling in the middle of the bad to good continuum. Whilst bad teaching practices are easy to identify, it is not so easy to identify bad reflective actions during teaching because reflection is an abstract concept that cannot be categorically identified as out rightly bad but can be unsatisfactory. The tacit nature of reflection necessitated that scoring of student teachers' reflective actions during teaching are done using the continuum unsatisfactory, satisfactory and good categories. The scoring of reflective actions

during teaching using these three categories was in tandem with the scoring of post-lesson reflective texts using the three levels of technical/descriptive, practical/dialogic, and systematic/critical reflections (van Manen, 1977; Hall, 1997; Hatton & Smith, 2006).   The scoring of reflective actions during teaching text was made collaboratively between the researcher, peer, and the student teacher during post-lesson reflective dialogues using the following taxonomy:

Table 6: Categories of reflective actions during teaching and narrations of typical indicators

Category of reflective actions	Typical indicators
Unsatisfactory	- Complete failure to deliver a lesson. - Notice learner misconceptions but cannot correct them. - Decisions made do not result in learner understanding. - Sequence of content is not logical to enhance learner understanding. - Ignores learner misconceptions in favour of right or wrong responses.
Satisfactory	- Satisfactory mastery of content under review. - Classroom management skills promote mediocre learning. - Teaching caters for some learner individual differences.
Good	- There is evidence of being self critical on the execution of pedagogical strategies. - Classroom atmosphere is conducive for learner individual and social construction of concepts. - Use of multiple pedagogical strategies enhance learner understanding. - Content is related to existent realities of learners and other subjects they study. - Selection, structuring, and sequencing of content are logical. - Caters for learner individual, intellectual, and emotional needs. - Improvises to increase learner understanding of concepts.

The ultimate reflective action during teaching category to which a student teacher achieved was socially negotiated by the researcher, peer, and student teacher. For instance, Richard taught the topic of sets in the first round of visits. The peer's verbatim assessment critique stated that:

> Richard's soliciting of learner prior knowledge through question and answer was effective despite a short 'wait' time between questions and learner answers.   The use of differentiated tasks on work cards for group activities was strength of the teaching. Ineffective reflective actions during teaching were depicted when Richard failed to notice learners' solutions that were not correctly presented in set notations. Ineffective reflection was also exposed through asking learners to solve

group activities quietly leading the learners solving them individually in order to maintain the quietness required. There were also limitations on picking learners seated in the front row of the class to present solutions on the board (Peer's assessment critique of Richard's reflective actions during teaching).

The new statements on the researcher's verbatim assessment critique were that:

> The definition of a set discussed in the lesson was not specific for learners to identify unique elements of a set. The use of objects in learners' environment to elaborate the signs of "element of" enhanced learner understanding of the concept. The question and answer session that was used to conclude the lesson was effective, (Researcher's assessment critique of Richard's reflective actions during teaching).

The researcher and the peer consensually agreed on Richard's level of reflective actions during teaching in the first round of visits as falling in the satisfactory category (level two). This agreement was based on Richard's showing acceptable mastery of content under review because he gave a functional definition of a set that could be improved on to make it more specific. The classroom management skills promoted mediocre group learning because asking learners to solve some questions quietly reduced their capacity to negotiate meaning in order to socially construct mathematical concepts.

Each of the assessment critiques of reflective actions during teaching written by the researcher and a peer were similarly analysed and the categories of reflective actions were collaboratively deduced. Interpretative processes were also used to collaboratively score the post-lesson reflective texts written by student teachers.

3.11.1.1 Piloting an instrument for assessing reflection-in-action

The open assessment instrument that was used in the main study to assess the validity of researcher and student peer collaborative assessments was piloted on in-service teachers in the field as described below:

3.11.1.2 Efficacy of college lecturer and student peer collaborative assessment of in-service mathematics teachers' teaching practice instruction (Nyaumwe & Mtetwa, 2006)

This pilot study explored the extent to which collaborative researcher and peer assessment of in-service teachers' teaching practice was viable. The study was in response to criticisms that college lecturers' assessments were not producing valid critiques of in-service teachers' mathematical and pedagogical competencies in implementing pedagogical strategies they learned at college during the in-service teachers' field practice. Case studies of two pairs of in-service teachers on teaching practice, one pair at a state and the other at a private high school, provided data for this study. The in-service teachers were from a cohort group of 22, learning new pedagogical skills and upgrading their content to undergraduate level.

Findings from the pilot study indicated that lecturer and peer assessment of the same lesson taught by an in-service teacher resulted in different but complementary critiques. A lecturer's critique highlighted both strengths and weaknesses of a lesson whilst some peers' critiques refrained from being judgemental. Collaborative lecturer and peer assessment of in-service teachers' classroom practices was possible as discussed in this pilot study.

The researcher and peer collaborative assessment of student teachers' teaching was critical for this study for two reasons. First, it was conceived that the collaborative assessment process would consolidate the collaboration that this study advocates. Second, the collaborative researcher and peer assessment of a student teacher teaching was viewed as a strategy that increased the validity of the data collection process through generating data from multiple sources and perspectives (see section 3. 8.2). Multiple data sources also have the potential to increase the vantage points for answering the research question.

3.11.2 Analyzing post-lesson reflective texts

Judging the extent to which a post-lesson reflective text was narrative, interpretive, or critical of teaching practice did scoring on the post-lesson reflective text. Placement of post-lesson reflective texts in appropriate reflection categories was done using the categorizations in the table below:

Table 7: Categories of reflection-on-action and narrations of typical indicators

Reflection level	Narration of typical professional skills
I Technical, or descriptive reflection	• Narration of pedagogy, information about learners, content mastery, availability of instructional resources. • Repetition of mistakes, preoccupation with techniques. • Places emphasis on personal survival. • Makes superficial conclusions and recommendations.
II Practical, deliberate or dialogic reflection	• Analyses pedagogy and theories of learning. • Desires to improve practice but suggests impediments. • Concentrates on technical skills. • Clarifies assumptions and predispositions underlying competing pedagogical goals. • Analyzes learner and teacher behaviours to see if and how goals were met.
III Critical or systematic reflection	• Involved multiple perspectives that are located in and influenced by multiple historical and socio-political contexts. • Shows critical analysis of pedagogy, theories of learning, and interests of students. • Admits errors and omissions and suggest clear ways of overcoming them. • Shows critical thinking, self assessment, and self directed learning. • Shows a broad understanding of the learning environment by reviewing personal conceptions in the light of the learning milieu. • Improvises in order to improve teaching. • Shows openness to moral and ethical considerations, interpretive and suggests practical ways to improve practice.

Using the taxonomy in Table 7 the post-lesson reflective texts that were written by student teachers were collaboratively placed in appropriate reflection categories. To increase the validity of interpretations, scoring of post-lesson reflective texts was done anonymously when the student teachers returned to campus for their final semester. The post-lesson reflective texts were typed verbatim by the researcher to preserve their originality. Pseudonyms used for student teachers in this study were put on the typed texts to disguise the identity of the student teachers who wrote them. The typed post-lesson reflective texts were produced in pairs so that different pairs of student teachers and the researcher could assess the reflection category of the post-lesson reflective text separately. In instances where a peer and the researcher differed on the reflection category achieved, a third assessor from a different pair of student teachers was asked to reassess the post-lesson reflective text. In circumstances when there was disagreement again on reflection category, the post-lesson reflective text was placed in the reflection category on which any two of

the three raters concurred. For instance, the post-lesson reflective text written by Charles in the first round of assessment visits on the topic summation of infinite series was assessed as follows:

> The groups were rather too large, they possibly created passiveness among some learners. Learners should work on group tasks in pairs to optimize negotiations. I should move around, and assist learners to sum up infinite series using the summation sign. I should not rush to get answers from learners. I was not also responsive to learners' needs and solutions. I should identify learners to work on the chalkboard and give them time to explain their answers or ask their peers to critique the methods used and the solutions obtained. I should allow more learners to participate in class activities in order for them to construct the general formulae for given series. Some group work tasks were not discussed in class. If time runs out it is necessary to concentrate on few concepts and ensure learner understanding of them. However, the lesson was particularly a good one. I had strong content mastery and have the confidence to speak before the learners (Post-lesson reflective text: Charles, 24 January 2006).

Charles' peer placed the post-lesson reflective text in the technical category (level one). The peer's verbatim comments to justify level one reflection were:

> This student teacher is pre-occupied with the identification of teaching misjudgements. The technical aspects form the major part of the reflection. After a lengthy narration of weaknesses, the student teacher has the audacity to say that the lesson was "particularly a good one". This is technical reflection where little or no analysis is put (Peer's comments).

The researcher placed Charles' reflection at practical reflection category (level two) arguing:

> The reflection notes the weaknesses of the student teacher, for instance, using large groups, not responsive to learners' needs etc. Some suggestions are made to improve practice though they are not well thought out for their practicality. Desire to improve practice is a practical reflection category predictor (level two) (Researcher's comments).

The differences in the researcher and a peer assessment of the category of reflection of the post-lesson reflective text written by Charles necessitated a third opinion. The third opinion placed Charles' post-lesson reflective text in technical reflection category (level one) arguing:

> The reflection focuses on self-assessment. This is revealed in statements like "I should have moved round the classroom, and assist learners to construct concepts and I should not rush to get answers." These are technical suggestions that are made without explaining the circumstances that warranted them (Third assessor).

The peer and third assessor concurred that Charles' post-lesson reflective text belonged to technical reflection category (level one). The other post-lesson reflective texts written by student teachers were scored in a similar way. Placement of the post-lesson reflective texts into categories of reflection partially answered the research question on whether student teachers can critically reflect on their teaching. To assess the extent to which the CRP framework influenced the category of reflection that student teachers achieved necessitated that data from post-lesson reflective texts be coded using typical indicators in the phases of the CRP framework.

3.11.3 Analyzing post-lesson reflective texts using phases of the CRP framework

The four phases of the CRP framework could not be discretely observed on post-lesson reflective texts but were spread throughout the text. Coding of the post-lesson reflective text using key words as indicators for specific stages of the CRP framework was adopted. The indicators for each of the phases in the CRP framework are shown in tabular form below.

Table 8: CRP phases and narrations of typical indicators on a post-lesson reflective text

CRP phase	Typical indicators
Conception	Drives for certain preferences such as teaching methods, learner prior knowledge, resources or, any other variables that are determined by student teacher choices among alternatives.
Context	Depicted by descriptions of the learning environment. For instance, learner behaviour, student teacher responses to learner knowledge and skills, pace of covering content, and level of difficulty of activities.
Evaluation	Depicts student teacher judgments. For instance, level of success or failure of a lesson, learner skills and knowledge, decisions on learner achievement, learning environment, and learner responses to questions.
Development	Suggestions for improving teaching. For instance, covering concepts at the learner pace rather than rushing to cover all concepts planned for a lesson, reduce group sizes to three or set more difficult work for bright learners, etc.

To assess the influence of the CRP framework on student teachers' reflections-on-action, the post-lesson reflective texts were coded using the framework phases. The effectiveness of the CRP framework to guide student teacher post-lesson reflections was determined by the extent to which the frequency of phase codes on texts influenced the overall reflection category. The coding was done as follows; 1 for indicators in the conception phase, 2 for indicators in the context phase, 3 for indicators in the evaluation phase, and 4 for indicators in the development phase. Scoring using the coding (numbers in parentheses [ ] show indicators for a phase in the

CRP framework) on a typical post-lesson reflective text is exemplified on Nyasha's post-lesson reflective text on parametric equations below:

> The lesson was challenging [3] enough to enable learners to develop [2] critical thinking skills. Learners could find [2] the Cartesian equations of given curves and equations of tangents and normals to given curves. Finding the gradient of a chord was easy [3] for most learners. However, more practice [4] is needed on finding the coordinates of the point of intersection of curves. Factorization of the polynomial equations of higher order was difficult [3] for most learners. I exposed [2] learners to various techniques of factorizing polynomials and this enabled them to recall [2] their factorizing knowledge.
>
> The group work [1] approach used in this lesson enabled learners and me to explore a variety of methods to solve problems. This benefited [3] learners since individual learners could comment on the effectiveness of a method used. Learners had sufficient [3] prior knowledge (gradients of tangents and normals, differentiation of explicit functions, etc). This made the content of the lesson covered without deviations [2] to some missing knowledge gaps. There was ample [3] time for some consolidation exercises on the concepts covered in the lesson. I led learners to correct themselves on mistakes they exhibited [2] rather than providing them with correct answers. Worksheets [1] reduced excessive use of the board rendering the lesson learner-centred [3]. Learners gave correct [3] responses to questions asked during lesson closure (Post-lesson reflective text: Nyasha, February 2006).

The other post-lesson reflective texts were coded in a similar way.

3.11.4 Analysis of group interviews

Transcripts of audiotapes were produced verbatim and the student teachers were asked to read them in order to ensure sensitivity to the linguistic differences between oral speech and written text (Patton, 1990). The transcripts from the interviews produced a large volume of materials that were condensed and categorized into emerging themes to facilitate meaningful interpretation of the data. Interview transcripts were used to construct vignettes of the student teachers. The vignettes were expressed in narrative form that exposed the evidence supporting the themes emerging from the data.

3.12 Summary

This chapter discussed the methodology and design for the study. The nature of the problem necessitated the use of case studies. Use of development research to design and trial test the CRP framework in two phases was discussed and formative evaluations from field trials enabled revision and refinements of the framework before full implementation in the third phase. The nature of data that was appropriate to answer the research question, instruments for measuring reflective actions during instruction, post-lesson reflective texts and post-lesson reflective interviews were also described. The validity and reliability of instruments for assessing reflection, procedures for data collection, and data analyses strategies were discussed. At the end of the chapter there is a discussion of scoring on typical reflective texts and placement into appropriate categories using levels of reflection gleaned from literature. Chapter Four presents the results from in-service teachers.

CHAPTER 4: RESULTS FROM IN-SERVICE TEACHERS

4.1 Chapter overview

This chapter presents the findings from in-service teachers. The results are presented sequentially by round of visits. This set up is assumed to increase the visibility of the levels of reflection that each in-service teacher attained at each of the field visits made to attachment schools. In section 4.2 the initial visit of the study is outlined with a view to reaching a common researcher and in-service teacher understanding on procedures for peer collaborative assessment and post-lesson reflective dialogues using the CRP framework. Sections 4.3 and 4.4 present the in-service teachers' reflections in the first and second rounds of visits. Section 4.5 presents the impact of the CRP framework on guiding in-service teachers to reflect on their teaching practice. The relationships between reflection-on-action and reflection-in-action are assessed in section 4.6. Section 4.7 presents intercepts of interviews conducted at the end of the in-service teachers' school attachment. The focus of the chapter is summarized in section 4.8.

4.2 The initial visit

During the initial round of visits the researcher and the in-service teachers reviewed goals of the research in order to establish a common understanding of what each part was to play. When a common understanding of what collaborative assessment and reflection entailed was reached, it was ripe time to embark on the first round of data collection visits to assess the extent to which collaborative pairs were using the CRP framework during collaborative reflection sessions.

4.3 Assessments of reflections in the first round of data collection visits

This section presents in-service teachers' reflective actions during lesson delivery and post-lesson reflective texts during the first round of data collection visits. The observations of reflective actions during lesson delivery are based on the researcher and peer open lesson assessment critiques. The indicators shown in Table 6 were used to consensually place in-service teachers' reflective actions during teaching into appropriate reflective action categories using the procedures discussed in section 3.10.2. Placement of self written post-lesson reflective texts into appropriate reflection-on-action categories was done using indicators shown in Table 7 and the

procedures discussed in section 3.10.1. An assessment of the influence of the CRP framework to guide in-service teachers' post-lesson reflections was done as discussed in section 3.10.3.

Peer and researcher open lesson assessment critiques were on average one and half pages long each, making a possible total of three pages per in-service teacher for a lesson observed. In most cases both the lesson observation critiques highlighted some common instructional actions. To minimize repetitions of instructional skills presented on the lesson observation critiques and maximize clarity, the researcher and peer lesson assessment critique texts are presented verbatim in bullet point forms. Only aspects that are not mentioned on a peer's lesson observation critique are highlighted on the point form of the researcher's critiques. Samples of selected copies of full researcher and peer lesson critiques of the in-service teachers' teaching are shown in Appendices C1 and C2. Samples of in-service teachers' self-written post-lesson reflective texts are shown in Appendices D1 and D2.

The in-service teachers' data on reflective actions during teaching for each round of visits are presented using a template as follows: (a) bulleted verbatim statements extracted from a peer and researcher's assessment critiques on an in-service teacher's reflective actions during teaching, (b) consensually researcher and peer agreed reflection category for reflective actions during teaching, and (c) the reasons supporting the placement in a reflection category.

Presentation of the in-service teachers' self written post-lesson reflective texts are presented using the same template as used for presenting reflective actions during teaching but with slight changes on some phrases. For instance, the wording for (a) was changed to read bulleted verbatim statements extracted from an in-service teacher's self-written post-lesson reflective texts and parts (b) and (c) remain unchanged. After the second round of visits the levels of reflections attained by each in-service teacher are depicted pictorially by line graphs in order to assess the extent to which collaborative reflection with a peer influenced an in-service teacher's cognition on teaching. The reflections of each of the four in-service teachers and the levels of reflections attained are presented below.

4.3.1 Peter

Peter was observed teaching sequences and series during this round of visits. The 'A' Level lesson was on Arithmetic and Geometric progressions as shown below:

Applications of formulae for nth terms (T_n) and sum to n terms (S_n) of Arithmetic Progression (AP) and Geometric Progression (GP) using the formulae:

1(i) AP, $T_n = a + (n-1)d$ (ii) $S_n = \dfrac{n}{2}[2a + (n-1)d]$ or $\dfrac{n}{2}(n+l)$

2(i) GP, $T_n = ar^{n-1}$ 2(ii) $S_n = \dfrac{a(1-r^n)}{1-r}$.

The peer wrote the following statements on the assessment critique:

- The in-service teacher described a logical link between the introduction and the concepts on the arithmetic and geometric progressions.
- He was sensitive to learner needs, used multiple strategies to solicit learner ideas, employed good questioning techniques, engaged learners in clarifying each other's alternative conceptions, and used group-work to enhance learner interactions.
- Effective assessment methods of learner understanding, and appropriateness of content of the lesson were employed.

The researcher's observation critique stated the following:

- Group sizes of four and five members each were too large for all learners to actively participate in the construction of group solutions.
- The formation and solution of simultaneous linear equations using the first term, *a,* and the last term, *l,* of an arithmetic progression in the third problem was not understood by the visual, average and below average learners because they had difficulties of following the oral presentation of steps involved in solving the problem.

(b) Satisfactory reflection category (level two).

(c) Group sizes were too large for learner active engagements in constructing solutions. Oral presentation of group solutions was comprehensive to a section of learners (auditory learners) and the other section seemed not to understand the oral formulation and solution of a pair of simultaneous equations involving two unknowns.

The previous lesson's post-lesson reflective text on the binomial and series expansion stated:

- Most learners achieved the lesson's objectives.
- I succeeded to pitch the lesson to learners' pace.
- Learners did not have the assumed knowledge on combinations (^nC_r), hence, some unplanned time was spend reviewing the concept of combinations.

(b) Practical reflection category (level two).

(c) The post-lesson reflective text focused on the analysis of learner and in-service teacher's behaviours to see if and how goals in the form of both pedagogical and lesson objectives were achieved. The post-lesson reflective text also clarified assumptions that Peter held on ^nC_r and predispositions underlying the achievement of set goals.

4.3.2 Charles

Charles was teaching a lesson on summing series using the summation sign and expanding sequences up to 'n' terms during this round of visits. An example of a problem covered in the lesson is shown below:

> *Expanding sums to n terms of sequences under the summation sign such as $\sum_{n=1}^{6} n$ and expressing given sequences under the summation sign such as 2 + 4+ 6 + ...*

The peer wrote the following statements on his assessment critique:

- The introduction was good in that lesson objectives were stated to make the learners aware of what they were going to learn in the lesson.
- Learners' prior knowledge was linked to the new content of the lesson.
- The learners responded to questions asked by their peers.
- Group-work increased learner-learner interactions.

The researcher's assessment critique noted the following:

- There was no challenging work to cater for learners' differentiated abilities.
- There were no mechanisms to check learner mastery of the concepts covered in the lesson.

- There was a typographical error in the sequence $2 + 6 + 8 + \ldots$ that was only noticed when a learner was verifying the viability of $\sum_{n=1}^{\infty} 2n$ as the summation formula for the series.

- A learner who provided the summation of $1 + \dfrac{1}{2} + \dfrac{1}{3} + \dfrac{1}{4} + \dfrac{1}{5}$ as $\sum_{n=1}^{n=\frac{1}{5}} \dfrac{1}{n}$ should have explained the solution rather than the in-service teacher correcting it.

(b) Unsatisfactory reflection category (level one).

(c) Charles could not reflect on what he wrote on the board to check for typographical errors and there was limited reflection on diagnosing learners' alternative conceptions.

On the post-lesson reflective texts on the binomial expansion, Charles wrote the following statements:

- The pedagogical approaches used to cover Pascal's triangle were appropriate for learners.
- Checking on assumed knowledge revealed that the learners had forgotten the concept of combinations, $^{n}C_{r}$.
- The work planned for the lesson was not finished because the assembly and staff briefing took 10 minutes of the lesson's time.
- The work planned for this lesson and not covered will be taught in the next lesson covering the expansion of binomial functions such as $(x + y)^{n}$, when n < 1 (powers less than one).

(b) Practical reflection category (level two).

(c) The post-lesson reflective text mainly narrated impediments encountered during the lesson and concentrated on technical skills without interpreting sources of learners' alternative conceptions.

4.3.3 Christopher

During the first data collection round of visits, Christopher was observed teaching division of complex numbers of the form shown below:

$$Evaluate \frac{7+4i}{3-2i}$$

The peer's assessment critique noted the following statements:

- There was a good link of the new concepts with learners' prior knowledge. For instance, position vectors and the Cartesian coordinates were used to introduce the argument and the Argand diagram.

- There were logical progressions from specific methods known by learners to generalizations used to establish some relationships such as $(a + bi)(a - bi) = a^2 + b^2$. This led to learners' understanding of multiplication of complex number conjugates.

The researcher wrote the following statements on the assessment critique:

- The in-service teacher showed competence in using learners' prior knowledge in the development of the concept of complex numbers.

- Linking imaginary roots of a quadratic equation with complex numbers facilitated learners' understanding of the concept of the imaginary part 'i'.

(b) Good reflection category (level three).

(c) There were appropriate uses of learners' prior knowledge on position vectors and the Cartesian coordinates to develop new concepts on the Argand diagram. Using concepts from different topics to develop new concepts shows good knowledge of the structure of mathematical concepts that was well reflected on to produce a logical pace that was comprehensive to learners.

Christopher's post-lesson reflective text on the previous lesson covering the trapezium rule stated the following statements:

- There was learner understanding of estimation of area under a curve.

- Learners accurately calculated the heights $y_1, y_2, y_3, ..., y_n$ of different trapeziums.

- Learner interactions during group-work were good.

(b) Technical reflection category (level one).

(c) The post-lesson reflective text portrayed successful teaching without giving evidence for the success. The successes of the lesson were highlighted to portray survival skills in the classroom.

<u>4.3.4 Nyasha</u>

In the first data collection round of visits Nyasha was assessed introducing complex numbers using learner knowledge of solving a quadratic equation with imaginary roots as shown below:

> *Introduction of i = $\sqrt{-1}$ as i² = -1 through solving a quadratic equation with imaginary roots such as   x ² - 6x + 13 = 0.*

The peer noted the following statements on the assessment critique:

- The introduction was good because it stretched learners' knowledge from the known to the unknown.
- The lesson development was characterized as individualized because learners were picked by names to answer questions.
- Chorus answers were discouraged.

The researcher's assessment critique noted that:

- After noticing that addition of complex numbers was not challenging enough for learners, the concept of multiplication of complex numbers was introduced using the discovery method.
- In the multiplication of (1 – 3i)(2 + 5i) one learner produced the solution of 17 – i and the other one obtained 2 -15i^2 .
- The in-service teacher explained the simplification of 2 -15i^2 using the relationship i^2 = -1.
- The error in the distributive law on multiplying the real parts in 2 – 15i was exposed and the solution was reduced to 17 – i.
- After summarizing how to multiply complex numbers, the concept of modulus of complex numbers was introduced.

(b) Good reflection category (level three).

(c) The in-service teacher used appropriate reflective actions on pacing the lesson content. Learners' prior knowledge were utilized in the development of addition and multiplication of complex numbers and the concept of the imaginary part, i. The pace of the lesson was increased after realizing that learners easily understood the concepts they were learning.

The post-lesson reflective text on the previous lesson on parametric equations noted the following points:

- Learners calculated easily the Cartesian equations of given curves as well as equations of tangents and normals to given curves.
- More practice is needed on finding the coordinates of the point of intersection of curves.
- Factorization of the polynomial equations of higher order was difficult for most learners.

(b) Practical reflection category (level two).

(c) The post-lesson reflective text mainly narrates events of the lesson without being interpretive.

4.4 Reflections during the second and final round of data collection visits

4.4.1 Peter

In the second and final round of visits Peter was observed teaching the topic of expansion of combined series shown below:

Use the Maclaurin's theorem to expand $f(x) = e^{2x} \cos 3x$ up to the term in x^3.

The peer's written assessment critique pointed out that:

- The in-service teacher told learners that they were going to use their knowledge of expansion of series to expand combined series, one at a time using Maclaurin's theorem and then perform the product.
- Learners were asked to respond to questions posed by their peers during class discussions.
- Learners were randomly selected to expand $f(x) = e^{2x} \cos 3x$ during group presentations.
- After class demonstrations of the application of the Maclaurin's theorem, pairs of learners were asked to expand nine more functions involving combined series using the theorem as consolidation exercises.

- The lesson was not concluded because it ended when learners were still solving the group tasks given.

The researcher's written assessment critique noted the following statements:

- A learner wrote $e^{2x}\cos3x = 1 + 2x + \dfrac{5x^2}{2!} + \ldots$ This was not up to the term in x^3 as stipulated in the instruction.
- The in-service teacher did not notice the sign error in simplifying $\dfrac{4x^2}{2!} - \dfrac{9x^2}{2!}$ to $\dfrac{5x^2}{2!}$ instead of $-\dfrac{5x^2}{2!}$.

(b) Satisfactory reflection category (level two).

(c) The in-service teacher failed to notice that the learners' solutions were not complying with the instruction of the question and that some computational errors involving directed numbers existed in some learners' solutions. However, a provision of nine problems to be solved by learners in pairs enabled them to practice the skill of applying the Maclaurin's theorem.

Peter's written post-lesson reflective text on the previous lesson on Maclaurin's expansion and applications made the following statements:

- The lesson was learner-centred in that almost all the learners were active in class and volunteered to answer the questions on the board.
- Some learners showed confidence in whatever ideas that they held on the range of convergence of x in the expansion of ln (1 + x).
- A lot of ranges for the validity of ln (1 + x) were considered by learners and they finally agreed on -1 < x < 1 as the range in which convergence of the function could occur.
- Both the content and pedagogical objectives were achieved.

(b) Critical reflection category (level three).

(c) The post-lesson reflective text emphasized learner active negotiations of the valid range of convergence of ln (1 + x). Learners agreed on the range of -1 < x < 1 after considering several convergence possibilities such as -1 < x > 1.

A summary of Peter's reflections during the two data collection rounds of visits is shown below:
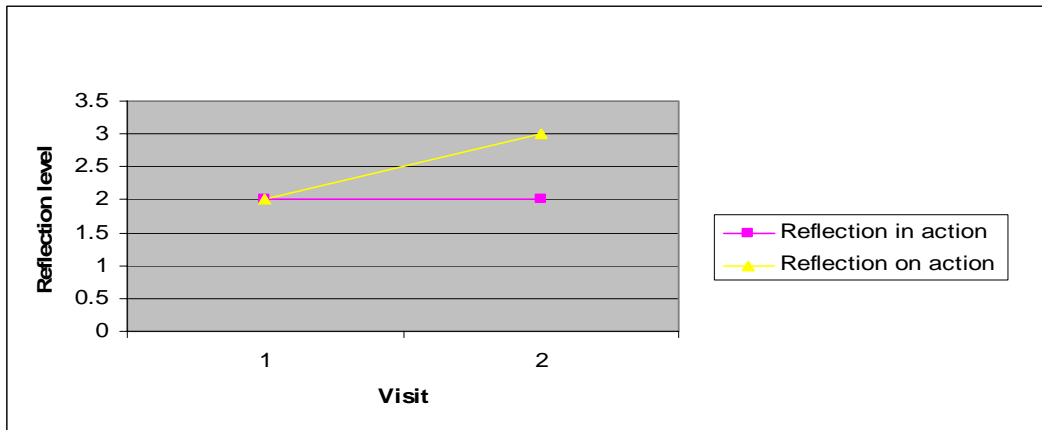
Graph 1. Peter's reflections

The graph shows achievement of constantly higher reflection categories on post-lesson reflective texts than on reflective actions during teaching during the period under review. The post-lesson reflective text increased from practical reflection category (level two) to critical reflection category (level three) during the first and second rounds of visits. The reflective actions during teaching remained constantly in the satisfactory category during the first and second rounds of visits.

4.4.2 Charles

In the second data collection rounds of visits Charles was observed teaching series expansion shown below:

> State the Maclaurin's theorem and use it to expand (i) $e^{2x} \cos3x$ and (ii) $ln(1 + x)$ up to x^2.

The peer wrote the following statements on the assessment critique:
- Learners were given some challenging series to expand using Maclaurin's theorem.
- There were high learner-learner and in-service teacher-learner interactions during the lesson that triggered debate and social construction of strategies for applying the theorem.
- The in-service teacher dismissed $-1< x \geq 1$ as the range for convergence of the expansion of $ln (1 + x)$ without explanations.

The researcher's assessment critique noted the following:

- Two learners wrote on the board the general term of the Maclaurin's theorem as $\dfrac{x''}{n!}$ and $\dfrac{f^{(n)}(0)x^n}{n!}$ respectively.
- The in-service teacher erased the first generalization and accepted the second one without debating the viability of the two generalizations.
- Concluding the lesson with an application of the Maclaurin's theorem on a chart showing the various steps involved exposed possible learner errors on applying the theorem.

(b) Satisfactory reflection category (level two).

(c) The in-service teacher was insensitive to learners' wrong responses. This conclusion was evident in the in-service teacher's insensitivity to learners' needs shown through discarding learner alternative conceptions on the Maclaurin's theorem without debating the viability of the responses they provided.

Charles's post-lesson reflective text in which the Binomial expansion was covered in the previous lesson noted the following:

- Learners were given hints to construct Pascal's triangle.
- Learners were asked to expand $(x + y)^3$ and $(2 - 3x)^3$ using Pascal's triangle.
- Higher powers of the binomial functions were used to introduce the Binomial theorem.

(b) Practical reflection category (level two).

(c) The post-lesson reflective text narrated the in-service teacher's and learners' actions without interpreting their outcomes. The post-lesson reflective text concentrated on technical skills without engaging in self criticism.

A summary of Charles's reflections during the two data collection visits is shown in Graph 2.
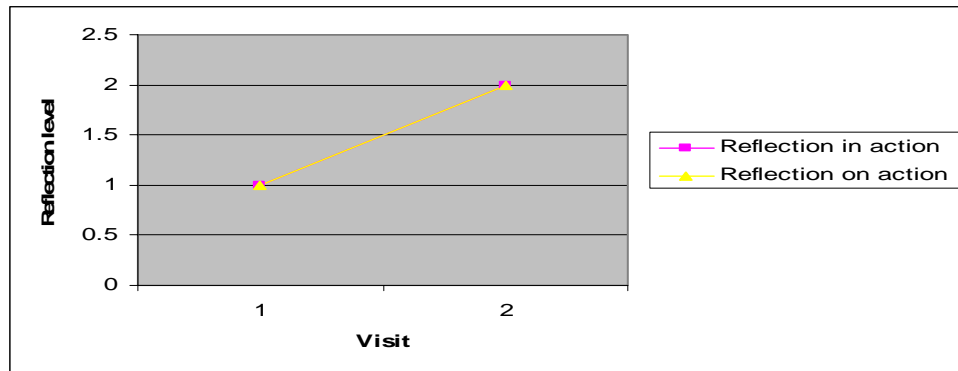
Graph 2. Charles' reflections

Charles's reflective actions during teaching and post-lesson reflective texts gradually improved at the same rate from technical and unsatisfactory reflection category (level one) to practical and satisfactory reflection category (level two) during the first and second rounds of assessment visits.

4.4. 3 Christopher

In the second round of visits Christopher was observed teaching the concepts of mean and variance to an 'A' Level class. The content of the lesson is shown below:

Deriving the variance formula, Var(X) = $\dfrac{\sum (x - \bar{x})^2}{n}$ or Var(X) = $\dfrac{\sum (x - \bar{x})^2}{n}$

$= \dfrac{1}{n} [\sum (x^2 - 2x\bar{x} + \bar{x}^2)]$ *and their applications to calculate variances of given data.*

The peer's written assessment critique noted the following on Christopher's teaching:

- The in-service teacher used small numbers that were less than 10 to simplify calculations of mean and variance.
- The data used in the lesson had the same numeral 5 for the number of terms ($n = 5$) and five the calculated mean ($\bar{x} = 5$).
- The learners were confused on which of the 5 was used to calculate the mean deviation.
- The verification of the two formulae for variance,

Var(X) = $\dfrac{\sum (x - \bar{x})^2}{n} = \dfrac{\sum x^2}{n} - \bar{x}^2$ was difficult for most learners to understand.

- The learners had difficulties to understand that $\sum \bar{x}^2 = n\bar{x}^2$.

The researcher's assessment critique noted the following points:

- The use of data comprising numbers less than ten was not suitable for learners with scientific calculators.
- The in-service teacher failed to adjust the level of difficulty of the numbers when learners mentally calculated the mean of the data with numbers less than ten.
- The counter example that used numerical values to illustrate that
  $\sum(x^2 - 2x\bar{x} + \bar{x}^2) = \sum x^2 - \sum 2\bar{x}x + \sum \bar{x}^2$ enhanced learners' understanding of the distributive law over the summation sign.

(b) Good reflection category (level three).

(c) The in-service teacher provided counter examples of algebraic equations involving numerical values that enhanced learners' understanding of the distributive law over the summation sign.

The in-service teacher's post-lesson reflective text of the previous lesson on standard deviation noted that:

- The introduction of the lesson appealed to most of the learners as it linked their prior knowledge of the mean with the new work on variance.
- The lesson objectives were achieved because learners were able to find the variance of given data using mean deviations and the formula $\text{Var}(X) = \sum \frac{(x - \bar{x})^2}{n}$.
- Learners should be exposed to calculator statistical functions that they are incapable of using.
- The pedagogical objectives were also achieved because the learners successfully worked in pairs when calculating the variances and standard deviations of the given data.

(b) Practical reflection category (level two).

(c) The post-lesson reflective text highlighted technical skills such as learners' correct use of the formula for finding variance and standard deviation. The text also narrated achievement of

objectives without analyzing the in-service teacher's interpretations of learners' actions and outcomes.

A summary of Christopher's reflections during the two rounds of visits is shown in Graph 3.
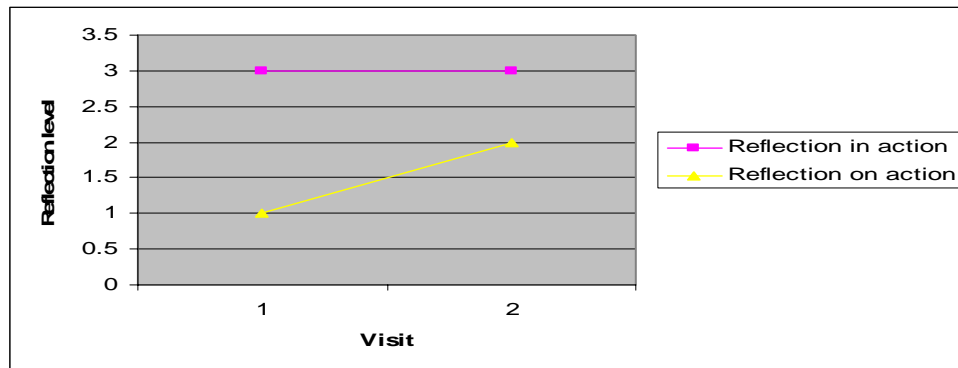
Graph 3. Christopher's reflections

Christopher's reflective actions during teaching were constantly at a good reflection category (level three) during the observation visits. The post-lesson reflective texts improved from technical reflection category (level one) to practical reflection category (level two) during the first and second rounds of visits respectively.

4.4. 4 Nyasha

Nyasha was teaching the concepts of standard deviation and variance of grouped data in the second round of data collection visits using the data shown below:

(i)   *Find the variance of the data 1, 2, 1, 2 1, 1, 4, 3, 4, 3, 5, 3, 3, 3, 4, 5, 5, 2, 3, 3, 3, 2.*
(ii)   *Find a general formula for calculating variance.*

The peer's written assessment critique noted the following statements:
- The discovery method was used for learners to find a suitable way of representing this data in an economic and orderly way.
- Learners used the tally method to express the data in frequencies.
- The learners were asked to find a formula for calculating the variance of grouped data. They suggested the following formulae a) $\dfrac{\sum f(x-\bar{x})^2}{\sum f}$, and b) $\dfrac{\sum (x-\bar{x})^2}{f}$.

The researcher's written assessment critique noted that:

- The in-service teacher preferred to use the formula $\text{Var}(X) = \dfrac{\sum f(x - \bar{x})^2}{\sum f}$ without explaining why $\text{Var}(X) = \dfrac{\sum (x - \bar{x})^2}{f}$ was not suitable.

(b) Good reflection category (level three).

(c) The in-service teacher actively involved learners through explorations to express repetitive data economically and construction of a formula for calculating variance of grouped data.

The post-lesson reflective text that Nyasha wrote in the second round of visits on partial fractions noted the following:

- The use of the question and answer session approach was appropriate because it kept learners attentive throughout the introductory stages of the lesson.
- The learners' responses to questions can be used to conclude that the assumed knowledge (improper fractions, long division etc) determined by the in-service teacher was appropriate.
- Some learners found division of polynomials difficult at the beginning of the lesson.
- Instead of me answering learners' questions I probed their solutions and provided clues that enabled them to answer some difficult questions asked.
- Insight developed from teaching this lesson is that learners can contribute a lot of useful ideas towards the development of new concepts and, therefore, they should not be treated as empty of mathematical knowledge that can be used to build some selected new concepts.

(b) Critical reflection category (level three).

(c) The in-service teacher used multiple teaching strategies that enhanced learners' understanding of decomposing polynomials into partial fractions.

A summary of Nyasha's reflections during the two rounds of visits is shown in Graph 4.
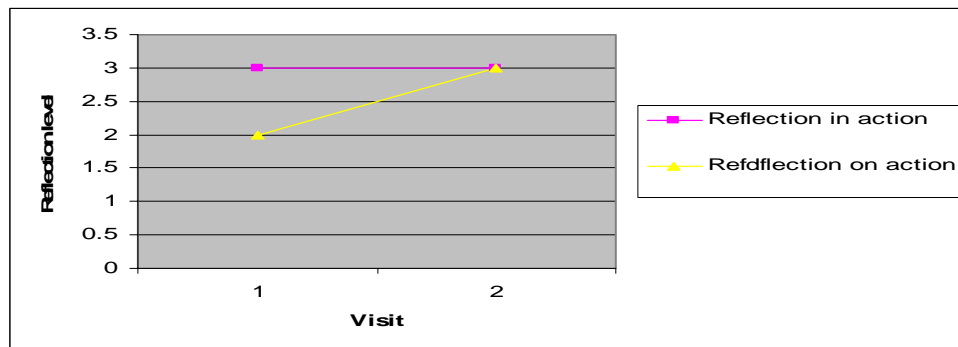
Graph 4. Nyasha's reflections

Graph 4 shows that Nyasha's reflective actions during teaching were constantly at the good reflection category (level three). The post-lesson reflective texts show improvements from practical reflection (level two) to critical reflection (level three) during the first and second rounds of visits respectively.

Some of the in-service teachers achieved different levels of reflection-on-action and reflection-in-action during different rounds of visits. It is necessary to determine whether there is a causal relationship between reflections-on-action and reflections-in-action.

4.5 Determining the relationship between reflection-on-action and reflection-in-action

A scatter diagram was used to assess whether there was a relationship between in-service teachers' reflections-in-action and reflections-on-action, that is to say, whether reflection-in-action influenced reflection-on-action or vice versa.
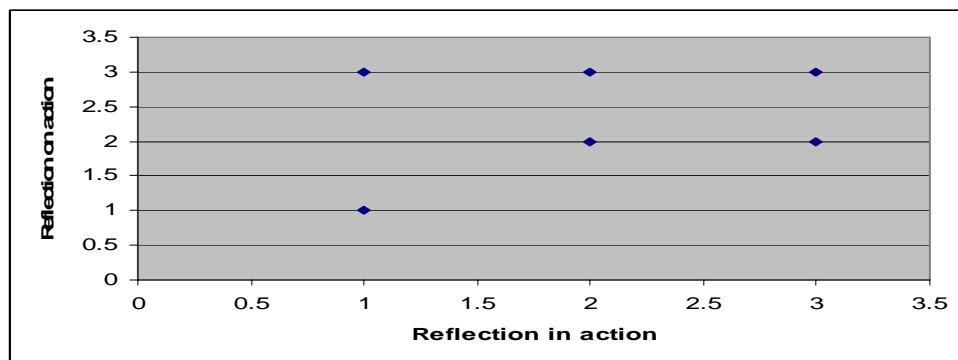
Graph 5. Relationship between reflections-in-action and reflections-on-action

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In order to obtain a prediction equation relating in-service teachers' reflections-on-action and reflections-in-action would be to place a ruler on the graph and move it about to pass through the points that provide the "best fit" line to the data. A "best fit" line divides the data symmetrically. A "best fit" line that can be drawn on the in-service teachers' scatter diagram is a line parallel to the reflection-in-action axis that passes through two. This is a constant line that cannot be used to predict the reflection-in-action of an in-service teacher when given the reflection-on-action. This inference can be used to conclude that the in-service teachers' levels of reflections-in-action were not influenced by their reflections-on-action.

The data of interest presented by in-service teachers do not make it possible to conclude whether or not changes in reflection influenced positively their cognitions and decision making during instruction and post-lesson reflective dialogues. The scatter diagram does not show a linear relationship between reflection-on-action and reflection-in-action (Graph 5). However, it is necessary to determine whether the CRP framework influenced the in-service teachers' reflections-on-action. The influence of the CRP framework on in-service teachers' reflections is discussed next.

4.6 The impact of the CRP framework

The impact of the CRP framework on in-service teachers' reflections was assessed by the level of its effectiveness to guide in-service teachers to reflect on the lessons they taught and positively influenced their post-lesson reflective dialogues. Table 9 summarizes the in-service teachers' reflective actions during teaching, using the scoring discussed in section 3.10.2, and levels of reflections-on-action of post-lesson reflective text, using the scoring discussed in section 3.10.1.

Table 9: Summaries of in-service teacher reflections and frequency of indicators in the CRP framework

Initial round of visits								
MODUS OPERANDI								
First round of visits								
Name	**Peter**		**Charles**		**Christopher**		**Nyasha**	
Reflection type	Ria	Roa	Ria	Roa	Ria	Roa	Ria	Roa
Reflection level	S	2	U	1	G	1	G	2
CRP stages	Frequency		Frequency		Frequency		Frequency	
Conception	2		0		1		4	
Context	6		0		5		4	
Evaluation	2		6		4		3	
Developmental	0		4		0		0	
Second round of visits								
Reflection level	**S**	3	S	2	G	2	G	3
CRP stages	Frequency		Frequency		Frequency		Frequency	
Conception	1		0		0		4	
Context	8		2		2		4	
Evaluation	5		3		3		6	
Developmental	2		2		1		1	

Key: Ria – Reflection-in-action   Roa – Reflection-on-action   U – Unsatisfactory

S – Satisfactory   G- Good

Table 9 shows that in the first round of visits, the in-service teachers' reflective actions during teaching were distributed among the three levels of unsatisfactory, satisfactory and good reflection categories. In the second round of visits Charles' reflective actions during lesson delivery improved from unsatisfactory to satisfactory, Peter's reflective actions during teaching remained constant at the satisfactory category whilst Christopher's and Nyasha's reflective actions during teaching remained at the highest level of good category (level three). These observations indicate that collaborative reflection with peers positively influenced some in-service teachers' teaching practice. This observation is based on the fact that the in-service teachers' reflective actions during teaching generally improved from low to higher levels of reflection or constantly remained at the 'good' reflective actions during teaching category (level three).

Table 9 also shows that the in-service teachers' post-lesson reflective texts in the first round of visits were in the first and second reflection categories, and none attained the critical reflection

category (third level). This means that the post-lesson reflective texts were merely descriptive in character. In the second round of visits all the post-lesson reflective texts improved from a lower category of reflection to a higher one. Peter and Nyasha improved from practical reflection category (level two) to critical reflection category (level three).   Charles and Christopher improved from descriptive reflection category (level one) to practical reflection category (level two).

Whereas the CRP framework phases of conception and context predominantly feature in the in-service teachers' post-lesson reflective texts in the first rounds of visits, it is the higher order phases of evaluation and development that dominate the post-lesson reflective texts in the second rounds of visits (Table 9). The shifts in the reflection phases brought about improvements in the categories of post-lesson reflective texts produced. The improvements of reflection from narrations of conception and context of learning to higher order skills of evaluation and development is used to conclude that the CRP framework positively influenced the in-service teachers' post-lesson reflections.

4.7 Results from reflective interviews with in-service teachers
During the week ending Friday 10 February 2006 when the in-service teachers' four weeks of teaching practice was coming to an end, Peter's and Nyasha's post-lesson reflective texts were in the critical reflection category (level three) while Charles' and Christopher's reflections were rated in the practical reflection category (level two). The reasons given by the in-service teachers during the end of teaching practice reflective interviews to explain the different reflection categories that they attained are presented next. Verbatim accounts from audio taped transcripts of interviews are presented in narrative form.

As shown in Graph 1, in the first round of assessment visits Peter's post-lesson reflective text was at practical reflection category (level two). In the second round of visits the post-lesson reflective text rose to critical reflection category (level three). His eagerness to learn how to handle 'A' Level content and learners enabled Peter to critically reflect on the lessons he taught as supported by the interview transcript below:

> I wrote 'A' Level examinations after certified as a teacher, … obtained a diploma in education. I
> eh…. lacked teaching experience of handling 'A' Level learners. That is to say … amount and

pacing of content and teaching 70 minute periods. My peer, Charles attended 'A' Level classes before training as a teacher. He provided me with several teaching advices… such as … choosing media, learner activities, logical sequencing of content… among others, using his personal experience as a learner. During post-lesson reflective dialogues I mentioned the strengths and weaknesses that I experienced during my teaching. Discussed… possible intervention measures to interpret my teaching actions and and and some suggestions for improvement were made ---for future teaching. Stating pedagogical objectives enabled me to balance eh eh eh narrations and and interpretations of learner achievement of content objectives and …. effectiveness of my implementation of teaching methods in a lesson (Peter: 2 February 2006).

The interview intercept shows that during post-lesson reflective dialogues Charles shared his personal experiences as an 'A' Level learner with Peter. He also provided Peter with insights to interpret teacher actions and learner outcomes during teaching. This enabled Peter to critically reflect on the lessons that he taught.

In the first round of visits Charles' reflection-on-action was at the descriptive category (level one). It then rose to practical reflection category (level two) in the second round of visits (Graph 2). Based on his motivations for reflection that were revealed in the interviews, it seems complacency and inability to cope with the demands of reflection on lessons he taught were the main reasons that prevented Charles from critically reflecting on his teaching. His motivations for reflection on lessons taught are presented in the following interview intercept:

> We maintain the same professional documents as those for pre-service teachers. There is eh, eh sort of too much writing and repetition of some of the professional skills we developed during initial training. I I I think we should be exempted from keeping some --- professional documents such as ….making detailed lesson plans and reflecting on lessons that we teach. Exemptions on these requirements could allow us to to--- concentrate on locating teaching resources. Reflecting on two lessons a day …my peer's lesson and mine… consumes considerable time. After the … ehhh reflective dialogues, I spent several hours alone writing the post-lesson reflective text and planning for the following day's lesson…. it means a routine of several hours of reflection on lessons taught,… and eh eh eh planning. This eh eh eh makes writing post-lesson reflections and planning lessons in a hurry as a course requirement rather than for my individual professional development (Charles: 2 February 2006).

Allocation of time for post-lesson reflective dialogues followed by writing post-lesson reflective texts and planning for the following lessons seems to be the main reason that made Charles to write post-lesson reflective texts in haste that did not go beyond practical reflection.

Christopher is a substantive non-teaching school head who was teaching mathematics as a requirement of the in-service programme. In the first round of visits his reflection was at the descriptive category (level one). It rose to dialogic reflection category (level two) in the second round of visits (Graph 3). It seems that due to his administrative duties he did not see the value for him of reflecting on teaching as revealed by the interview intercept below:

> I think … reflection is an important skill that teachers should develop… during training in order to improve their teaching. Knowing that I I I will not directly use the reflective teaching practice skills that I am developing now… makes me less less less devoted to reflect on the lessons that I taught. I think I have liked the the the collaborative assessment of lessons with a peer. It widened my eh eh eh scope of supervision and assessment of teachers (Christopher: 1 February 2006).

Christopher's post-lesson reflective texts were influenced by the purposes to which he was going to use the reflective practice skills. He reflected on the lessons he taught in order to pass teaching practice because reflecting on lessons was not relevant to him as an administrator.

Nyasha benefited from collaborative reflection with Christopher. As shown in Graph 4, Nyasha's post-lesson reflective texts changed from practical reflection category (level two) to critical reflection category (level three). Her motivation for reflection was attributed to the complementarities of Christopher's strengths and her weaknesses and vice versa. Her argument during the interview was:

> I benefited … from reflecting with a peer. For instance, I was weak at introducing lessons. I, I benefited from the insight I got from my peer. The inclusion of content and pedagogical objectives helped our post-lesson reflective dialogues to be focused …on teaching strategies that were implemented in a lesson and ….learner understanding. Collaborative reflection enabled me to review my conceptions of how learners master mathematical concepts and, and, and teaching strategies which we anticipated would be effective in the context of learners we taught (Nyasha: 1 February 2006).

For Nyasha pedagogical objectives and a review of the conceptions on how learners master mathematical knowledge and skills were two critical aspects that enabled her post-lesson reflective text to attain critical reflection category at the end of four weeks of teaching practice.

From the in-service teachers' data of interest, motivation for teaching is coming out strong as a factor that influenced their critical reflection development.

4.8 Summary

This chapter presented the in-service teachers' results from the main study. The results indicated gradual increase in the levels of both reflective actions during teaching and post-lesson reflections. This observation supports the inference that the observations from data of interest indicate, that the CRP framework provided positive guidance that improved the in-service teachers' reflections with their peers. The next chapter, Chapter Six, presents pre-service teachers' findings from the study.

CHAPTER 5: RESULTS FROM PRE-SERVICE TEACHERS

5.1 Chapter overview

This chapter presents the findings from pre-service teachers. As discussed in section 4.2 the results are presented sequentially and separately for each of the three rounds of data collection visits to schools. In section 5.2 the *modus operandi* of the study is outlined with a view to reach a common understanding of peer collaborative assessment and post-lesson reflective dialogues using the CRP framework. In sections 5.3; 5.4 and 5.5 the pre-service teachers' reflections in the first, second and third rounds of data collection visits are presented. Section 5.6 presents the relationships between post-lesson reflections and reflections during teaching. Section 5.7 presents the impact of the CRP framework on guiding pre-service teachers' reflections on their teaching. Section 5.8 presents results from reflective interviews. The focus of the chapter is summarised at the end.

5.2 The rounds of visits

The initial visit and the three data collection rounds of visits were made between 24 January and 27 March 2006. After 27 March learners were writing end of term tests that the pre-service teachers were not involved in teaching. Similar field entry procedures used on in-service teachers presented in chapter four were used during the data collection process of pre-service teachers.

5.3 Assessments of reflections in the first round of data collection visits

For each of the three rounds of data collection visits made on pre-service teachers, the reflective actions during teaching are presented as follows: (a) bulleted verbatim statements extracted from peer and researcher's assessment critiques of a pre-service teacher's reflective actions during teaching, (b) consensually agreed researcher and peer category of reflective actions during teaching, (c) reasons for the placement of reflective actions in a reflection category. Presentation of the pre-service teachers' self written post-lesson reflective texts are presented using the same template used for presenting reflective actions during teaching with minor changes. For instance, the wording for (a) was changed to read, bulleted verbatim statements extracted from a pre-service teacher's self-written post-lesson reflective text and parts (b) and (c) remain unchanged.

After the third rounds of data collection visits, the levels of reflections attained by each pre-service teacher are depicted pictorially by line graphs. This presentation facilitates assessment of the extent to which CRP influenced a pre-service teacher's cognitions on teaching. The reflections of each of the three pairs of pre-service teachers and the levels of reflections that they attained are presented below:

5.3.1 Tendai

Tendai taught multiplication and division laws of indices to a Form Two class during the first round of data collection visits. The content of the lesson is shown below:

> *Applying the laws of indices for (i) multiplication, $x^a . x^b = x^{a+b}$ and (ii) division, $x^a \div x^b = x^{a-b}$ to simplify multiplication and division of numbers with the same bases.*

The peer wrote the following statements on his lesson assessment critique:

- The lesson started with a recap of concepts covered in the previous lesson on expanding algebraic letters to given powers.
- The pre-service teacher demonstrated the multiplication and division laws of indices using numbers with the same base.
- Group work was given to learners in order for them to help each other to consolidate the application of the multiplication and division laws of indices.
- The use of challenging tasks such as $\dfrac{27 \times 3^8}{54 \times 3^5}$ provoked learner thinking as it involved insight to express 27 and 54 to base 3 and using both laws to simplify them.
- The pre-service teacher accepted learners' chorus answers during class demonstrations.

The researcher's written critique stated that:

- Some questions illustrated as examples on the board were too easy for some learners to solve them independently of the pre-service teacher.
- The pre-service teacher did not probe learners' solutions to assess their understanding.

(b) Satisfactory reflection category (level two).

(c) The content covered in the lesson was easy for some learners. Learner generalizations and applications of the laws of indices covered in the lesson were appropriate for maximizing the

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learning of some learners who found most of the demonstrations easy to follow and performing them on their own.

Tendai's post-lesson reflective text on finding the highest common factors (HCF) of given numbers had the following statements:

- I assumed that learners were able to express given numbers as products of primes.
- Learners were asked to find the prime factors of 30 and 12.
- A learner volunteered to find the lowest common multiple (LCM) of 30 and 12 on the board and wrote the following: $12 = 2 \times 2 \times 3$, and $30 = 2 \times 3 \times 5$,
  $$\therefore \ \text{LCM} = 2 \times 2 \times 3 \times 5 = 60.$$
- Learners were given tasks to work in groups after a demonstration on finding the LCM of given whole numbers.
- Time management was a problem faced in the lesson because it ended during group presentations that it was not concluded.
- I will try as much as possible to adhere to times allocated for respective stages of a lesson with the hope of improving time management in future lessons.

(b) Practical reflection category (level two).

(c) The post-lesson reflective text narrated events of the lesson without interpreting them. It did not clarify assumptions underlying the choice of teaching methods used.

5.3.2 Richard

Richard introduced sets to a Form Two class in the first round of visits as shown below:

(i) Definition of a set.   (ii) Listing elements of given sets using set braces, { }. (iii) Concept of subset.

The peer wrote on the assessment critique:

- Richard solicited learners' prior knowledge through question and answer.
- There were short "wait" times between questions and learners' answers.
- The use of differentiated tasks on work cards for group activities was effective for learner understanding of the concepts of set braces, element of, not an element of, and subset.
- At times the pre-service teacher failed to notice learners' solutions without set braces when listing the elements of a set.

- The pre-service teacher picked learners who were seated in the front row of the class only to present solutions on the board.

The researcher wrote the following statements on his assessment critique:
- The definition of a set discussed in the lesson was too general.
- The use of objects in the learners' environment to elaborate the signs for element of ($\in$) and not an element of ($\notin$) enhanced learners' understanding.
- The question and answer session that was used to conclude the lesson was effective to assess learners' understanding of concepts covered in the lesson.

(b) Satisfactory reflection category (level two)

(c) The pre-service teacher was not consistent in the instructions he gave out to learners. For instance, he failed to notice learners' solutions without set braces when listing the elements of a set. There were also instances when learners' solutions were not accurately presented such as non-specific definition of a set.

The pre-service teacher's post-lesson reflective text on the previous lesson on expansion of algebraic expressions noted the following statements:
- After a review of the tasks that learners found problematic in the previous day's homework, I demonstrated how to expand $2(x + y)$ and $(x + 2) (x - 5)$.
- I stressed the distributive law carefully, that is, the need to multiply each term in the first bracket by all the terms in the second bracket and being careful of sign changes when numbers of different signs multiplied each other.
- After demonstrations of how to expand given brackets, learners were given consolidation exercises involving expansions of two functions with coefficients of x greater than one.
- During class discussions most learners were able to present correct solutions of the expansion problems they were given

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(b) Technical reflection category (level one).

(c) The post-lesson reflective text narrated events that unfolded in the lesson and learner achievement without interpreting them. There was no assessment of instructional weaknesses and what is desirable to improve future teaching practice.

5.3.3 Munashe

In the first round of visits Munashe was observed teaching linear equations to the last stream of Form Three classes. The learners were placed into classes by ability rating. An example of the equation type covered in the lesson is shown below:

> *Find the value of y in the equation $xy + x^2 = 15$ when $x = -1$.*

The peer wrote the following statements on his assessment critique:

- The pre-service teacher identified learners' prior knowledge on substitution of algebraic letters by their numerical values. The prior knowledge was used to develop new concepts on solving linear equations involving one unknown.
- The pre-service teacher posed well-framed questions that were clear to learners.
- The random selection of learners to answer questions enabled the learners to be actively involved in the lesson.
- Group work facilitated learner social construction of methods for solving linear equations.

The researcher wrote the following statements on his assessment critique:

- The pre-service teacher was able to expose learners' alternative conceptions when substituting variables by negative numbers.
- The pre-service teacher gave learners ample consolidation exercises to enable them to practice and master the skills of solving linear equations.
- The pre-service teacher encouraged learners to verify the viability of their solutions by substituting in the original equations the numerical values of variables obtained.
- Group work enabled learners to remain actively involved throughout the lesson.

(b) Good reflection category (level three).

(c) The pre-service teacher listened to learners' points of views and exposed their alternative conceptions on applying the distributive law to remove brackets on algebraic expressions

involving directed coefficients. He also allowed learners to negotiate strategies for solving equations, and encouraged them to verify the validity of their solutions.

The pre-service teacher wrote the following statements on the post-lesson reflective text on solution of simultaneous equations involving two unknowns:

- Learners showed lack of prior knowledge of solving linear equations involving one unknown, removing brackets, and operations on directed numbers.
- The knowledge that learners were assumed to posses which they had forgotten was revisited so that they could build concepts of the lesson from it.
- More time than planned was spent on scaffolding learners on the concepts they had forgotten. This resulted in solving simultaneous equations using the method of substitution done in a hurry.
- To effectively teach this class, few concepts at the Form level of learners should be planned for a lesson so that some reasonable time is reserved for reviewing the assumed knowledge that learners might have forgotten.

(b) Descriptive reflection category (level one).

(c) The post-lesson reflective text describes learners' inability to recall the content that they learnt previously and narrated events of the lesson without interpreting them.

5.3.4 Mavis

Mavis taught introductory linear equations involving one unknown during the first round of data collection visits to a Form Three class as shown below:

Solving linear equations involving one unknown such as $3(4c - 7) - 4(4c - 1) = 0$

The peer wrote on the assessment critique:

- The objectives of the lesson were stated in the introduction so that learners could become aware of what they were expected to achieve in the lesson.
- In solving the equation $9 - 12x = 4 - 4x$, a learner wrote $9 - 4 = -4x -12x \Rightarrow 5 = 16x$
- The pre-service teacher demonstrated the additive inverse to show sign changes when numbers cross the equal sign.

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- Learners were asked to solve $3(4c - 7) - 4(4c - 1) = 0$ in order to consolidate the skill of sign changes when numbers in an equation are transposed.
- The conclusion of the lesson highlighted the steps taken in solving linear equations through a question and answer session.

A new statement on the researcher's assessment critique was:

- The pre-service teacher assessed learner understanding in consolidation exercises by asking them to explain the steps they took when solving linear equations.

(b) Good reflection category (level three).

(c) Demonstrations of sign changes for numbers that cross the equal sign and exposition of the solution steps on the board at the appropriate stages of the lesson, followed by group consolidation exercises enhanced learner understanding of solving linear equations involving one unknown.

Mavis' self-written post-lesson reflective text on teaching the equation of a circle noted that:

- Finding the equation of a circle using given information and rearranging the equation to determine the centre and radius of a circle was easy for most learners.
- Some learners received assistance on determining whether a given equation represented a circle or not.
- The demonstration method that was used in the development of concepts of the lesson enhanced learner understanding of the concepts and how to present their written work.

(b) Technical reflection category (level one).

(c) The post-lesson reflective text concentrated on the technical steps involved in finding the coordinates of the centre of a circle without interpreting the pre-service teacher's actions and learners' behaviours.

5.3.5 Michael

In the first round of visits Michael was found using Venn diagrams to solve real world problems to a Form Two class of the type shown below:

> *A farmer has some cattle. Some of them are cows and bulls without horns. Show this information on a Venn diagram.*

The peer's assessment critique stated:

- The question and answer session that was used to introduce the lesson enhanced assessment of learner prior knowledge.
- The use of cows and bulls with horns and those without horns to form two intersecting sets enhanced learner understanding of the intersection concept.

The researcher's assessment critique noted the following statements:

- The use of group work enabled learners to help each other to understand the problem-solving tasks given, and representing the information on a Venn diagram.
- The diagrammatic illustration of practical examples familiar to learners enhanced their understanding of the concept of intersection and Venn diagrams in general.

(b) Good reflection category (level three).

(c) The pre-service teacher judiciously used real-world examples that were familiar to learners, which enhanced learners' development of both cognitive and psychomotor skills in the lesson.

Michael's post-lesson reflective text on applications of Maclaurin's theorem to approximate logarithmic and trigonometric functions noted the following statements:

- The introduction was on a review of Maclaurin theorem and its applications.
- Students were asked to calculate the Maclaurin's series of some trigonometric, logarithmic, and exponential functions in class up to the term in x^3.
- Learners who completed group tasks were given more challenging problems while the rest of the learners worked on the given tasks at their own pace.
- The pedagogical strategies that were used in the lesson (teacher demonstrations, question and answer) enhanced learners' understanding of the application of Maclaurin's theorem.
- The pedagogical and content objectives set for the lesson were achieved.

(b) Technical reflection category (level one).

(c) The post-lesson reflective text narrated achievement of pedagogical and content objectives without evidence, and showed preoccupation with techniques for applying a theorem without interpreting learner behaviour in the light of pre-service teacher's actions.

5.3.6 Cynthia

In this round of visits Cynthia was observed teaching conditional probability to an 'A' Level class of the form shown below:

> *A and B are exhaustive events and it is known that P(A/B) = $\frac{1}{4}$ and P(B) = $\frac{2}{3}$. Find P(A).*

The peer wrote on the assessment critique:

- The pre-service teacher used learners' prior knowledge on statistical events to define dependent and independent events.

- The conditional probability formula, P(A/B) = $\frac{P(A \cap B)}{P(B)}$, was exposed to learners.

- Learners were encouraged to recall the formula and be able to transpose it to suit different demands of questions.

The researcher's assessment critique noted the following statements:

- The conditional probability formula, P(A/B) = $\frac{P(A \cap B)}{P(B)}$, was imposed on learners without logically deriving it.

- Learners were able to apply the formula for conditional probability after they translated the information in a problem into mathematical notations and substituting the variables in the formula.

(b) Satisfactory reflection category (level two).

(c) The pre-service teacher imposed the conditional probability formula on learners without deriving it or proving its viability. Learners were given ample consolidation exercises that enhanced their applications of the formula to solve problems presented.

Cynthia's self written post-lesson reflective text on types of sets to a Form One class noted the following statements:

- The learners understood the concepts of empty and infinite sets but had problems to understand the concept of a subset.

- The use of practical examples of a set of goats as a subset of domestic animals enhanced learners' understanding of the concept of a subset.

- In the next lesson I will be firm but fair to learners in order to limit their movements and talking about issues not related to tasks at hand during group work.

- Learners achieved the objectives of the lesson.

(b) Technical reflection category (level one).

(c) The reflective remarks highlighted learner achievement of objectives, pedagogical techniques and classroom management without evidence to support the claims made and there were no interpretations of learner and pre-service teacher's behaviour. The reflective remarks emphasize personal survival by focusing on the achievement of lesson objectives.

5.4 Assessment of reflections in the second round of data collection visits

5.4.1 Tendai

Similarity of plane shapes was the topic that Tendai taught to a Form Two class in the second round of visits. The illustrative example used to build learner understanding of similarity of two triangles was demonstrated using the dimensions given below:

> *Triangle FDE has length FD = 6cm, angle D = 90^0 and angle F = 53^0. Triangle XYZ*
> *is right angled at Y and has XY = 3cm, YZ = 4cm, ZX = 5cm and angle Y = 37^0.*
> *Show that $\triangle XYZ /// \triangle EDF$.*

The peer wrote on his assessment critique:

- The concept of similarity was introduced using the ratios of the dimensions of two rectangles.

- A learner was asked to read a problem from the main textbook whilst the pre-service teacher drew sketches on the board of the triangles described in the problem.

- Learners were asked to calculate the missing angles of the triangles that were drawn. The learners concluded that corresponding angles of the two triangles were equal, prompting their conclusion that the two triangles were "equal".

- The conditions for equality of two shapes were discussed leading to the conclusion that the two triangles were similar and not equal.

- In example 2, the similarity property of the two triangles was also illustrated using two triangles of given dimensions (4cm, 7cm and 6cm; and 2cm, 3.5cm and 3 cm) and similarity deduced from the constant ratio of sides that are in the ratio 2 : 1.

- Learners were given some paired triangles to test whether they were similar.

The researcher noted the following issues on his assessment critique:

- The reasons for the similarity of triangles in the first and second examples were not stated.

- The first example was left incomplete after showing that the two triangles were similar. Calculations of the missing sides of ΔEDF were revisited after example 2 that established that the ratio of sides of similar triangles EDF and XYZ were equal, $(\frac{ED}{XY} = \frac{DF}{YZ} = \frac{EF}{XZ}$ and that the missing sides can be calculated using the relationships $\frac{6}{5} = \frac{DF}{4}$ and $\frac{6}{5} = \frac{EF}{3}$).

(b) Unsatisfactory reflection category (level one).

(c) Presentation of the content in the lesson was not logically sequenced to promote learner understanding of the concept of similar triangles and applications of angle and side properties of similar triangles in calculating missing sides of similar triangles. A logical sequence could have linked the introduction with the second example followed by the first example.

Tendai wrote the following statements on the post-lesson reflective text on the topic of problem solving using the lowest common multiples of numbers:

- Based on the belief that learners were familiar with methods for finding the HCF and LCM of given numbers, they were given some problem-solving tasks to work out in groups.

- A problem that most learners found difficult to solve was "Find the greatest mass that can be taken an exact number of times from 360g, 504g and 672g".

- I spent a lot of time explaining the problem until I realized that the learners were failing to understand that the question required them to find the HCF of 360, 504, and 672.

- The learners' problems emanated from their lack of understanding the language used in the problem and translating words into mathematical symbols.

- To minimize learners' linguistic problems, I should express problem-solving tasks in simple terms that enable learners to understand the problem. Another strategy to limit learners' linguistic problems may be to express word problems into learners' first language.

After implementing the strategies that were suggested to improve learners' understanding in a second class, Tendai's post-lesson reflective text noted that:

- After reading the problem-solving question (shown above) several times the learners were asked to express it in their own words using their vernacular language or English.

- The use of both English and the learners' vernacular language during interpretations of problem-solving tasks enhanced learners' understanding of the context of the problem and the mathematical notations involved. However, the use of vernacular language has to be used carefully because learners' summative examinations are in English language.

(b) Critical reflection category (level three).

(c) Guiding learners to understand word problems using strategies suggested after teaching a first class was successful for enhancing learner understanding in the second class. Experimenting with strategies to improve practice in a second of the same Form level class indicate a desire to improve teaching practice.

In the second round of visits Richard was teaching expression of numbers into prime factors to a Form One class as shown below:

(i) Express 18, 20, and 90 in prime factors.	*(ii) Express your prime factors in index form.*

The peer's written assessment critique noted that:

- The use of discovery method enabled learners to find the prime factors of 18 and 20.
- A learner expressed the prime factors of 18 as $2 \times 3 \times 3$. A second learner expressed the prime factors of 18 in index form as $18 = 2^3$.
- The pre-service teacher should have asked the second learner to explain the index form of the prime factors of 18 in order to diagnose the source of the alternative conception.
- The pre-service teacher did not notice the mismatch between the divisors and dividends when finding the prime factors of 90 step-wise using long division, probably because the prime factors obtained were correct.

The researcher's assessment critique noted the following extra comments:

- In introducing the concepts of power and base, the example $20 = 2^2 \times 5$ was not appropriate because learners had difficulties of understanding which 2 was the base and which one was a power.
- An illustration with different numerals in the base and power could have enabled learners to match the visual and the mental notions of power and base without conflicts.
- The nature of the challenging tasks engaged group members in debates.

(b) Satisfactory reflection category (level two).

(c) The pre-service teacher provided learners with challenging tasks but was not sensitive to learners' methods for calculating prime factors. He was interested in products and not processes and some of the examples were not clear to promote learner understanding.

On a previous lesson on factorizing perfect squares the pre-service teacher wrote the following statements on the post-lesson reflective text:

- The learners had a good understanding of factorization that they were able to factorize algebraic expressions like $y^2 - 2y + 1$ as a perfect square $(y - 1)^2$ without my assistance.

- Exercises that were thought to be problematic to learners such as factorizing $25x^2 - 30xy + 9y^2$ were easily expressed as perfect squares as $(5x - 3y)^2$.

- The work planned for this lesson was unsuitable for the learners because the content of the lesson was not challenging to most of them as shown by their finishing class work in less time than planned.

(b) Technical reflection category (level one).

(c) There is evidence that there was no learning in the lesson because the pre-service teacher failed to provide content that challenged learners' cognitive capacities. Suggestions for improving future teaching were not made although the weakness of planning unchallenging content was noted from the lesson taught.

5.4.3 Munashe

Munashe taught simultaneous linear equations to a Form Three class in the second round of visits using the solution methods specified below:

> *Solve the simultaneous linear equation $2x + y = 6$ and $x + 2y = 3$, using   (i) the substitution method,   (ii) the elimination method*

The peer's assessment critique noted that:

- The pre-service teacher made an appropriate decision to demonstrate on the board the methods of substitution and elimination to solve simultaneous linear equations.

- The demonstrations were followed by learner consolidation exercises in order to help them to fix the skill of solving the equations using the two methods through drill and practice.

- During group presentations on the board one learner faced difficulties in removing brackets when using the substitution method to solve $3x + 2y = 7$ and $y = \dfrac{1}{3}(8 - 4x)$.

- A second learner was selected to make the substitution.

- Removing brackets involving fractions is usually problematic to most learners at this level that other learners could have benefited from the pre-service teacher's probing of the first learner's incorrect substitution on the board.

The researcher's assessment critique stated that:

- A second learner correctly substituted y by $\frac{1}{3}(8 - 4x)$ in $3x + 2y = 7$ leading to

  $3x + 2\,[\frac{1}{3}(8 - 4x)] = 7$ … (3) but failed to remove the brackets.

- The pre-service teacher took over and solved equation (3).
- The learners in this class seemed to face difficulties in understanding the steps taken in solving equation (3) because it involved fractions.
- After noticing that the learners were facing difficulties to follow the steps when involving fractions in the solution, the pre-service teacher could have eliminated fractions in the equation by multiplying equation (3) by 3. This approach could have reduced the learners' anxieties on working with fractions.

(b) Unsatisfactory reflection category (level one).

(c) The pre-service teacher used a single method to remove fractions in an equation that learners did not understand. The decision to take over solving problematic linear equations from a learner solving it on the board showed ineffective reflection during teaching.

Munashe's post-lesson reflective text on solutions of linear simultaneous equations involving two unknowns to a Form Three class noted the following statements:

- The lesson did not proceed as planned because some learners were unable to use the method of substitution to solve simultaneous linear equations involving two unknowns.
- Although the learners covered the method of substitution recently, they had forgotten how to apply it in solving a pair of simultaneous equations.
- The method of elimination was used to solve one pair of simultaneous linear equation

x + 2y = 3 and 2x + 3y = 6 only. The other pair of simultaneous linear equations that were planned for the lesson will be covered in the next lesson because the lesson ended before learners were asked to solve them in groups.

(b) Technical reflection category (level one).

(c) The pre-service teacher blames the failure to complete work planned for a lesson on the learners' slow pace of understanding. No reasonable suggestions for improving teaching to the learners are made although problematic situations that hinder covering new content with the class are identified.

5.4.4 Mavis

Mavis was consolidating learner understanding of solving simultaneous linear equations to a Form Three class in the second round of visits using the pair of equations shown below:

> *Solve the simultaneous linear equations 2x – 5y = 1 and 3x – 2y = 30 using either the elimination or the substitution method.*

The statements written by the peer on his assessment critique were:

- Two learners were asked to solve the above simultaneous linear equations, one using the elimination method and the other using the substitution method.

- The rest of the learners were asked to solve the same simultaneous equations individually using any method of their choice.

- The first learner obtained the solutions $x = \dfrac{148}{11}$ and $y = \dfrac{57}{11}$ for the simultaneous equations.

- The second learner committed a computational error when multiplying 30 by 5 to get 155 instead of 150. After the computational error, the learner conducted the preceding steps correctly getting $x = \dfrac{153}{11}$,

- The pre-service teacher considered the solutions of the simultaneous equations unrealistic and temporarily left the equations, promising to revisit them later.

- The pre-service teacher asked the learners to solve some simultaneous equations written on work cards while she looked for the source of the initial simultaneous equations.

- After noticing that she made a typographical sign error in equation (1) she corrected it to read $2x + 5y = 1$.
- Learners were asked to stop solving the simultaneous equations on work cards in order to revisit the initial simultaneous equations with "unrealistic solutions".
- A learner solved the revised simultaneous equations and obtained the solutions of $x = 8$ and $y = -3$.

The researcher noted the following extra statements on his assessment critique:
- There was an error on simplifying the directed numbers in the new simultaneous equations in $3 - 15y - 4y = 60 \Rightarrow -11y = 57$,
- The other learners noticed the computational error and pointed it out. The learner on the board corrected it to get $-19y = 57$ leading to $y = -3$.
- A different learner was asked to verify the viability of the values of x and y.

(b) Good reflection category (level three).

(c) Sensing queerness of a solution, scrutinizing its source; identifying an error and solving the simultaneous equations afresh revealed evidence of self-critical reflection on choice of examples and learner solutions. Critical analysis of examples and making decisions that warrant further scrutiny of work set based on learner solutions to ensure accuracy in presentation and solution methods was consensually agreed to belong to good reflective actions during teaching.

The post-lesson reflective text that Mavis wrote on the previous lesson on solutions of fractional simultaneous linear equations involving two unknowns noted the following comments:
- To verify the assumption that learners had some prior knowledge on solving simultaneous linear equations involving two unknowns, a learner was asked to solve a pair of equations on the board whilst others solved the equations on pieces of papers.
- Equations involving fractions such as $x + 3y = 0$ and $\frac{1}{2}(y + 4) = x$ were thought to challenge learners' current knowledge on solving simultaneous linear equations.
- After some time of working in pairs, a learner was randomly selected to come to the board to solve the simultaneous equations using the substitution method.

- The learner faced challenges to use the distributive law to remove the brackets, writing

$$\frac{1}{2}(y+4)\frac{1}{2}=x \Rightarrow y+4=x.$$

- This learner conceptualized that multiplying $\frac{1}{2}$ by $\frac{1}{2}$ yields 1 and not $\frac{1}{4}$ but failed to realize that in order for the equation to balance what is done on the left hand side of the equal sign should also be done on the right.

- A different learner was picked to remove the brackets after the first one failed.

- I should have probed the learner who wrote $\frac{1}{2}(y+4)\frac{1}{2}=x$ in order to get insight into how she understood the process of removing brackets.

- To enhance the development of pedagogical skills on probing learners' responses and allowing the learners to present work in multiple ways that were generated in group discussions, the approaches used in this lesson will be repeated in the next one and weaknesses noted in the present lesson addressed.

(b) Critical reflection category (level three).

(c) Admittance of incorrect pedagogical decisions and suggesting practical ways of improving teaching practice are evidence of broad understanding of the learning environment. This shows broad understanding that emerged from own teaching.

5.4.5 Michael

During the second round of visits Michael was observed teaching the topic on cumulative frequency curves and histograms to an 'A' Level class. The content of the lesson is shown below:

The lengths of 30 bananas were measured and the information grouped as shown. Measurements were taken correct to the nearest centimetre. Draw a histogram and a frequency polygon to illustrate the data.				
Length of banana (cm)	6 – 9	10 -13	14 – 17	18 -21
Frequency	3	8	12	7

The peer's written assessment critique noted that:

- The pre-service teacher demonstrated how to draw a histogram using the data given in the frequency table above.

- Later a frequency polygon was drawn on the histogram by joining the mid-points of the tops of the rectangles in the histogram.
- Some learners faced problems to find the mid-points of the tops of the rectangles in the histogram resulting in drawing inaccurate frequency polygons.

The researcher's assessment critique noted the following statements:
- There was need to minimize demonstrations in the lesson because learners encountered the concepts of histogram and frequency curves at 'O' Level.
- To enable learners to recall these concepts, frequency curves, histogram, and form higher order ones, discovery learning was appropriate.

(b) Satisfactory reflection category (level two).

(c) The pre-service teacher realized that a demonstration method was not effective to enable learners to recall previously learnt concepts in order to build new understanding at a higher level, but continued to use the demonstration method when the discovery method was an alternative method that could facilitate learners' connections of their prior knowledge and the new concepts of the lesson.

The pre-service teacher's self-written post-lesson reflective text on the previous lesson on integration of trigonometric functions stated that:
- The use of question and answer session approach was effective in the introduction of the lesson because it enabled the pre-service teacher to establish learners' prior knowledge (six trigonometric functions) and their misconceptions on the topic at lower levels.
- Learners recalled the six trigonometric functions but showed partial knowledge on the derivatives of some trigonometric functions such as sine, cosine and tangent functions.
- I used the expository method to show how to differentiate the secant, cosecant and cotangent functions.
- The use of group work to differentiate given trigonometrical functions enabled learners to identify each other's misconceptions in ways that complemented my functions as an instructor.

- During supervision of group work, I provided remedial assistance to learners who were noted to have some misconceptions on differentiating some trigonometric functions.
- In future learners are to be made aware of the objectives of the lesson at the beginning of a lesson so as to remind them of the depth to which content is to be covered.

(b) Critical reflection category (level three).

(c) The pre-service teacher showed a broad understanding of the learning environment on integrating trigonometric functions through the use of remediation to slower learners. He suggested strategies for alerting learners of the depth that content was to be covered in a lesson in order to meet the requirements of the 'A' Level curriculum.

5.4.6 Cynthia

Cynthia taught applications of cycle theorems to a Form Three class during the second round of visits of the form shown below:

The points P, Q, and S are on a circle with centre O. QP is produced to X. If angle $XPS = 77^0$ and angle $PSO = 68^0$, find the angle PQO.

The peer's assessment critique noted the following points:
- The recap method used in the introduction of the lesson was effective to facilitate checking learners' prior knowledge on cycle theorems.
- Through the use of question and answer, learners were able to recall the relationships between interior and exterior angles of a cyclic quadrilateral.
- Learners were asked to apply the cycle theorems on a cyclic quadrilateral to solve problems similar to the one shown above in groups.

The researcher's assessment critique noted that:
- Group sizes of four to five members each were too large for learners to actively engage in meaningful group activities.

(b) Satisfactory reflection category (level two).

(c) The expository method used was appropriate for learners to connect their prior knowledge and the new concepts of the lesson, but the group sizes were too large for the mixed ability learners to actively engage in group activities.

On the post-lesson reflective text on the Maclaurin's theorem and series expansion the pre-service teacher wrote the following statements:

- From polynomial functions of the form $f(x) = a_0 x^0 + a_1 x + a_2 x^2 + \ldots$, learners were asked to express $f(x)$ as a function involving its derivative terms after determining the values of $a_0, a_1, a_2, a_3 \ldots$

- This approach enhanced learners to derive the Maclaurin's theorem, that is,

$$f(x) = f(0) + f'(0)x + f''(0)\frac{x^2}{2!} + f'''(0)\frac{x^3}{3!} + f^{(4)}(0)\frac{x^4}{4!} + \ldots$$

- Most learners failed to use the product rule to differentiate $2xe^{x^2}$ and to determine the valid range for the convergence of the function $\frac{1}{1+x}$.

- Four learners need remediation in order for them to be able to use the Maclaurin's theorem to expand given functions.

- Valid conditions for convergence of functions should be revisited in the next lesson because this lesson ended without the learners mastering the concept of convergence of functions.

(b) Technical reflection category (level one).

(c) Learners' problems in applying the Maclaurin's theorem to expand given functions up to a certain power were stated in the text without diagnosing their causes or how to reduce them. Narration of learner learning difficulties, events of the lesson without interpreting them, and inability to evaluate the strengths and weaknesses of a lesson are indicators of technical reflection category (level one).

5.5 Assessment of reflections in the third and final round of visits

5.5.1 Tendai

In the third round of visits Tendai was teaching fractional linear equations involving an unknown to a Form Two class. A sample of the fractional linear equations that were covered in the lesson is shown below:

> Solve (i) $\dfrac{x}{5} = \dfrac{1}{2}$ (ii) $\dfrac{4-z}{7} = z$

The peer's written assessment critique noted the following statements:

- The discovery method in which a learner was asked to come to the board to solve $\dfrac{x}{5} = \dfrac{1}{2}$ whilst the rest of the class solved it individually on pieces of paper was appropriate.

- Each time learners solving equations on the board wrote incorrect steps, the pre-service teacher provided hints to correct it.

- The pre-service teacher's interventions in order to provide hints to a learner to correct a wrong step in their solution were necessary to guide learners on how to proceed correctly. Providing hints at appropriate steps of a solution did not only enhance logical arrangements of content to solve a problem of the learner presenting on the board but other learners as well.

- Learners were asked to verify that x = 2.5 was a viable solution of the equation $\dfrac{x}{5} = \dfrac{1}{2}$ by substituting the value of x in the equation.

The researcher noted the following statement on the assessment critique he wrote:

- The pre-service teacher's explanations on eliminating fractions in linear equations using the lowest common multiple (LCM) and illustrating the use of the concept in subtracting fractions with different denominators enhanced learners' understanding of how to remove fractional coefficients of variables in an equation.

(b) Good reflection category (level three)

(c) The pre-service teacher's reflective decisions enhanced learners' understanding of eliminating fractions in the coefficients of variables in linear equations using the concept of LCM. Encouraging learners to verify their solutions is a good habit for them to develop because it enables them to evaluate the reasonableness of their solutions.

The pre-service teacher's self written post-lesson reflective text on the topic of addition and subtraction of directed numbers noted the following points:

- Based on the belief that learners were able to add whole numbers using the number line, the discovery method was used for learners working in groups to explore subtraction of directed numbers using the number line.

- After learners showed competence to use the number line to simplify directed numbers, they were given more challenging problems of the form, $-2 - (-2)$; $-3 + (-4)$.

- Some learners faced difficulties in working out the two problems because they failed to interpret the direction of movement of $-(-2)$ and $+(-4)$ on the number line.

- The fundamental results $-(-1) = -1 \times -1 = +1$ and $+1(-1) = +1 \times -1 = -1$ were demonstrated on the board in order for learners to determine the direction of movement of numbers involving two signs on the number line.

- In this lesson I realized that for consolidation exercises to be effective in developing learner understanding, challenging group tasks that enable learners to pose, think and discuss the methods for solving the problems should be set.

(b) Critical reflection category (level three).

(c) The post-lesson reflective text analysed pedagogies used in the lesson, theories of learning, learners' interests, and insights drawn from teaching the lesson.

A summary of Tendai's reflections during the three rounds of assessment visits is shown below:
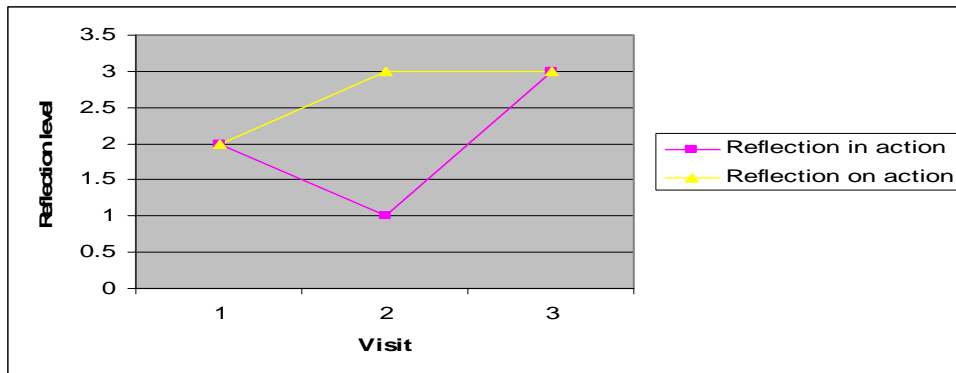
Graph 6. Tendai's reflections

Graph 6 shows that Tendai's reflective actions during teaching attained the satisfactory reflection category (level) during the first round of visits, dropped to unsatisfactory reflection category (level one) in the second round of visits. It then improved to good reflection category (level three) during the third round of visits. His post-lesson reflective text started at practical reflection (level two) improved to critical reflection category (level three) in the second round of visits and constantly remained there during the third round of visits.

5.5. 2 Richard

In the third round of visits Richard was teaching equivalent fractions to a Form One class. The learners were asked to fill in the gaps of the equivalent fractions shown below:

Fill in the gaps in the equivalent fractions $\dfrac{1}{2} = \dfrac{2}{} = \dfrac{}{100} = \dfrac{500}{} = \dfrac{450}{}$.

The peer's assessment report noted that:

- The pre-service teacher used the discovery method to introduce equivalent fractions by asking learners to fill in gaps of given equivalent fractions.

- The first learner to be picked up to fill the gaps provided wrong explanations that led to the correct result. Her explanation was… "to reduce $\dfrac{10}{50}$ to its lowest term, we divide $\dfrac{10}{50}$ by 10 to get $\dfrac{1}{5}$" (instead of saying divide both the numerator and denominator by 10).

- In filling the denominator for 450 in the relationship $\dfrac{450}{} = \dfrac{1}{2}$ a learner wrote

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$$\frac{450}{900} \div \frac{450}{450} = \frac{1}{2}, \qquad \therefore \frac{450}{900} = \frac{1}{2}.$$

The researcher's comments on the assessment critique were:

- Learners explained the concept of a fraction both pictorially (through diagrams of concrete objects cut into fractions) and numerically as a number with a numerator and a denominator.

- The pre-service teacher asked a learner who wrote the equivalent fractions of $\frac{2}{3}$ thus

$$\frac{2}{3} = \frac{4}{12} = \frac{20}{60} = \frac{2}{6} = \frac{300}{900} = \frac{8}{24}$$ to simplify any one of the fractions to its lowest term in order to assess whether it reduced to the first fraction for the learner to identify her error and correct it. This enabled the learner to realize that she provided equivalent fractions for $\frac{1}{3}$ and corrected her solutions by multiplying the numerators by 2.

(b) Good reflection category (level three).

(c) The pre-service teacher led learners to identify their errors in ways that facilitated self-correction after appropriate reasoning. The presentation of concepts on equivalent fractions was sequentially paced in a manner that facilitated learner understanding.

The pre-service teacher's post-lesson reflective text on geometrical constructions of special angles taught on the previous lesson noted that:

- The method of guided discovery was used for learners to construct angles of 105^0, 120^0 and 135^0 using their knowledge of constructing special angles such as 30^0, 45^0, 60^0, and 90^0.

- Some learners faced difficulties to construct an angle of 105^0 because they did not realize that 105^0 is the sum of 90^0 and 15^0 or 45^0 and 60^0.

- Learners were given group work to construct triangles with special angles of given dimensions and asked to measure angles or lengths not given in the diagram.

- I put emphasis on the construction of neat diagrams, arcs and careful measurements using a sharp pencil in order for learners to obtain accurate measurements of missing dimensions.

- Shortage of mathematical instruments was a problem that limited learners' achievement of the objectives of the lesson.

(b) Practical reflection category (level two).

(c) The post-lesson reflective text narrated the pre-service teacher's and learners' activities without interpreting their effectiveness. The text also gave reasons for not achieving learner objectives as shortages of resources such as mathematical instruments.

A summary of Richard's reflections during the three rounds of visits is shown in Graph 7.
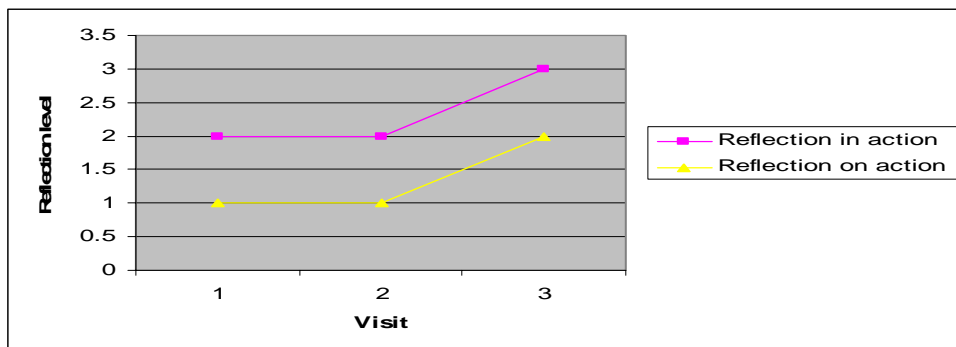
Graph 7. Richard's reflections

Graph 7 shows that Richard's reflective actions during teaching were constantly different from reflections on post-lesson reflective texts. The reflective actions during teaching were constantly at the satisfactory category (level two) during the first and second rounds of visits and improved to good reflection category (level three) during the third round of visits. The post-lesson reflective texts constantly attained technical reflection category (level one) during the first and second rounds of visits and improved to practical reflection category (level two) during the third round of visits.

5.5.3 Michael

In the third round of visits Michael was assessed teaching probability of given events using outcome tables of two tossed dice of the form shown below:

> *Find the probability of getting (i) a sum of 8, and (ii) a product of 12 when two dice are thrown.*

The peer wrote on the assessment critique:

- The description of an unbiased die was made in the introduction of the lesson.
- Two dice were thrown once and their outcomes were noted, theorized and represented on an outcome table.
- Learners were asked to find the solution of given probability questions by first drawing the outcome table and identifying the possible events in the outcome table.

Comments written on the researcher's assessment critique were:
- Learners were actively involved in the activities of the lesson.
- The utilization of both concrete and theoretical reasoning enhanced learners' understanding of outcome tables and how to calculate probabilities from them (outcome tables).

(b) Good reflection category (level three).

(c) The practical nature of the lesson created a learning environment that enabled learners to use practical events in constructing outcome tables and using logical thinking to identify combinations of numbers that gave a required outcome. The instructional environment enhanced learner active construction of mathematical concepts and promoted learners' social negotiations of the viability of the solutions that they obtained.

Michael's post-lesson reflective text on the topic of locus highlighted the following points:
- The concepts of locus, and equidistance were discussed in the introduction of the lesson.
- Using their understanding of locus and equidistance, learners were asked to construct the locus of points equidistant from a fixed point which they identified as a circle.
- Learners were later asked to find in groups the loci of points three centimetres from a fixed line and points fixed on an angle of 60^{0} from a given line.
- Some problems were encountered on assessing learners' group-work diagrams because I was not sure whether the learners' solutions were correct or not.
- In future worked examples for problems to be covered in a lesson should be available in advance of the lesson so that learners' solutions can be assessed for their viability. Solutions of problems made in advance could allow exposing learners to alternative approaches different from the ones that they use to answer given questions.

(b) Critical reflection category (level three).

(c) By highlighting lack of knowledge on the viability of the locus of some diagrams that were produced by learners, the pre-service teacher shows critical thinking, self assessment and self directed learning. Clear suggestions for overcoming the shortfall in some knowledge on locus were made.

A summary of Michael's reflections during the three rounds of visits is shown in Graph 8.
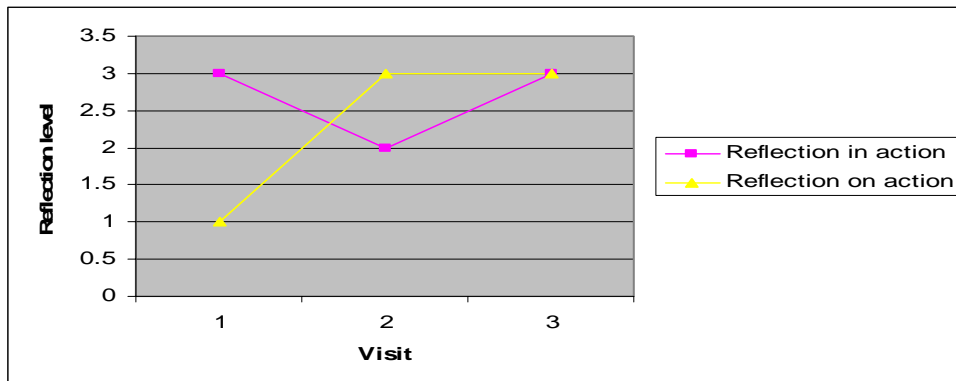
Graph 8. Michael's reflections

Graph 8 shows that Michael's reflective actions during teaching were at the good reflection category (level three) during the first round of visits, dropped to satisfactory reflection category (level two) in the second round of visits. It picked again to good reflection category (level three) in the third round of visits. The post-lesson reflective text was in the technical reflection category (level one) in the first round of visits and jumped to critical reflection category (level three) in the second round of visits. It remained in the critical reflection category (level three) in the third round of visits.

5.5.4 Cynthia

Cynthia was assessed teaching the topic "arc length and sector area of a circle" to an 'A' Level class in the third round of visits. The lesson focused on deriving and later applications of the formulae of length of an arc and area of a sector with an angle θ subtended at the centre as shown below:

A chord subtends angle θ radians at the centre of a circle. Find the general formula for finding   (i) the length of the arc,   (ii) the area of the sector.

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The peer's lesson assessment critique highlighted that:

- The introduction of the lesson focused on the number of degrees in one revolution.
- The angle that an arc subtended at the centre of a circle was pictorially shown.
- The angle subtended by an arc at the centre of a circle was expressed either in degrees or radians and demonstrations of how to convert degrees to radians were made.
- The formulae (i) area of sector = $\frac{1}{2}$ r² θ, and (ii) length of arc = rθ were derived and later applied to calculate given sector areas and arc lengths.
- The demonstrations were followed by learner consolidation exercises in groups.

The researcher's assessment critique noted the following statements:

- The pre-service teacher underestimated learners' ability to deduce the length of an arc and area of a sector from their knowledge of angles in degrees subtended at the centre of a circle that was developed previously in their lower level mathematical courses.

(b) Satisfactory reflection category (level two)

(c) The use of the discovery method was more appropriate than pre-service teacher demonstrations of the derivations of the formulae (i) area of sector = $\frac{1}{2}$ r² θ, and (ii) length of an arc = rθ, because learners could have used their prior knowledge on angles in degrees to derive the formulae.

Cynthia's post-lesson reflective text on the previous lesson on integrating trigonometric functions stated that:

- Although most learners recalled some trigonometrical identities, they struggled to express the identities into forms that could be integrated. For instance, expressing $\sin^2 x$ in its double angle form as $\sin^2 x = \frac{1}{2}(1 - \cos 2x)$ which can be integrated.
- To enhance learners' ability to express trigonometrical functions raised to high powers into identities that can be integrated, several examples of conversions were demonstrated.

- Demonstrations on the board involved question and answer sessions in order to enable learners recall some appropriate identities for trigonometrical functions raised to given powers.

- Combinations of pedagogical strategies such as exposition, demonstration, question and answer and group-work were used in the lesson in order to cater for learners' different learning styles.

- In future, I will continue to blend teaching methods in order to ensure that at least one of the methods may appeal to different learning styles of different learners.

(b) Practical reflection category (level two).

(c) The post-lesson reflective text emphasized technical skills of integrating trigonometrical functions, clarified assumptions and predispositions that underlie competing pedagogical goals, and analyzed learner and pre-service teacher behaviours to see the extent to which objectives of the lesson were achieved without being interpretive.

A summary of Cynthia's reflections during the three rounds of visits is shown in Graph 9.
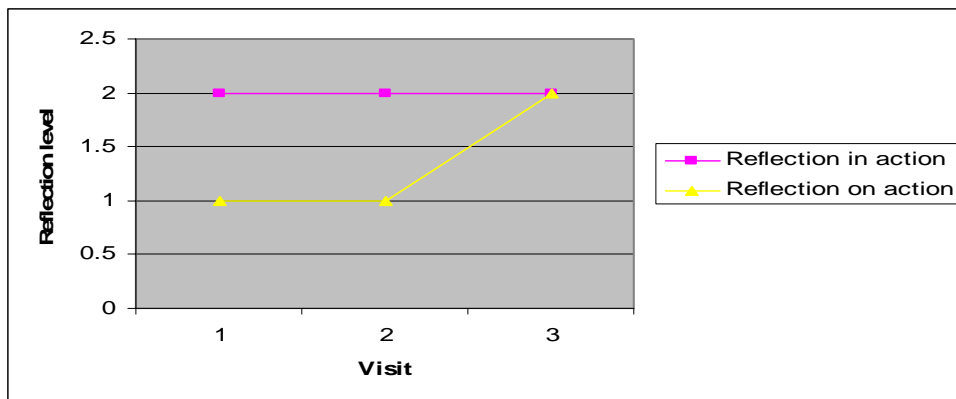
Table 9. Cynthia's reflections

As depicted in graph 9 Cynthia's reflective actions during teaching were constantly at the satisfactory reflection category (level two) during the first, second, and third rounds of visits. Her post-lesson reflective texts attained the technical reflection category (level one) during the first and second rounds of visits and improved to technical reflection category (level two) during the third round of visits.

The relationship between post-lesson reflective texts and reflective actions during teaching was assessed in order to determine the extent to which collaborative reflection with peers influenced pre-service teachers' cognitions and decision making during instruction and post-lesson reflective dialogues.

5.6 The relationship between reflection-on-action and reflection-in-action

A scatter diagram was used to assess the extent to which pre-service teachers' post-lesson reflections influenced their reflective actions during teaching. Graph 10 shows the scatter diagram.
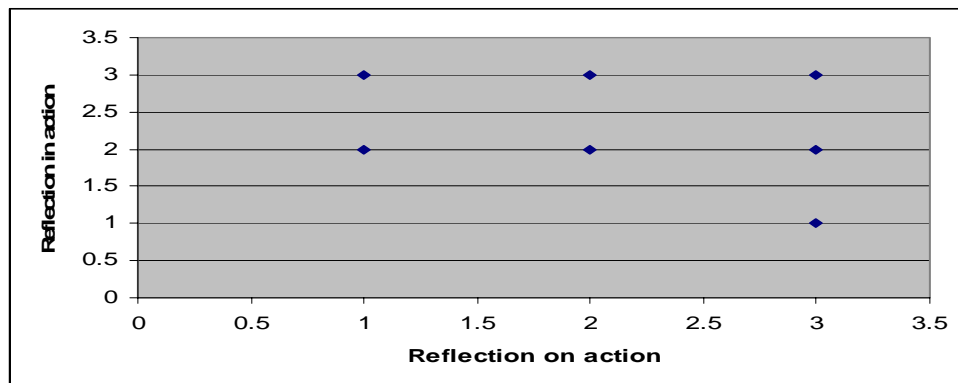
Graph 10. Scatter diagram showing the relationship between pre-service teachers' reflections

To obtain a prediction equation relating post-lesson reflections with reflective actions during teaching, one would place a ruler on the graph and move it about to pass through the points that provide the "best fit" to the data. A "best fit" line divides the points symmetrically. The "best fit" line that is possible from the scatter diagram in graph 10 is a line parallel to the reflection-on-action axis that passes through 2.5 (reflection-in-action = 2.5). This "best fit" line for the pre-service teachers' reflections is a constant that cannot be used to predict the level of reflection-in-action of a pre-service teacher when the level of reflection-on-action is known. This observation makes it possible to conclude that pre-service teachers' post-lesson reflections are not related to their reflective actions during teaching.

The data of interest presented by pre-service teachers do not make it possible to conclude whether or not changes in reflections influenced positively their cognitions and decision making during

instruction and post-lesson reflective dialogues. It is necessary to determine whether the CRP framework influenced the pre-service teachers' post-lesson reflections. This determination is done through assessing the influence of the CRP framework on the pre-service teachers' reflections, which is discussed next.

5.7 Assessment of the impact of the CRP framework

The impact of the CRP framework is assessed by its level of effectiveness to guide pre-service teachers to reflect on the lessons they teach and positively influence their teaching cognitions. The pre-service teachers' reflections during the three rounds of visits generally show some improvements by the third round of visits as shown in Graph 11. For instance, Tendai's reflective actions during teaching dropped from satisfactory in the first round of visits to unsatisfactory in the second round of visits. It picked up to good in the third round of visits (Graph 6).

Munashe's reflective actions during teaching also dropped from good to satisfactory category in the first and second rounds of visits. The reflective actions during teaching for Munashe during the third round of visits could not be determined because he had dropped from teaching practice. Michael's reflective actions during teaching dropped as well from good in the first round of visits to satisfactory in the second round of visits (Graph 8). The level of reflective actions during teaching picked up to good in the third round of visits. Richard's reflective actions during lesson delivery were constantly in the satisfactory category in the first and second rounds of visits and increased to good in the third round of visits (Graph 7). Cynthia is the only pre-service teacher whose reflective actions during teaching remained constantly in the satisfactory category during the three visits (Graph 9). Using these observations one can conclude that CRP positively influenced the reflective actions during teaching of three of the four pre-service teachers who completed teaching practice. Table 10 summarizes the pre-service teachers' reflective actions during teaching, scoring was discussed in section 3.11.1, and collaborative post-lesson reflections, scoring were discussed in section 3.11.3.

Table 10: Summaries of pre-service teacher reflections and frequency of indicators in the CRP framework

	Tendai		Richard		Munashe		Mavis		Michael		Cynthia	
Initial round of visits												
MODUS OPERANDI												
First round of visits												
Name	**Tendai**		**Richard**		**Munashe**		**Mavis**		**Michael**		**Cynthia**	
Reflection Type	Ria	Roa	Ria	Roa	Ria	Roa	Ria	Roa	Ria	Roa	Ria	Roa
Reflection level	S	2	S	1	G	1	G	1	G	1	S	1
CRP stage	Frequency		Frequency		Frequency		Frequency		Frequency		Frequency	
Conception	2		2		0		1		0		0	
Context	6		5		4		7		4		2	
Evaluation	4		2		3		4		6		3	
Development	2		0		2		1		1		1	
Second round of visits												
Reflection level	U	3	S	1	S	1	G	3	S	3	S	1
CRP stage	Frequency		Frequency		Frequency		Frequency		Frequency		Frequency	
Conception	1		2		0		2		5		2	
Context	2		2		4		4		6		1	
Evaluation	3		5		1		3		3		3	
Development	3		1		1		4		4		1	
Third round of visits												
Reflection level	G	3	G	2	A	A	A	A	G	3	S	2
CRP stage	Frequency		Frequency		Frequency		Frequency		Frequency		Frequency	
Conception	3		1		A		A		1		1	
Context	4		7		A		A		5		2	
Evaluation	3		2		A		A		4		3	
Development	4		4		A		A		2		1	

Key: Ria – Reflection-in-action   Roa – Reflection-on-action   U – Unsatisfactory
  S – Satisfactory   G- Good   A - Absent during the round of visits

The pre-service teachers' post-lesson reflective texts generally increased from a lower to a higher category of reflection during the three rounds of visits (Table 10). During the first and second rounds of visits three of the pre-service teachers' (Richard, Munashe and Cynthia) post-lesson reflections remained constantly at technical category (level one). The levels of reflection on the post-lesson reflective texts for Richard and Cynthia improved to practical reflection category (level two) in the third round of visits. The categories of the post-lesson reflective texts for

Tendai and Michael improved from practical reflection (level two) and technical reflection (level one) respectively in the first round of visits to critical reflection (level three) in the second round of visits and constantly remained in the critical reflection category in the third round of visits.

Analysis of the reflections-on-action using the CRP framework phases reveal that the pre-service teachers' improved reflections at each of the phases of the CRP framework influenced positively their reflective actions during teaching (Table 10). This observation makes it possible to note that the CRP framework enhanced the pre-service teachers to reflect on their practice. This is despite that two of the pre-service teachers (Richard and Cynthia) reached the practical reflection category (level two) and the other two (Tendai and Michael) reached the critical reflection category (level three).

Generally the pre-service teachers attained higher categories of reflective actions during teaching than the categories of reflections on post-lesson reflective texts during the first round of visits (Table 10). One post-lesson reflective text attained practical reflection category (level two), and the other five were at the technical reflection category (level one), compared to three satisfactory and three good reflective actions during lesson delivery respectively in the first round of visits (Table 10). In the second round of visits, three of the pre-service teachers' reflective actions during teaching improved to a higher level of reflection while another three reflective actions during teaching decreased to a lower category. In the third round of visits some improvements are noticed in the reflective actions during teaching and post-lesson reflective texts attaining higher categories. The relationships between the post-lesson reflective texts and reflective actions during teaching in the final round of visits is shown on a graph in order to make an informed assessment of the pre-service teachers' reflections at the end of teaching practice.
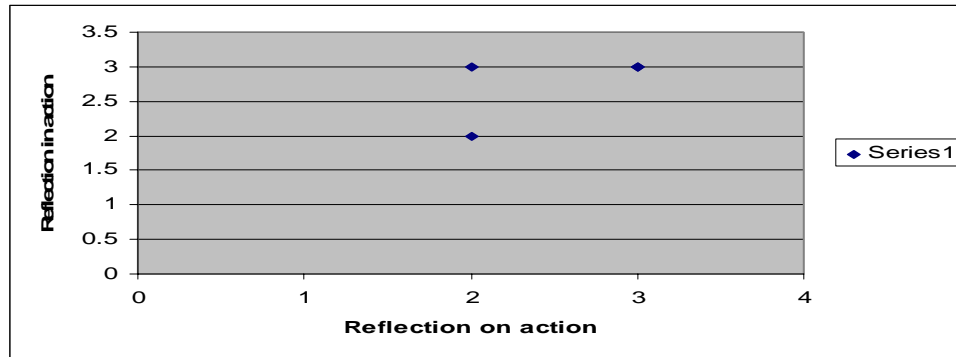
Graph 11. Relationships between pre-service teachers' reflections in the fourth round of visit

Note: Reflections for Tendai and Michael coincide on the scatter diagram at the point (3, 3).

As shown in Graph 11, a line of 'best fit' for reflections in the final round of visits passes through the points (2,2) and (3,3). This linear relationship facilitates concluding that there are positive relationships between post-lesson reflective texts and reflective actions during teaching categories. The line of best fit shows a high reflection-on-action that is associated with a high reflection-in-action. On the basis of the positive relationship that appears between reflective actions during teaching and post-lesson reflections in the third and final round of visits (only), it can be concluded that improvements in the pre-service teachers' collaborative reflections influenced positively their cognition and decision making during teaching and post-lesson reflective dialogues.

5.8 Results from the end of school attachment reflective interviews

The pre-service teachers in this study reflected on the lessons they taught in pairs using the CRP framework, although their post-lesson reflective texts reached different levels of reflection. Motivations for their reflective actions were elicited through reflective group interviews at the end of the teaching practice period in order to determine the factors that influenced the pre-service teachers' reflections. Knowledge of the factors that influenced the pre-service teachers' reflections might provide insights into the reasons for the different levels of reflections that each of them attained. This insight is useful in order to suggest some strategies that may enhance pre-service teachers reflecting on their teaching using the CRP framework to attain critical reflection categories.

During the first round of visits Tendai's post-lesson reflective text was at practical reflection category (level two). In the second round of visits the reflective text improved to critical reflection category (level three) and constantly remained there in the third round of visits (Graph 6). During the interview Tendai's purposes for writing post-lesson reflective texts seemed to be influenced by intrinsic motivations for teaching mathematics as depicted in the interview intercept:

> I like teaching mathematics … I wish my learners can enjoy the subject as I do. Mathematics is an important subject whose pass opens learners' doors to … a variety of job opportunities. A sort of eh … eh combination of enjoyment of mathematics and care for learners' success and wide selection of career opportunities, --- enabled me to devote a lot of time to plan for my lessons. When I reflected with my …peer on the lessons that I taught, I was open to divulge my eh, …. my teaching strengths and weaknesses so that I could get maximum assistance to interpret my instructional practice … in order to improve it. I seeked details and clarifications during … collaborative reflections so that I could assess the practicality of the suggestions we made to interpret and improve our teaching (Tendai: 13 March 2006).

Tendai highlighted a desire to improve learner understanding of mathematical procedures through improved personal teaching practice. Openness to admit instructional weaknesses so as to assist a peer to interpret teaching actions is another factor that enhanced Tendai to improve his post-lesson reflective texts.

Richard had different perspectives on the contents of a post-lesson reflective text. As shown in Graph 7 in the first and second rounds of visits Richard's post-lesson reflective texts were constantly at the technical level (level one). In the third round of visits the post-lesson reflective text improved to deliberate reflection (level two). A conflict between transmission and active methods for teaching mathematics influenced Richard's post-lesson reflective texts:

> Learner constructions of concepts posed a lot of challenges on time and classroom management for me. Implementation of such teaching methods … required time, eh eh for the learners … to talk to each other in order to negotiate meaning. Based on my experience as a learner … demonstrations on the board are effective and …enable lessons to proceed as planned. …. Collaborative reflections on our teaching were useful… but, at at times we did not agree on how to teach some concepts.
>
> … I did not find it useful to repeat writing my teaching weaknesses on a post-lesson reflective text when we discussed them during reflection. When I got convinced that I made some incorrect

decisions during my teaching, I, I, put effort to correct them without highlighting them in writing. I felt that teaching weaknesses … can be written on a lesson critique rather than on a post-lesson reflective text (Richard: 13 March 2006).

Richard's interview intercept reveals a clash of instructional conceptions with his peer and a reluctance to expose his teaching weaknesses in writing. A reluctance to expose his instructional weaknesses limited his capacity to interpret his teaching actions in light of learner outcomes in order to discuss strategies to improve teaching the following lessons.

Cynthia's development of reflective categories was similar to those of Richard. In the first and second rounds of visits her post-lesson reflective texts were constantly rated at the descriptive category (level one) as shown in Graph 9. The basis of her reflections was on teaching experience rather than reflection as depicted in the following intercept:

> I think teaching improves with experience rather than reflection. … during reflection we identified strengths and weaknesses in our teaching practices and theorized alternative strategies to improve them. The intervention measures that I wrote were sometimes criticised …. for being not practical for implementation … in a classroom. I wrote the strategies for improving my teaching from a theoretical perspective …. because this is my first time to teach. I lacked the foresight to predict eh eh the practicality of what we discussed (Cynthia: 15 March 2006).

On why she made premature conclusions without evidence to support the claims made, she had this to say:

> The details required on a post-lesson reflective text…involves too much writing. To analyse and …provide evidence for the strengths and weaknesses of a lesson, and learners' achievement of objectives requires writing … covering several pages. Without mentioning these three aspects,…strengths, weaknesses of a lesson, and achievement of objectives,… the post-lesson reflective text is not complete,… because it does not show the effectiveness of my teaching (Cynthia: 15 March 2006).

Cynthia correctly perceives that a post-lesson reflective text should mention the extent to which learners achieved lesson objectives and some suggestions on intervention measures to improve future teaching. For her, providing evidence for learner achievement of lesson objectives takes a lot of time and space to write. Without insight from teaching experience, she found it difficult to write practical intervention strategies to improve her teaching practice.

Unlike Cynthia, Michael showed evidence of the conclusions and suggestions that he made in his post-lesson reflective texts. During the first round of visits Michael's post-lesson reflective text was at the technical reflection category (level one). As shown in Graph 8 in the second and third rounds of visits the post-lesson reflective texts were constantly at critical reflection category (level three). His post-lesson reflective texts pitched in at the critical reflection category because of his broad understanding of the purposes of reflection shown in the interview intercept below:

> The post-lesson reflective text has at least…eh, eh two functions to me. It portrays my teaching experiences and, and how I am learning to teach. For this reason it shows cumulative mastery of teaching competencies that I … mastered from lessons that I taught. For reporting purposes …the text should show my strong and… weak instructional practices and the developmental insights I gained from the lessons I taught. For these reasons … I provided evidence from classroom events of conclusions that I made on the text in order to expose … my interpretations of the learning situations. Exposition of my teaching decisions and actions on the text enabled me to get feed back from, eh eh my peer that helped me to improve my interpretations of learning contexts (Michael: 15 March 2006).

Michael perceived the functions of the post-lesson reflective text as a reporting document that depicts how he was acquiring teaching competencies and as a formative assessment document that informed him of the contexts in which pedagogical strategies trial tested were effective in local learning contexts. To serve these two purposes of reporting and formative assessment, Michael felt that there should be ample evidence of the conclusions he made on a post-lesson reflective text.

The data of interest indicate that the pre-service teachers' motivations, purposes, and goals for reflecting on their teaching influenced the level to which they reflected on their teaching. This observation makes it possible to conclude that the pre-service teachers' attainment of a category of reflection was influenced by their affective rather than their cognitive potentials.

5.9 Summary

This chapter presented pre-service teachers' findings. Their levels of reflective actions were fluctuating during the period of the study. The majority of the pre-service teachers' reflections attained higher categories of reflections during the third and final round of visits than at the beginning of teaching practice. Based on observations from data of interest, it was concluded that the CRP framework provided positive guidance, though not dramatic, to pre-service teachers reflecting on their teaching with a peer. Chapter Six provides the discussion, recommendations and the future of the CRP framework in order to enhance student teacher reflections and influence positively their cognitions and decision making during instructional practice.

CHAPTER 6: DISCUSSION, RECOMMENDATIONS, AND THE FUTURE OF COLLABORATIVE REFLECTION WITH PEERS

6.1 Chapter overview

This chapter discusses findings from the study. In order to determine whether collaborative reflection with peers enabled student teachers to critically reflect on their teaching and influence positively their cognition and decision making during instruction and post-lesson reflective dialogues, findings from the post-lesson reflective texts are discussed first, followed by those from reflective actions during teaching, and finally by those from reflective interviews. Two theories that emerged from these findings are proposed. Conclusions based on findings from the study are made. They are followed by the recommendations, the future of CRP, limitations, and personal trajectory.

6.2 Discussion of in-service teachers' reflections

6.2.1 In-service teachers' post-lesson reflections

During the early rounds of visits most in-service teachers' post-lesson reflective texts attained low categories of reflection (Table 9). The texts narrated the first few phases of the CRP framework without being interpretive or showing insight developed from teaching a lesson. Peter and Christopher are used as illustrative of this conclusion. Peter focused on describing the context of the learning environment, narrated a bit of his conceptions of the nature of student learning and made some evaluative statements. By narrating personal conceptions, context of the learning environment, and the extent of learner achievement of objectives without being interpretive and showing insight developed from teaching a lesson, Peter's post-lesson reflective text attained the practical reflection category (level two).

A gradual familiarity with the use of the CRP framework in the third round of visits enabled Peter to be more analytic in his reflection at all the four stages of the framework. This enabled him to attain critical reflection category (level three). Analytic reflective statements on the post-lesson reflective texts such as "…I shall be more sensitive to learners' needs without rushing through the content and avoid being a servant of time factor to facilitate learner understanding,"

showed a broad understanding of how students learn and the learning environment that can facilitate their understanding. On the other hand a statement like "…learners' understanding and needs should determine the pace of the lesson" reveal Peter's instructional needs to pitch the pace of a lesson to a rate that enabled learners of different ability levels to understand the content planned for a lesson. As can be noticed from the post-lesson reflective texts, Peter attained critical reflection category (level three) in the second round of visits because of his eagerness to learn and willingness to share instructional problems with a peer. The sharing of instructional insights between Peter and Charles enabled Peter to design alternative teaching strategies with "insight I got from my peer" (Peter: 2 February 2006).

Christopher illustrates another case of gradual improvement in reflection categories over time. His post-lesson reflective text in the first round of visits focused on the first two phases of the CRP framework of conception and context. It showed total absence of the evaluation and the development phases. As shown in section 4.3.3 the post-lesson reflective text that Christopher wrote in the first round of visits stated successful teaching without evidence of the assertions made. This made his post-lesson reflective text rated at the technical reflection category (level one). A gradual familiarity of using the CRP framework enabled Christopher to improve to practical reflection category (level two) in the second round of visits. In this round of visits Christopher's post-lesson reflective text narrated some aspects of the development stage of the CRP framework but was not interpretive enough to attain critical reflection category.

It seemed Christopher's reflections were influenced by some affective factors because his commitment to reflect on his teaching was weak. As a head of a school, Christopher viewed reflection on his teaching as a trivial activity because he believed that he had minimal use of reflective teaching skills in his career (Christopher: 1 February 2006). Christopher reflected on his teaching in order to pass teaching practice. Reflecting on a lesson taught was a requirement of the in-service degree programme, which Christopher was willing to comply with. It seems that reflecting on one's teaching in order to fulfil mandatory requirements does not make a student teacher to reflect deep enough to reach critical reflection level because the act of reflection is an intentional rather than a forced one. Intentional reflection enabled some student teachers to pay attention to events of a lesson in ways that enhanced focusing and sustaining the

value of a reflective activity. Personal commitment that enabled paying attention to the events and outcomes of teaching activities was critical to attaining critical reflection category.

The in-service teachers' views on purposes of reflection expressed through interview intercepts can be used to explain why a pair of in-service teachers reflecting together on a lesson taught attained different reflection categories. For instance, conceptions of the purposes of reflection that the pair of Peter and Charles held influenced the quality of their post-lesson reflective texts. Peter reflected with his peer on the lessons he taught in order to get insight into the 'A' Level content and learners. As a result of his eagerness to learn from his teaching as well as that of his peer's experience as a learner, Peter's teaching improved through reflection. Peter's eagerness to reflect with a peer who used both his experience as a learner and a student teacher sustained his confidence to handle 'A' Level content and learners. On the other hand Charles wrote post-lesson reflective texts of lessons taught in a "hurry as a course requirement rather than for my professional development" (Interview: 2 February 2006). As a result of a lack of understanding the value of reflection on lessons taught, Charles' highest reflection level fell in the second category.

Findings from this study also revealed that in-service teachers' post-lesson reflective texts were influenced more by affective factors rather than cognitive factors. For instance, Christopher's attitude towards reflection on his teaching was negative because he was a non-teaching head of a school who felt that reflective practice skills were not relevant to him. On the other hand Peter's positive attitude toward reflection with a peer enabled him to pay attention to collaborative reflection activities. The evidence provided by in-service teachers, for instance Charles, revealed that in order to improve student teachers' reflections, it is necessary to make them develop positive attitudes toward reflection so that they can have intrinsic motivation to develop a desire to improve their teaching.

One possible way of facilitating student teachers' development of positive attitudes towards reflection is to engage them in dialogues with peers. They may develop positive attitude toward reflection if reflection improve their teaching practice through attaining high assessment grades from their supervisors. Effective student teacher dialogues with peers have potential to become

vehicles of enquiry and models of listening that can facilitate reviewing of their attitudes, values, and beliefs about reflection on their teaching. For instance, in the case of Peter, engagement in dialogic acts with a peer during post-lesson reflective dialogues improved his reflective capacity. Listening to, thinking about, making meaning from, and responding to suggestions made by a peer to improve teaching practice facilitated the improvement in the reflective capacity. Effective dialogues in collaborative reflection with a peer had potential to enable student teachers to verify, extend, or modify their attitudes towards reflection in ways that may extend their reflections beyond practical levels.

Although the in-service teachers in this study implemented the CRP treatment and agreed on the strategies to improve the next lessons, enactment of the agreed teaching plans was an individual student teacher's activity. Enactment of agreed lesson plans is presented in the next section.

6.2.2 In-service teachers' reflective actions during teaching

The enactment of collaboratively designed lesson plans in actual teaching was influenced by personal interpretations of the unfolding classroom contexts by an individual in-service teacher. In-service teachers' decisions and actions during teaching sometimes made their reflective actions fluctuate between lower, the same or higher reflection categories than the previous ones. For instance, three of the in-service teachers' reflective actions during teaching (Peter, Christopher and Nyasha) were unchanged and one (Charles) improved the reflection category during the two rounds of assessment visits. Peter's reflective actions during teaching remained in the satisfactory reflection category while Christopher's and Nyasha's reflective actions during teaching remained in the good reflection category.

The CRP treatment may only clarify and redirect some in-service teachers' thinking and teaching practices but could not succeed in completely erasing or modifying their conceptions of teaching and learning. Some in-service teachers' own conceptualization of teaching influenced the implementation of agreed upon reflective practice strategies. For instance, Peter's reflective actions during teaching remained at the satisfactory reflection category, perhaps due to the robustness of his prior teaching conceptions. As suggested by Posner, Strike, Hewson and Gertzog (1982) for student teachers' existing teaching conceptions on a reform to be altered; the reform should fit their long held instructional conceptions. Similarly, in order for some in-

service teachers' conceptions of reflection on their teaching to be influenced by CRP treatment, collaborative reflection with a peer should fit in their individual teaching conceptions.

Whilst Brown and Borko (1992) acknowledged that most research has shown that student teachers' instructional beliefs seldom change during teacher education, Even and Lappan (1994) posited that teacher education courses should challenge student teachers' views on mathematics teaching in order for them to review their teaching conceptions. Challenging student teachers' conceptions of teaching mathematics during teacher education courses that extend to learning to teach during teaching practice, may encourage them to be more collaborative and creative in ways that may facilitate the CRP treatment to enable them to influence positively their cognition during post-lesson reflective dialogues and teaching practice.

Some in-service teachers' reflective actions during teaching improved during the rounds of visits while for others they were pitched at a constant level. For instance, the consistency of Christopher's and Nyasha's reflective actions during teaching at the highest reflection category can be explained in terms of their teaching experiences which enabled them to organize learning activities that suited students' different learning styles. On the other hand, Charles' unsatisfactory reflective actions during teaching in the first round of visits derived in part from his insensitivity to learners' errors, and failure to notice typographical errors on a problem the learners were solving in groups. This was despite going round the groups to assess group discourses and solution strategies (Section 4.4.2). In the second round of visits Charles' reflective actions improved to the satisfactory reflection category (level two). He taught an interactive lesson that was spoiled by an inability to handle learners' incorrect responses (see Section 4.5. 2).

Charles' failure to achieve good reflective actions during teaching can be attributed to his overconfidence on the teaching skills that he developed during initial teacher training that gave him the complacency to trial test the new instructional skills introduced in the in-service programme. As a result of this confidence, he wished to have some teaching practice documents such as daily lesson planning and writing of post-lesson reflections on lessons taught exempted for in-service teachers on teaching practice (Interview: 2 February 2006).

Exempting in-service teachers from reflecting on their teaching as suggested by Charles could be acting contrary to current trends in teacher education programmes which suggest that space and time should be allocated for reflection. Global trends as reported by Freed-Garrod and McNaughton (2004) and Hatton and Smith (1994) acknowledge that reflection, like any other imaginative activity, requires both space and time in teacher education programmes. The availability of space and time for reflection may enable student teachers to analyse classroom events, narrate, and carefully interpret them. This may facilitate reviewing their cognitions in ways that may influence their decision-making during teaching. Exempting student teachers from writing detailed lesson plans and post-lesson reflections on the lessons that they teach might be suffocating the time and space that is available for reflection. Contrary to Charles' opinions, in-service teacher education programmes should balance time for self-reflection on teaching with planning. Self-reflection may enhance student teachers to critically assess the efficacy of teaching resources, pedagogical approaches, and learning activities. Student teachers' reflections as integral part of teacher education programmes, is premised on van Manen's (1990: 5) conclusion that "every moment of teaching is always a complex temporal region of actions" that needs to be reflected upon in order to understand teaching and improve it.

Peer collaborative reflection was effective to those pairs of in-service teachers who exchanged instructional ideas that helped them to improve their teaching. For instance, Christopher and Nyasha constantly attained 'good' reflective actions during teaching in the first and second rounds of visits. The basis of their successful collaboration was the conceived benefits that each of them derived from the other as explained by Nyasha who said, "I benefited from Christopher's teaching strengths" (Nyasha: 1 February 2006). The pair benefited from instructional insights that they provided each other through identification of teaching strengths and weaknesses, which enabled them to constantly reflect on their teaching at a 'good' reflection category. As in-service teachers tried out new teaching ideas and practices, examine their effects, and elicit a peer's insights to plan the next lesson, they developed instructional judgments that facilitated wise choice for handling lessons that they taught. The next section presents pre-service teachers' reflections.

6.3 Discussion of pre-service teachers' reflections

This section discusses pre-service teachers' post-lesson reflective texts followed by reflective actions during teaching.

6.3.1 Pre-service teachers' post-lesson reflections

Similar to observations made on the in-service teachers' post-lesson reflections in the first rounds of assessment visits, five of the six pre-service teachers' post-lesson reflective texts attained descriptive reflection category (level one). Only one pre-service teacher, Tendai, had post-lesson reflective text that attained practical reflection category (level two). The claim on Tendai's post-lesson reflective text attaining practical reflection category in the first round of visits is that it described, without interpretation, the four phases of the CRP framework. For instance, in the conception phase the following statement was written "the assumption that learners were able to express given numbers as products of prime factors was verified to be correct". Written in the context phase was, "two randomly picked learners correctly expressed the prime factors of 30*"*. "The objectives of the lesson were achieved", was written in the evaluation phase. In the development phase a statement written was "the learner-centred approaches used in this lesson were effective to develop learner understanding of expressing given numbers in their prime factors that the methods will be used again in the next lesson in order to see whether they are always effective" (Tendai: Post-lesson reflective text, January 2006). Without interpreting classroom events, the post-lesson reflective text did not reveal Tendai's understanding of the interplay of theoretical and practical implementation of the teaching strategies used in the lesson.

Continuous use of the CRP framework and feedback from a peer in subsequent teaching enabled Tendai's post-lesson reflective text to discuss each of the phases of the CRP framework more analytically with evidence from teaching episodes. For instance, critical reflection was evident in the post-lesson reflective text shown below:

> The use of English and Shona (the learners' vernacular language) during interpretations of problem-solving tasks enhanced learners' understanding. However, the use of vernacular language has to be employed carefully because learners' summative examinations are in English language. Issues of whether it is professionally right to teach word problems in Shona when it is not the medium of instruction need to be carefully considered in the light of school ethos. Perhaps

it is necessary to code switch English and Shona when learners show signs of not understanding some phrases in English (Tendai: Post-lesson reflective text, 10 February 2006).

Post-lesson reflective texts of this type enhanced Tendai's constant attainment of critical reflection category (level three) in the second and third rounds of visits. The improvements in Tendai's post-lesson reflective texts can be attributed to devoting a lot of time on lesson planning that enabled him to be open to divulge his teaching strengths and challenges during reflections with his peer, Richard (Tendai: 13 March 2006). Giving authority to student teachers and their peers to use their personal experiences to develop each other's teaching efficacy while learning to teach, was central to Tendai's understanding of how and what he was learning from personal and a peer's experience. Effective teaching requires a commitment to integrate personal aspects of a student teacher's life and professional aspects in order to develop self-understanding as a critical component in professional development.

Some pre-service teachers, Richard for instance, had potential to develop professional skills through collaborative reflection with a peer who could provide them with meaningful alternative perspectives on teaching. As pre-service teachers interact with their peers during collaborative reflection, they influence each other psychologically in ways that facilitate their cognitive understanding and development of self-concept as professionals that can enhance teacher identity. Such understanding enabled student teachers to develop teacher identity through awareness of the roles that influenced their teaching effectiveness (Borich, 1999).

The five pre-service teachers who wrote descriptive post-lesson reflective texts in the first round of visits focused their texts on the descriptions of the context of learning and narration of the weaknesses of their teaching. The post-lesson reflective texts ignored assessment of the effectiveness of the pre-service teachers' conceptions of teaching and developmental insights gained in the lessons that had potential to improve future teaching (Table 10). Part of Richard's post-lesson reflective text is used as illustrative of those written by the five pre-service teachers in the first round of visits:

> During class discussion most learners were able to present correct solutions to the algebraic problems they expanded. This might be used to conclude that the lesson objectives were achieved.

The pedagogical strategies used in the lesson were appropriate and effective for the development of intended skills (Post-lesson reflective text: Richard, 10 February 2006).

This type of post-lesson reflective text showed superfluous conclusions that were used to make decisions on teaching. For instance, the post-lesson reflective text did not point out the number of learners who presented their solutions on the board to validate the conclusion that the "objectives of the lesson were achieved". Furthermore, there is no evidence to support the appropriateness of the pedagogical strategies used in the lesson. As also observed by Power, Clarke and Hine (2006), some pre-service teachers had a tendency to make claims portraying teaching success without evidence in order to portray a picture that everything in the classroom was working smoothly. Despite the pre-service teachers accepting the idea of reflection on their teaching, they appeared to maintain a commitment to stating the competencies that they were expected to develop in their post-lesson reflective text.

In the second round of visits two of the pre-service teachers (Mavis and Michael) improved from writing post-lesson reflective texts belonging to the descriptive category (level one) to critical post-lesson reflection category (level three). Illustrative statements like "the use of group-work enabled learners to teach each other in ways that complemented my functions as a teacher" reveal a pre-service teacher's perception that a teacher is not the only source of learner understanding. This and similar statements can be attributed to pre-service teachers' openness in exposing their instructional strengths and weaknesses.

The post-lesson reflective texts of the other three pre-service teachers (Richard, Munashe and Cynthia) remained at the descriptive reflection category (level one) during the second round of visits (Table 10). The three post-lesson reflective texts improved in the distribution of the phases of the CRP framework in the second round of visits. This was despite the text making "conclusions and recommendations that were not substantiated", (Peer's justification for level one reflection category on Munashe's post-lesson reflective text, February 2006). The reason for the three pre-service teachers' post-lesson reflective texts to remain at the descriptive reflection category in the first and second rounds of visits may be attributed to the possible tensions that existed between them and their peers. For instance, Richard held different conceptions of teaching from his peer. Cynthia, on the other hand, believed that teaching improved with

experience rather than theorizing during reflection, contrary to Michael's formative and normative values on reflection.

The sources of the tensions can be hypothesized to emanate from differences in teaching views. Many student teachers went for teaching practice with beliefs, values, assumptions, and knowledge about teaching and learning from personal theories. For instance, they expected their teaching of mathematics to be similar to that which they received when they were learners. Reflection enabled such student teachers to review the web of deeply entrenched personal theories about teaching that they held. For some student teachers, Michael for instance, collaborative reflection with a peer provided welcome experience both cognitively and emotionally. For other student teachers, Richard for instance, the cognitive dissonance they experienced during collaborative reflection was intense and disorienting leading to a belief that there is only one correct way for teaching mathematics effectively. When the tensions (agreeing to disagree) that sometimes developed between a student teacher and a peer were resolved, for instance, between Cynthia and Michael, the post-lesson reflective texts gradually improved. Cynthia's trajectory of improvement is discussed below as illustrative of the others.

Cynthia's post-lesson reflective texts that depicted descriptive reflection consecutively in the first and second rounds of visits improved to practical reflection category in the third round of visits. Practical reflection category that analysed pedagogy characterized Cynthia's post-lesson reflective texts in the third round of visits as shown below:

> In this lesson (integration of trigonometric equations), I used a combination of demonstration, question and answer, and group-work pedagogical strategies to cater for students' different learning styles. Although my peer said that these approaches portrayed mathematics as a fixed body of knowledge that is learnt by rote, algorithmic, and repetitive procedures, we never agreed on a more practical way of teaching the concept of integration at this level. The use of multiple pedagogical strategies was effective to enhance learners' understanding because they complemented each other. In future I will continue to blend teaching methods in order to ensure that at least one of them appeals to students' individual learning styles (Cynthia: Post-lesson reflective text, 15 March 2006).

Improvements in the post-lesson reflective texts in the third round of visits can be attributed to the improved spread of the text over the four phases of the CRP framework and the quality of

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evidence of the conclusions and suggestions that were made to improve teaching. For instance, improvement in Cynthia's post-lesson reflective texts from descriptive to practical reflection category can be attributed to a combination of her experience in using the CRP framework and the collegiality with her peer that was established during collaborative reflection. This was possible because learning how to teach and using the CRP framework was not a spectator sport but a participatory activity that developed with practice over time with assistance from peers.

The factors that influenced pre-service teachers' reflections with a peer on each other's teaching were more of affective rather than cognitive. For instance, Cynthia believed that teaching improved with experience rather than reflection. Cynthia's correct observation can be complemented by reflection that can accelerate the rate of understanding of one's teaching practice. Developing insights into one's teaching through non-reflective practice may occur after years of teaching experience. As Handal (2003) noted, pre-service teachers' conceptions on development of teaching skills (for instance, Cynthia) can curtail their teaching efficacy because their beliefs, values, and dispositions can influence their teaching decisions more than pedagogical understanding or curriculum requirements. Assuming that such deeply rooted beliefs, values, and dispositions that some pre-service teachers bring to teaching practice are undesirable for teaching, they can possibly be dislodged through authentic dialogues with peers using critical incidents drawn from classroom settings.

Unlike Cynthia, the other pre-service teachers acknowledged that reflection was effective to improve their instructional practices but differed on what to write as the post-lesson reflective texts. For instance, Michael perceived post-lesson reflective text as serving both formative and normative functions. Michael's stance was rooted in the belief that, "the post-lesson reflective text has at least…eh two functions. It portrays my teaching experiences and how I am learning to teach". By documenting his instructional trajectory, Michael was informed of the teaching skills that he had mastered and those that required developing. The post-lesson reflective texts also provided Michael with information of the cumulative teaching skills that he acquired during teaching practice. Thus for Michael, exposing teaching weaknesses facilitated provision of professional guidance that gave him foresight to improve his teaching. A discussion of pre-service teachers' reflective actions during teaching is presented next.

6.3.2 Pre-service teachers' reflective actions during teaching

The pre-service teachers had reflective actions during teaching fitting into the 'satisfactory' reflection (level two) and 'good' reflection (level three) categories in the first round of visits. In the second round of visits some pre-service teachers maintained and others lowered their reflection categories. For instance, Richard and Cynthia maintained their reflective actions during teaching at the satisfactory reflection category while Mavis maintained hers at the good reflection category. Three of the pre-service teachers' reflective actions during teaching dropped from a higher to a lower reflection category. For instance, Tendai' reflective actions during teaching dropped from satisfactory to unsatisfactory category whilst Munashe's and Michael's reflections during teaching dropped from good to satisfactory reflection category.

The claim of the drops in the levels of reflective actions during teaching for the three pre-service teachers is levelled at the complexity of the learning enterprise that varies from one moment to another that rendered teaching not a straightforward implementation of standard strategies. The unpredictability of the numerous variables that rendered teaching as interpretive in learning environments that vary from time to time, made effective teaching invoke different skills and strategies from one lesson to another. As also noted by Betoret and Artiga (2004), a student teacher is a dynamic agent who makes decisions, assesses student learning situations, and uses personal thoughts and theories to interpret and respond to learner needs. At times some instructional decisions that student teachers made in response to learner demands promoted student learning, and at other times they did not meet learner needs. For instance, Tendai's reflective actions during teaching the concept of similar triangles in the second round of visits were at an unsatisfactory reflection category after attaining satisfactory reflection category in the previous round of visits. The drop in Tendai's reflective actions during teaching can be explained in terms of the complexity of teaching that required wisdom in choosing the logical sequence of presenting content in a manner that was comprehensive to learners.

In the second round of visits Tendai exhibited unsatisfactory sequencing of content on similar triangles. The illogical sequencing of examples was evident when the first example modelled on the board (similarity of triangles using the equi-angular property) was left incomplete and revisited after covering the second example (section 5.4.1). Example two showed that similarity

of triangles meant that the two triangles' sides were in a constant ratio. Covering the ratio property of similar triangles before the equi-angular property could have facilitated learner applications of the knowledge of ratio of sides to calculate the required sides of similar triangles in the equi-angular property example. Discussing an example half way, leave it incomplete, and revisiting it after covering another example, was illogical sequencing of content that had the potential to confuse learners. Based on this conclusion, Tendai's reflective actions during teaching in the second round of visits were considered to belong to the unsatisfactory reflection category.

In the third round of visits three of the remaining two pairs of pre-service teachers' reflective actions during teaching achieved the good reflection category whilst one remained in the satisfactory reflection category. Tendai who attained unsatisfactory category of reflective actions during teaching in the second round of visits improved to achieve a good reflection category in the third round of visits. The lesson Tendai taught to a Form Two class on solution of fractional equations is used here to illustrate the influence of good reflective actions during teaching in which concepts were sequentially and cognitively connected.

During teaching, Tendai interpreted learners' difficulties in solving linear equations involving fractions as due to lack of understanding of the processes of removing the denominators. He utilized learners' prior knowledge of lowest common multiple to add and subtract fractions with different denominators. The fractions were expressed to their equivalent forms to enable learners to remove the fractions of variables when solving fractional linear equations. Illustrations using skills developed by learners earlier in their learning brought to the fore the structure of mathematical concepts. This strategy enhanced learners' understanding of solving linear equations involving fractions before the learners were introduced to the shorter method of cross multiplication algorithm.

This is the claim and explanation emerging from Tendai's attainment of reflective actions during teaching at the good reflection category in the third round of visits. Correct interpretation of learner prior knowledge and using correct concepts that enhanced learner recall of previously learnt concepts that were applied in new and unfamiliar situations involved thorough planning of

lessons on the part of pre-service teachers. Thorough planning enhances pre-service teachers' diagnosis of possible learner alternative conceptions in ways that can facilitate framing of multiple approaches to overcome them (use of lowest common multiple or common denominators). As also observed by Prescott and Cavanagh (2006), thorough planning enhances student teacher careful explanations of well-chosen examples. Through thorough planning student teachers can present content in a logical form that facilitates locating suitable examples which can utilize learner prior knowledge in ways that can overcome the learning difficulties that learners are predicted to face. The similarities and differences of student teachers' reflective actions during teaching are presented next with a view to theorizing student teacher reflections during teaching.

6.4 Similarities and differences between `student teachers' reflections

The two common instructional difficulties that student teachers in this study experienced in their reflective actions during teaching were: (a) failing to handle learner incorrect responses and (b) demonstrating algorithms that learners could possibly derive on their own using their prior knowledge. Each of these instructional errors is briefly elaborated.

A common teaching difficulty that influenced the categories of reflective actions of student teachers during teaching was that of responding to learner wrong responses. When a student teacher noticed a learner's wrong response during group presentations of solutions on the board, they either picked a different learner to solve the problem or they took over solving the problem. In the first and second rounds of visits the difficulty was dominating in the student teachers' teaching practice. For instance, Charles (section 4.4.2) and Munashe (section 5.4.3) showed that student teachers' responsiveness to learner misconceptions was an important skill that they should develop if student learning in mathematics classrooms is to improve. Ignoring learner misconceptions exposed in their solutions was caused by the student teachers' inability to elicit, listen, and engage with a learner's ideas. As also noted by Broddie, Lelliott and Davis (2002) student teacher eliciting, listening and engagement with learners' ideas are the three key tenets of successful teaching. Student teacher engagements with learner ideas that are characterized by negotiations and willingness to gain insight into learner understanding through probing of the steps they took and the taken-for-granted procedures was crucial for diagnosing learner

misconceptions. Maoto and Wallace (2006) described this teacher-learner engagement as hermeneutic listening. Hermeneutic listening is an important skill that student teachers should develop during teaching practice because it can enable them to design artistic teaching methods aimed at addressing learners' individual needs. Some student teachers' limited skills to engage in hermeneutic listening to learners' responses made them use demonstration methods when discovery methods seemed more appropriate for learner explorations and comprehension of the concepts under review.

Student teachers' demonstrations of mathematical procedures to learners with relevant background knowledge that they could use to explore and discover new concepts can be viewed as unsatisfactory reflective actions during teaching that curtailed learner interactions in a lesson. For instance, Michael showed how to draw a histogram of grouped data to 'A' Level learners (section 5.4.5). Learners covered the concepts of the histogram and the bar chart previously at 'O' Level that they could have extended their knowledge to the development of grouped data concepts. The excessive use of teacher-centred methods were discouraged as that was interpreted to perceiving learners as if they were empty of mathematical concepts. Student teachers' demonstrations of mathematical procedures on the board also have the potential to encourage learners to memorize the steps involved in the procedures in order to reproduce them later in tests and examinations. Whilst class demonstrations are effective in some instances, they can be limited when teaching concepts that learners encountered at a lower class level, which is typical in the spiralled mathematics curriculum.

Student teacher limited use of demonstration methods could allow frequent implementation of discovery methods that can facilitate learners' recall and application of previously learnt knowledge to develop new concepts. For instance, Cynthia could have used the discovery method for learners to establish the area formula of a sector of a circle as $\frac{1}{2}r^2\theta$ and arc length as $r\theta$ where θ is an angle in radians. Frequent uses of discovery methods have the potential to enable students to learn mathematical concepts from the known to the unknown in ways that can facilitate relational understanding and retention of concepts learnt.

Most student teachers who attained 'good' categories of reflective actions during teaching created interactive lessons in which multiple instructional strategies were used to solicit learner ideas. The lessons also employed good questioning techniques, used learners to answer their peers' questions and clarified the peers' misconceptions. Such student teachers picked a different learner to repeat explanations to solutions provided by another. For instance, part of a peer's assessment critique on Peter's reflective actions during teaching a topic on sequences stated that:

> The in-service teacher used various feedback mechanisms to solicit ideas from learners. His questioning techniques were good. He used other learners to correct their peers' errors, for instance, on an arithmetic progression problem with no common difference. He assessed learners' understanding of concepts covered in the lesson by asking questions, (Lesson critique written by a peer, Charles).

The interactive lessons that utilized learners' ideas enhanced creation of debates which facilitated assessments of the extent to which learners understood the concepts covered in a lesson and solutions provided by other learners. Such lessons allowed assessments of learner understanding from a range of learner contributions that were possible from the elicitation of learner thinking during discussions. In cases where student teachers required learners to verify the correctness of their solutions, the quality of the discourse was enhanced. Discourse on the extent to which student teachers' collaborative reflections with peers positively influenced their cognitions and decision-making during teaching and post-lesson reflective dialogues is presented next.

6.5 Correlation between post-lesson reflections and reflective actions during teaching

The level of devotion that some of the student teachers put in their post-lesson reflections and reflective actions during teaching influenced the depth of their reflective activities. For instance, Charles and Christopher were less devoted to collaborative reflection due to the time factor (Charles) and lack of relevance of reflection to their daily professional duties (Christopher). Peter's devotion to improve his teaching efficacy made him reflect again while alone after collaborative reflection with a peer in order to tighten up any loop holes that could have escaped unnoticed in the interpretation and suggestions of strategies to improve his next teaching. Devotion and eagerness are two important characteristics for effective reflection as depicted in the improvements in Peter's post-lesson reflective text, which reached the critical reflection category (level three) in the second round of visits.

Friendship that nurtured trust and openness to each other was conducive for the development of reflective skills in some student teachers. For instance, Nyasha confided in Christopher and the pair shared the complementarities of each other's strengths and weaknesses. The sharing of professional insights facilitated revision of personal conceptions of mathematical concepts and the professional development of Nyasha. Though Christopher's devotion to teaching was low at first, the friendship he later developed with Nyasha facilitated an exchange of professional insights that enabled their reflection-in-action to reach a peak of good reflection category (level three) and constantly remained there during the two rounds of assessment visits.

Despite their lack of teaching experience to design feasible intervention measures to improve their teaching, changes in some pre-service teachers' reflections influenced their cognition and decision-making during instruction and post-lesson reflective dialogues. There were a number of factors that influenced the pre-service teachers' collaborative reflections. Differences in conceptions on the teaching of mathematics influenced the degree of openness and receptiveness to ideas and suggestions made during discussions that were possible during collaborative reflection phases. Richard and Tendai at times disagreed on how to teach certain concepts due to the different conceptions of teaching that they held. For instance, Richard alluded that "….collaborative reflections were useful but at times we did not agree on how to teach some concepts. Implementation of learner-centred methods posed a lot of challenges on time and classroom management to me" (Richard: 13 March 2006).

The pair of Michael and Cynthia worked well though they held different purposes for reflection on their teaching. Cynthia believed that her teaching improved with experience whilst Michael accepted that reflection was an audit that served to provide formative and normative assessments. Formative assessment enabled Michael to identify learner needs in order to improve instructional practice in identified areas of weaknesses. Normative assessment was used to assess Michael's progression in the acquisition of teaching skills. To achieve these purposes of reflection Michael was committed to improving his teaching practice through exposition of his teaching strengths and weaknesses in post-lesson reflective texts in order to get useful feedback. The exposition of

instructional strengths and weaknesses allowed the pair to inform discussions and concentrate on areas that required improvement and suggesting strategies to improve subsequent teaching.

Michael reflected on the post-lesson dialogues again on his own before he wrote post-lesson reflective texts. This was necessary for him to develop a deeper understanding of what was discussed, and to assess the feasibility of the interpretations and suggestions that were made in the light of his learners and the content of the next lesson. Michael's second reflection is similar to what Schon (1983) termed reflection-on-action-on-action that enhances deeper understanding of teaching strategies. Michael's planning of the following lesson was informed by the new understanding that was developed from the two reflections. The next lesson was used to implement the suggestions and personal strategies developed during reflection and planning. In the following post-lesson reflective dialogue after implementing the suggested strategies to improve teaching, Michael reported to his peer the effectiveness of the suggestions he implemented. This enabled discussions on the effectiveness of the strategies they were designing to improve teaching.

As suggested by Dewey (1933) on reflection, successful collaborative post-lesson reflective dialogues of student teachers required a set of essential attitudes of trust, openness, responsibility, and wholeheartedness in order to achieve cooperation. For instance, Richard said that "… I did not find it useful to expose my teaching weaknesses during reflection" (Interview: 13 March 2006). A result of his not being open during collaborative reflection was that Richard's post-lesson reflective text did not exceed practical reflection category (level two). Openness to admit one's teaching errors was a necessary attribute for Richard in order to allow a peer to design or accept alternative viewpoints on plausible pedagogical approaches that were possible for improving teaching effectiveness. Responsibility for correcting one's professional errors had the potential to enable a peer to consider the consequences of actions suggested after consideration of possible outcomes. This entailed debating and negotiating the suggestions that were proposed to improve teaching practice with a view to providing better understanding of how to apply the pedagogical strategies discussed. When openness was established, a student teacher and a peer reflected on a lesson wholeheartedly. For instance, Michael relied on a peer wholeheartedly saying "when I identified a teaching weakness I looked to Cynthia for assistance to interpret and

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design an intervention measure to minimize the weakness" (Michael: 15 March 2006). This statement illustrated the cooperation that developed between Michael and his peer, Cynthia, during collaborative reflection.

Wholeheartedness enabled a student teacher and a peer to reflect on each other's lessons and accept responsibility for correcting misconceptions or misunderstandings that they sometimes held. For instance, Tendai said when "we discussed some strategies to improve my teaching, I asked for details so that I could weigh what was practical to my learners and what was not. This helped both of us to design workable intervention strategies for some weak teaching areas we experienced" (Tendai: 13 March 2006). Without trust and openness, peers treated each other nicely without critically challenging each other's teaching practice. For instance, Richard was not receptive to suggestions made by a peer on teaching some concepts because of differences in conceptions of teaching that they held. He begged to differ or agreed to disagree with his peer. Unlike mentor suggestions, peer reflective discussions held in a free atmosphere were usually powerful and meaningful as they were based on experiences of learning how to teach in non-threatening environments. This is so because mentor telling of good practice may not be teaching and student teacher listening to mentor suggestions may not be learning (Loughran, 2001). When a student teacher and a peer agreed to disagree, they made their positions clear in ways that challenged each other to seek for convincing examples.

The student teachers' results from the study can be used to frame two possible theories on collaborative reflection with peers.

6.6 Collaborative reflection with a peer: Emerging theories

Two possible theories may be discerned from the selected data of interest. The two theories are: (a) a cognitive theory of collaborative reflection and (b) a theory of student teachers' affective goals for reflection on mathematics teaching. Each of these emerging theories is briefly outlined below:

6.6.1 The cognitive theory of collaborative reflection with a peer

The cognitive theory of collaborative reflection with a peer was discerned from the data of interest. It sought to find a strategy that makes collaborative reflection with a peer enable student

teachers to improve reflection on their teaching and positively influence their cognitions during post-lesson reflective dialogues. The theory highlights the cognitive stages that occurred during reflective dialogues.

Some definite and sequential stages in which the post-lesson reflective dialogues of student teachers with peers went through can be deduced from the data of interest. Typically, a post-lesson reflective dialogue started with an assertion derived from a lesson collaboratively assessed. For instance, 'A' Level learners are "expected to have scientific calculators and it seems that the data, 2, 4, 5, 6, 8 given for them to find the mean were too small to use calculators" (Researcher's assertion on Christopher's question on descriptive statistics). This assertion was based on problem-solving pedagogical theories that contend that learning should be based on real problems that are found in learners' environments. The researcher's assertion that the data was not challenging enough for learners' use of calculators was supported by evidence from the lesson taught. For instance, the researcher supported this assertion arguing, "…it seemed as though some learners calculated the mean mentally rather than using calculators". A peer supported the assertion made by the researcher that the data were small enough for mental calculation of the mean. The in-service teacher (Christopher) supported his decision for using such numbers arguing that some learners in the class did not have scientific calculators. Such learners were free to calculate the mean either mentally or using borrowed calculators. In this case there was agreement between the collaborative team (researcher, peer, and the in-service teacher) that the data provided was not appropriate for learners with calculators to compute the mean. The trio then theorized the appropriate uses of calculators in mathematics classrooms beyond computational efficiency to include learner explorations that can lead to critical thinking during applications of mathematical results in problem-solving tasks.

Five stages that are quoted in a student teacher's teaching of descriptive statistics presented above can be identified in the post-lesson reflective dialogue. The researcher stated an *assertion* that the data provided were not challenging enough for learners with calculators to find the mean. *Evidence* that some learners calculated the mean of the data mentally was provided to *support* the assertion. The collaborative team agreed that some learners performed mental computations to find the mean of the data. The student teacher who taught the lesson provided a reason that some

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learners had no calculators to support his decision of using data that learners could find the mean mentally or using calculators. This explanation enabled the reflective team to *theorise* the effective uses of calculators as catalysts for student learning of mathematical procedures. For instance, when calculators are available in mathematics classrooms, learners should be involved in exploratory activities rather than utilize them in a conservative way where calculators are casually, instrumentally and uncritically used for computations (Goos, Galbraith, Renshaw & Geiger, 2000). The theorization led to *understanding* the type of data and appropriate pedagogical strategies that were possible in classrooms where learners have calculators to aide their computations. The sequence of the post-lesson reflective dialogue can be presented schematically in the cognitive theory of collaborative reflection shown below:

Flow chart 1: Cognitive theory of collaborative reflection when there is agreement

Assertion $\longrightarrow$ evidence $\longrightarrow$ support $\longrightarrow$ theorization $\longrightarrow$ understanding

Challenges were sometimes inevitable during collaborative reflection when any two of the collaborative team members disagreed on assertions proffered to interpret teaching actions. For instance, on the multiplicative law of numbers with the same base of the form $x^a \times x^b = x^{a+b}$, a peer asserted that a pre-service teacher's use of the demonstration method to expose the multiplicative law of exponents was appropriate. The peer supported the assertion arguing, "since laws are like theories they were better developed through teacher exposition, so Tendai (a pre-service teacher) used an appropriate approach to demonstrate the multiplicative law of indices" (Richard's critique on Tendai's lesson).

The researcher challenged the peer's assertion. The researcher's challenge against the use of the demonstration method was that using algebraic numbers with the same base and different powers, learners could establish the multiplicative rule on their own. Evidence of how this could be done was provided through the expansion of algebraic letters to given powers and counting the number of bases and expressing the counted number as a power. The source of the challenge was differences between the researcher and peer's conception of how learners can learn the multiplicative rule of indices. There was argument on whether active engagement of learner construction of the multiplicative law of indices or passive recipient was effective for learner

understanding. The challenge and supporting statement on active learner engagement provided additional evidence to refute the absolutist-learning proposition on learner passive recipient of the multiplicative law of indices.

The additional evidence generated theorization of the efficacy of active engagement of learning versus passive learner recipient of mathematical knowledge. The theorization was based on intuitive reasoning and practical experiences premised in pedagogical paradigms, the nature of the content at hand, and the interest of the learners. Engagement in the brainstorming debate nurtured new understanding (agreement, disagreement, or agreeing to disagree) of teacher-centred and learner-centred teaching approaches. A schematic presentation of the collaborative reflection when there was a challenge is summarised below:

Flow chart 2: Cognitive theory of collaborative reflection when there is a challenge

Assertion ⟶ evidence ⟶ challenge ⟶ additional evidence ⟶ theorization ⟶ understanding

The general discussion that emerged from collaborative reflection with a peer during post-lesson reflective dialogues can parsimoniously be represented by combining flaw charts 1 and 2 as shown below:

Flow chart 3: Cognitive theory of collaborative reflection

Assertion ⟶ evidence   Challenge   Support   additional evidence ⟶ theorization ⟶ understanding
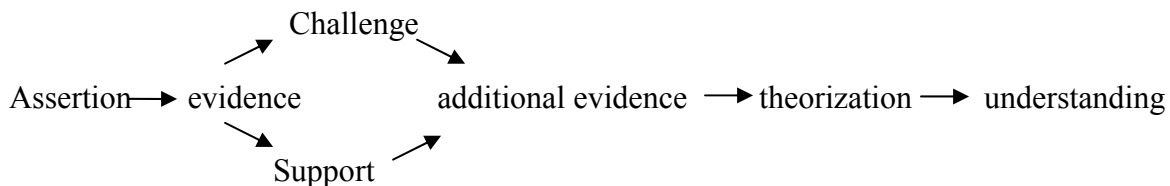
The cognitive theory of collaborative reflection with a peer is a problematic activity that is based on theoretical and practical evidence from a teaching episode. The assertions that are made to interpret teaching actions are supported by theoretically sound evidence in order for them to make sense. Based on the evidence provided for an assertion, the assertion is either supported or challenged through a provision of additional evidence. The additional evidence that can either support the assertion or challenge it, can give rise to theorization in which a collaborative team negotiates the suitability of pedagogical strategies that may be effective in a learning context that

unfolded during teaching. The discussion can analyse teaching conceptions held by a team member, the teaching context and the evaluation of the effectiveness of the decisions made during teaching. This may enhance team members' understanding of the pedagogical strategies implemented and their effectiveness in classroom situations.

The discourse of student teachers using the CRP framework to reflect on their teaching with peers was different from the Aristotelian deductive syllogism of: if, then, therefore logical argument. It is also different from the Toulmin's practical argument (Toulmin, 1958) that focuses on the justificatory function of validating a conclusion. The discourse that was generated in the cognitive collaborative reflection with peers theory were different from Aristotelian syllogism and Toulmin's practical argument theory in that the purpose of the reflective dialogue was not to reach a conclusion of good or bad teaching but to allow student teachers to understand teaching practices from different perspectives. Understanding in post-lesson reflective discourse was born out of agreement, disagreement or agreement to disagree after exploring varieties of teaching strategies that could give student teachers and peers insight to implement pedagogical theories in ways that can improve their teaching. In order to challenge student teachers' cognitions and instructional decisions, arguments generated in the post-lesson reflective dialogues promoted their critical thinking, self-assessment, and self-directed learning.

The cognitive theory of CRP is partially influenced by student teachers' affective goals for reflection. Such goals are explained in the theory of affective goals for collaborative reflection presented next.

6.6.2. Theory of student teachers' affective goals for reflections on mathematics teaching

The student teachers' affective goals for collaborative reflection were explicit from post-lesson reflective texts and reflective interviews at the end of school attachment period. The affective goals provided a theory that might reveal the attitudes that influenced student teachers' reflections during teaching practice. For instance, during the first round of assessment visits the majority of the student teachers' post-lesson reflective texts attained technical reflection category (level one) whilst a few attained practical reflection category (level two). Common statements on the post-lesson reflective texts and verified in reflective interviews were "all content planned for

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the lesson were covered" (Cynthia), "I managed to guide learners to work in groups" (Charles), and "learners discussed their solutions on problems involving Pascal's triangle on the chalkboard" (Peter). Other common statements on the post-lesson reflective texts and verified in reflective interviews were, "the objectives of the lesson were achieved", (Christopher), "work planned was challenging to learners", (Mavis), and "some learners needed assistance and encouragement to express their ideas on the board" (Tendai). These statements portray surviving teaching practice through managing classroom situations. Based on these statements it is concluded that the student teachers had high priorities on creating conducive learning environments that enabled them to conduct lessons as planned during the first round of visits.

Statements dominating some student teachers' post-lesson reflective texts in the second round of visits were the following ones, "the discovery method followed by the group-work approach was effective for learners' mastery of applying the variance formula" (Christopher) and "the use of learner-centred methods in the lesson was instrumental for learner achievement of lesson objectives" (Nyasha). Other statements were "learners worked cooperatively in groups" (Tendai), and "the guided discovery method used on finding the areas of rings, lengths of arcs and areas of sectors was suitable for student learning" (Richard). The conclusions on these statements that were verified in reflective interviews portray priority for implementing pedagogical strategies that student teachers were encouraged to adopt in their teaching.

Priorities on classroom management and implementation of pedagogical strategies were sometimes stated in the post-lesson reflective text without evidence or interpretations of student teachers' actions and learners' outcomes. The post-lesson reflective texts that contained statements portraying classroom management and implementation of pedagogical strategies stated in narrative form satisfied the reflective indicators in the technical reflection category (level one). Those post-lesson reflective texts that contained interpretive statements on learners' actions during implementation of pedagogical strategies usually attained practical reflection category (level two).

The student teachers who achieved critical reflection category showed commitment for learner understanding. For instance, "I probed learners' responses and provided clues that enabled them

to answer their own questions through guided discovery rather than me answering learners' questions" (Nyasha), and "to enhance the development of pedagogical skills on probing learners' responses and allowing them to present work in multiple ways that they can generate in cooperative groups, the approaches used in this lesson will be repeated in the next one and weaknesses noted in the present lesson reduced" (Mavis). These statements are typical of goals for student teachers' priorities on individual learner understanding. One can conclude that these and similar post-lesson reflective texts revealed student teachers' priorities for emotional and social learning needs of individual learners.

Summarizing the student teachers' affective goals for reflection on mathematics presented above brings out a theory on professional attitudes that student teachers held when reflecting on their teaching that can be drawn from the post-lesson reflective texts and interview data. Sophistication of the student teachers' levels of reflections can be theorized to progress through three phases of priorities of learning environment, pedagogical theories and individual learners' understanding. The hierarchies of student teachers' priorities for reflective actions during teaching at each of the reflective phases are shown diagrammatically below:
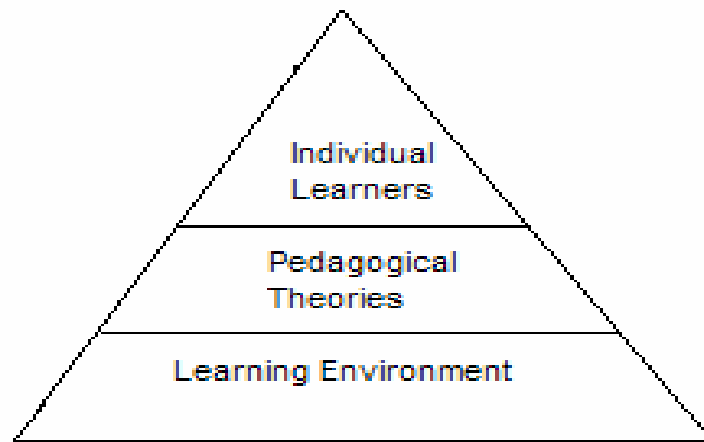
**Figure 7:** Theory of student teachers' affective goals for reflections on mathematics teaching

Categories of priorities in the base of the triangle are achieved first before higher order ones. The rate at which student teachers achieved their priorities depended on individuals. Student teachers who attained critical reflection category (level three) at the end of the teaching practice period

achieved all the three priorities. Those who attained the practical reflection category (level two) at the end of teaching practice period mastered professional skills in the first two priorities.

The theory of affective goals for collaborative reflection shows the attitudes, values, and beliefs that enabled collaborative reflection with a peer to positively influence student teachers' decision-making process during teaching. A student teacher's receptiveness to suggestions made by a peer during collaborative reflection, openness to admit teaching weaknesses, and willingness to learn from, or value the contributions of a peer facilitated the achievement of affective goals from a lower phase to a higher order one.

The theory of student teachers' affective goals for reflections on mathematics teaching can be used as a vehicle to monitor changes in student teachers' actions and intentions in their teaching practice and related beliefs. The purpose of collaborative reflection with a peer, as conceived in this study, was to make student teachers' teaching practices personal and exposed. In pursuing this goal, peers provided opportunities for student teachers to reason out and learn from personal teaching and that of others in ways that enhanced reviewing of personal cognitions on teaching mathematics. It was difficult to change student teachers' beliefs and attitudes towards their instructional practice. As exposed by the cognitive theory of collaborative reflection, student teachers' understanding in post-lesson reflective dialogues guided by the CRP framework was born out of agreement, disagreement or agreement to disagree. Such understanding was not unique to this study. It was also observed by Breen (2005) who concluded that divergence in teaching and learning mathematics broaden possibilities of different strategies for teaching a concept and how learners may respond to the multiple methods enacted by a student teacher.

Similar to results by Easen (1985), findings from this study reveal that peers could not easily change student teachers' conceptions of teaching mathematics. Peers provided a structure, which helped student teachers to review, modify, or maintain their teaching cognitions. Consequently peers were more effective in providing student teachers with multiple interpretations of teaching practices from which they could make informed decisions about their new understanding of teaching more than changing their cognitions on teaching. The conclusions that were made from this study are presented next.

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6.7 Conclusions

Findings from this study revealed that during collaborative reflection, a peer played an influential supporting role in making pedagogical decisions and student teacher learning from personal and a peer's teaching practices. A peer was influential enough to offer ideas and resources as well as become a listener, critical friend, resource person and colleague who provided opportunities for student teachers to reason about, and learn from, personal and others' teaching practice. The use of a CRP framework during collaborative reflection enabled student teachers to broaden their perspectives and overall foci of classroom events.

Fostering reflective practice in student teachers during teaching practice is important because reflective skills are unlikely to develop as professional perspectives after graduation due to the busy and demanding nature of teachers' duties. Findings from this study inform debates on how to improve the effectiveness of the CRP framework to guide student teacher development of critical reflection skills on their personal and their peers' teaching practice.

The two factors that influenced CRP to enable secondary school student teachers to critically reflect on their practice and positively influence their cognitions and decision making during instruction and post-lesson reflective dialogues were: (a) the quality of debate and openness that student teachers were prepared to expose to their peers and, (b) the student teachers' goals for attaining specific teaching skills. These factors are briefly outlined below:

- Student teachers' attitudes, values, and beliefs affected the CRP framework to positively influence their cognitions during teaching and post-lesson reflective dialogues. Openness, commitment, interest, and responsibility for each other's understanding enhanced psychological and cognitive changes at each of the phases in the cognitive collaborative reflection theory of assertion, evidence, challenge, additional evidence, theorization, and understanding. The brainstorming theorizations that characterized effective reflective dialogues where openness was achieved facilitated student teachers' review of their personalized conceptions of teaching and the nature of mathematical content through negotiations of evidences provided. The negotiations nurtured understanding of

pedagogical strategies, content, and how it can be taught, and interpretation of learner actions during a learning context.

- Student teachers' personal goals for teaching a lesson accounted for the priorities that influenced their reflective actions during teaching. The three priority phases of learning environment, pedagogical strategies and individual learner understanding characterized the professional goals that influenced student teachers' reflective actions during teaching. Confidence in enacting lower order priorities facilitated devotion to practice the next higher order ones. Devotion to improve personal teaching was shown through willingness to expose personal teaching weaknesses in post-lesson reflective dialogues, interpretation of pedagogical theories implemented in a lesson, discussion of intervention measures to improve teaching, and evaluation of the suggestions that were made by a peer to improve teaching when alone, before planning the next lesson.

To facilitate student teachers' attainment of the phases in the cognitive theory of collaborative reflection and theory on affective goals on reflection, student teachers should be convinced of the purposes of reflection on their teaching. Student teacher awareness that reflection on their teaching is an important professional skill that shows their honesty to expose their instructional weaknesses and strengths, and assurance that they will be credited for carefully reflecting on their teaching, showing insights drawn from teaching a lesson and designing strategies to improve teaching the following lessons, may go a long way in changing student teachers' attitudes towards reflection. To facilitate student teachers' changes in attitudes towards reflection on their teaching, lecturers on supervision and assessment of student teacher teaching practice should carefully read the post-lesson reflective texts that are written by student teachers and grade them. Lecturer grading of student teacher post-lesson reflective texts may encourage the student teachers to critically reflect on their teaching in order to earn high evaluation grades. When student teachers value reflection on their teaching as an important component of their practicum experience, they are likely to be open to discuss their teaching challenges and develop insight from personal teaching and that of peers in ways that may facilitate collaborative development of strategies to improve their teaching.

The CRP framework, the case studies and the two theories of cognitive and affective goals of reflection were the significant products of this study. The cognitive theory of collaborative reflection and the associated affective motivational goals for reflection can enable student teachers to critically reflect on their teaching, positively influence their cognition and decision making during teaching and post-lesson reflective dialogues. The theories also inform the professional development of secondary mathematics student teachers through collaborative reflection. These theories are also essential for providing insight to teacher educators on coaching student teachers to develop reflection skills and to student teachers on how to achieve critical reflection during the school attachment part of their programme. Based on these conclusions the following recommendation is made.

6.8 Recommendations

To improve student teachers' capacities to collaboratively reflect on their teaching and positively influence their decision making during teaching and post-lesson reflective dialogues, it is recommended that two student teachers be attached to one experienced teacher in an attachment school. The student teachers should share the teaching load of the experienced teacher. For instance, an experienced teacher's teaching load of 24 periods per week may be split into 10 periods per week for each of the two student teachers and the remaining four periods could be taught by the experienced teacher. The experienced teacher uses the four lessons that they teach to demonstrate professional skills that student teachers are encouraged to implement in their teaching after collaborative reflection. The teaching loads of a student teacher or an experienced teacher for the following day are determined on a daily basis during reflection on a lesson taught. The two student teachers and the experienced teacher sit in the lessons that one of them is teaching. The student teachers can practice implementing the teaching strategies that are suggested in reflective discussions during their teaching turns.

Collaborative experienced teacher and student teacher teaching entails planning lessons, making assessments of student learning and reflecting on taught lessons together. The following are some of the potential benefits that may ensue from collaborative teaching:

- Enhancement of student teachers' interpretations of classroom events during reflection.

- Creation of more time than the current situation between student teachers and the experienced teacher. Such arrangements can reduce the problems of time for collaborative reflection activities presented in section 3.7.3. Regular meeting times between experienced teachers and student teachers have potential for development of relationships that can facilitate openness to discuss each other's instructional practice.

- Openness that is likely to develop from regular meetings may enable student teachers to confide in their peers and the experienced teacher. This can enable student teachers to seek advice on instructional strategies that may lead them to experimenting with a variety of teaching methods.

- Teaching the same learners and interpreting their learning needs from a peer and an experienced teacher's points of view may facilitate reviewing of one's cognitive and affective teaching goals.

- Making suggestions to improve student learning during reflection using multiple sources of interpretations may limit the tendency of agreeing to disagree on suggested strategies to improve teaching. When a student teacher and an experienced teacher concur on a teaching strategy during reflection, a peer with contrary views may review their instructional conceptions in order to effectively teach an identified group of learners. This might prompt them to critically reflect on their teaching beliefs in ways that might positively influence their cognitions and decision making during instruction and post-lesson reflective dialogues.

Student teacher peers and mentor collaboration on coaching student teachers' teaching skills can improve collegial mentoring as reported by Nyaumwe, Mtetwa and Brown (2005), and assessment of student teachers' classroom practice noted by Nyaumwe and Mavhunga (2005) and Nyaumwe and Mtetwa (2006). The strategy can also improve the general mentoring programmes of secondary school student teachers in Zimbabwe that Mavhunga (2004) noted to be unsatisfactory. Generalisations of findings from this study to professional developments are presented in the next section.

6.9 Generalizations of findings to other teacher professional development programmes

Generalisations of findings and recommendations from this study should be made with caution due to the small number of case studies involved. The generalisations can be restricted to the cohort of BUSE student teachers on teaching practice in 2006. Promotion of conversations among student teachers on school experience are dominating discourse on how to improve teaching practice models (Rhodes, Phillips, Tomlinson & Reems, 2006). The discourses are made in search of a teaching practice model that can facilitate student teacher sharing and eliciting mathematical and pedagogical thinking that may enable both experienced teachers and student teachers to teach mathematics through active engagements and not through student teacher passive recipient of effective teaching techniques from experienced teachers. It is hoped that such a model will enhance student teacher interactions in supportive environments that encourage them to experiment with teaching theories in order to gain instructional skills that support their professional development as reflective practitioners.

This study has provided insight that can stimulate discussion on how student teachers can benefit more from being involved in reflective conversations with peers on planning, implementation, and student learning. The insight can be extended to other communities of practice that can be organised for student teacher development programmes. In order to put into practice the professional insights developed from this study the future of collaborative reflection with peers is briefly outlined next.

6.10 The future of collaborative reflection with peers

The future of collaborative reflection with peers in Zimbabwe is influenced by global teacher education trends. The focus of teacher education during the past three decades was dynamic. In the 1980s research on teacher development was in relation to self-development and teacher identity where reflection was viewed as a means to improve teachers' teaching performance (Polkinghorne, 1988). The work of Schon (1983, 1987) on reflection-in-action and reflection-on-action highlight the focus of reflection during this decade. The 1990s focused on research on teacher autobiography and narrative thinking (McEwan & Egan, 1995). Teacher conceptions on the nature of mathematical knowledge and how learners master it (Davis, 1990) dominated teacher narratives and reflections during this decade. In the current decade (2000s) research is

concentrating on student teacher moral and socio-cultural perspectives, and reflective practice that facilitates learner achievement of curriculum goals (Hoffman-Kipp, 2003; Kincheloe, 2004).

Overwhelmed by evidence that teacher beliefs influence teaching, the corpus of research in this millennium is focusing on the development of student teacher reflection (Betoret & Artiga, 2004; Handal, 2003). The focus on student teacher reflective practice is influenced by a realization that pedagogical decisions that they make have moral consequences. Choices about what to teach, how to teach it, and ways of communicating mathematical concepts have consequences on learners' values, perspectives, and activities. The focus on reflection is premised on the need to develop student teachers' habits to read critically, reason analytically, communicate persuasively, and perpetually develop a commitment to improve personal teaching from an early stage of their teaching career.

Similar to the case of Scotland (Bloomer, 2002), there is a tendency in Zimbabwe to measure teacher effectiveness in terms of learner performance in summative examinations rather than achievement of both cognitive and affective goals stated in the national curriculum statements. This method of assessing teacher efficacy may be valid if learner examination performance offers a complete proxy for achieving curriculum goals. Examinable mathematical knowledge is generally of a factual and readily accessible nature that cannot be a proxy of curriculum goals because learners are also expected to develop higher-order capabilities of reasoning and problem solving. Student achievement of a wide range of cognitive, affective and psychomotor goals may be enhanced by teacher reflection on how they implement mathematics curricula. Critical reflection enables student teachers to organize the complexity of teaching situations that facilitate learner understanding and application of mathematical concepts in a variety of contexts (Brown & Jones, 2001). Reflective student teachers strive to meet the challenging aspects of teaching through their endeavours to be resourceful, responsive, careful, and analytical self-assessment in order to improve their teaching efficacy.

A supportive learning community can facilitate development of reflective skills where student teachers are encouraged to experiment with pedagogical theories using a CRP model to guide reflections on their teaching. A model of reflection can facilitate student teacher careful and

detailed observations of critical episodes in their teaching before rushing to interpret or evaluate instructional efficacy and student learning. The availability of a CRP framework can slow down student teacher natural inclination to leap to conclusions about classroom events without sufficient evidence in order to critically reflect on their teaching and interpret teacher actions in the light of learner outcomes. Critical reflection facilitates student teacher ability to collect evidence about student learning in order to analyze the effects of their teaching, and using the analysis to revise and improve their instructional practice (Morris, 2006). By considering the extent to which collaborative reflection enabled student teachers to critically reflect on their teaching and positively influence their cognition and decision making during instruction and post-lesson reflective dialogues, this study provides insight into ongoing debates on improving student teacher instructional practice through reflection.

Findings from this study have shown that experience and reflective engagements with peers can influence student teachers' learning to teach mathematics during school attachment. Teaching mathematics, inevitably, is subjected to adaptations relating to changes in societal and technological demands that determine broader educational goals and curricula reform to enable the subject to maintain a core status in the school curriculum. Being an adaptive mathematics teacher involves the ability to be able to cope with the ever-changing demands that the subject continuously brings to the classroom. This requires that mathematics teachers should become continuous learners who are capable of adapting to the changes that mathematics teaching continuously demand from time to time. CRP is an attempt in that direction of educating adaptive student teachers who have the capacity to be life long learners of teaching mathematics through reflection on their practice and that of teacher peers at schools where they teach.

In promoting the goals of CRP, future studies may look into deployment modalities and motivations those student teachers need in order for them to freely expose their teaching strengths and weaknesses in ways that can lead to the development of devotion to improve their teaching. The following questions may guide debates on improving CRP in future studies:

- How can student teachers from diverse backgrounds be kept engaged in post-lesson reflections with peers that facilitate the acquisition of knowledge and attitudes to implement curriculum reform?

- How can CRP enable student teachers to develop appropriate attitudes, values, beliefs, and knowledge that make them take charge of their learning how to teach, from peer and personal teaching practice?

- To what extent can peer assessment of classroom practice of student teachers be used for personal development of a repertoire of teaching skills and for purposes of summative evaluation?

These questions and similar ones that seek to understand implementation strategies of CRP may form the agenda of future studies. Future studies that seek ways of improving student teacher reflections with peers may take note of the following limitations that were inherent in the present study.

6.11 Limitations of the study

Assessment of teaching competencies is usually associated with some inherent limitations as they are coloured by personal observer idiosyncratic tendencies that the results of this study cannot be replicated. By nature, the process of interpreting instructional decisions and actions, and placing them into specific reflection categories may never be hundred percent correct. The possible errors in interpretations were reduced by using open assessments and negotiations for placing reflection levels into appropriate categories. Discourse on classifying reflection levels into appropriate reflection categories depended on the negotiations that took place between the researcher, a peer, and a student teacher and was bound to be different from one pair of student teachers to another. The interpretations made on lessons observed and post-lesson reflective texts assessed may be viewed as temporal (dependent on time and pairs) and tentative.

A second limitation of this study includes external validity or the generalisability of results. There were only four pairs of student teachers who participated in the complete study. The number of the cases was too limited to make broad generalizations. The cases were limited in number, geographical location, and school types to produce a general theory on CRP appropriate

for BUSE student teachers. Inclusive theorization of the feasibility, practicality and effectiveness of the CRP framework can validly be based on a broad range of studies in a variety of school types and teacher education learning contexts.

A third limitation was on time factor. At times it was not possible for student teachers to sit in the lessons taught by their peers and conduct post-lesson reflective dialogues afterwards. Some student teachers attached to urban schools taught lessons in different sessions with their peers, that is to say, one taught lessons in the morning till 12:30 and the other started at 12:30 till 17:00 hours. Such arrangements constrained the pair's collaborative reflection meeting times on the lessons taught towards the end of the day.

These limitations had no negative influence on the recommendations, the strength and validity of findings from this study. This is so because as also observed by Betoret and Artiga (2004) and Even (2005) teaching is a complex profession that is influenced by a myriad of variables which are difficult to replicate. The recognition of the difficulty of replicating the contextual variables that contribute to the complexity of teaching makes the validity of findings from this study to depend on the descriptions of reflective actions that were provided for readers to understand the procedures involved that gives them freedom to make their independent conclusions. Conducting this study provided me with a personal trajectory that I document next.

6.12 Personal trajectory: Some introspection

Four steps of conceptualization, shaping, reconceptualization, and focus epitomize my personal trajectory in conducting this study. At the conceptualization phase my ideas on collaborative reflection with peers were hardly coherent. Coaching from my supervisors, comments made in doctoral and conference presentations helped me to shape the incoherent ideas that I held during the initial phase of the study. Critiques generated after doctoral or conference presentations provided me with insight that facilitated focusing the study to a more comprehensive state. Some pessimistic critiques of a novice helping novice to develop teaching skills inspired me to produce manuscripts that sought to clarify my argument. The resultant manuscripts were sent to refereed journals for possible publications during the first phase of the study.

Reviewers' comments on manuscripts submitted for possible publications complemented my supervisors' coaching in providing insight into some issues that I was overlooking. The comments also reinforced the rigor, precision, and thoroughness that were emphasised by my supervisors as essential in conducting research and writing research reports. Publications of the manuscripts provided me with insight into the viability of my intuitive ideas that student teachers and their peers have potential to make meaningful contributions to the development of each other's teaching skills.

Overall, conducting this study provided me with new understanding of the theoretical and practical characterization of student teacher learning to teach that has enhanced my development as a researcher and a teacher educator.

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APPENDIX A: GUIDE FOR WRITING MATHEMATICS CONTENT AND PEDAGOGICAL OBJECTIVES FOR STUDENT TEACHERS ON TEACHING PRACTICE

Below are pedagogical and content objectives that some student teachers on full time teaching practice of their programme can frame. Traditionally, student teachers on teaching practice used to write content objectives only in order to show the extent to which they were managing the lessons that they were teaching (curriculum implementation and content mastery). In the old paradigm it was difficult to evaluate the extent to which a student teacher was implementing the pedagogical theories that they studied during the residential part of their programme.

To enhance assessment of the extent to which student teachers implement learner-centred strategies that they learn at BUSE in their teaching, the trainee teachers are encouraged to write both content and pedagogical objectives. This approach provides insight to educators of the extent to which theoretical knowledge are put in practice using Zimbabwean classrooms with a view to aligning teacher education courses with the unique realities of the local contexts. Below are examples of mathematical and pedagogical objectives:

Mathematical content objectives	Pedagogical objectives
Solve at least three out of five problems involving patterns and functions in a variety of ways.	Learn to use learner responses to mathematical tasks in productive ways.
Interpret and construct at least six out of ten different graphs of functional relationships related to the real world.	Help learners to generate and make connections between different representations of functions.

APPENDIX B: GROUP INTERVIEW GUIDE

The purpose of this interview is to get insight into your views about collaborative reflection with your peer. The successes, the weaknesses, and your opinions on strategies for improving student teachers' teaching during school attachment are sought.

1. Why were the two of you deployed at this school?

2. Do you think your presence at this school has improved your working relationship?

    2(a) Support your response.

3. What specific professional skills did you gain from collaborative reflection with your peer?

4. How can collaborative reflection with your peer be improved?

5. What problems did you encounter during collaborative reflection with your peer?

6. Do you think your peer influenced your conceptions of the nature of mathematical knowledge and how it should be taught?

    6(a) How did this happen?

7. What suggestions do you want to make in order to facilitate the roles of peers in helping student teachers to develop professional skills during school attachment?

Thank you very much for attending this group interview. I will get in touch with you should I need further clarifications on any of the issues that were raised in this interview.

THANK YOU

APPENDIX C: SAMPLES OF COPIES OF FULL RESEARCHER AND PEER LESSON ASSESSMENT CRITIQUES

C1: Researcher and peer assessment reports on in-service teachers in the second round of visits

Peter: Sequences and series

Peer's assessment critique

Introduction

There was a good link of learners' prior knowledge and the introduction on arithmetic and geometric progressions. Learners' interests were aroused by asking them to present the formulae on the chalkboard.

Lesson development

The student teacher developed the lesson by logically linking concepts in different steps. The logical progression of the lesson was good. The concepts developed during the lesson such as finding sums to the nth term of an AP or GP were applied to solve problems on series.

The student teacher used various feedback mechanisms to solicit ideas from learners. His questioning techniques were good. He used other learners to correct their peers' errors, for instance, on a problem with no common difference. He assessed learners' understanding of concepts covered in the lesson by asking questions.

The content planned for the lesson was appropriate to the learners' ability levels. It was well structured and logically sequenced. The student teacher's mastery of sequences and series was good. The questions that learners solved in groups were challenging to them.

Classroom management

The student teacher maintained discipline and the learners remained focused on the goals of the lesson.

Teaching and learning

The student teacher-learner interaction was good and learners were allowed to interact among themselves in groups. Learner-centred methods such as group work and learner presentations on the board dominated the lesson. Learners were kept busy solving some problems to consolidate concepts learnt in the lesson.

Conclusion: The lesson closure was good.

Researcher's assessment critique

Introduction

The introduction was on the conceptual meaning of arithmetic progression (AP) and geometric progression (GP). Through a question and answer session learners were able to write the nth terms of an AP and GP:

AP $\quad$ $T_n = a + (n - 1)\,d$ $\quad$ and $S_n = \dfrac{n}{2}\,[2a + (n\text{-}1)\,d]$ or $\dfrac{n}{2}\,(n + l)$

GP $\quad$ $T_n = ar^{n-1}$ $\quad\quad$ and $S_n = \dfrac{a(1 - r^n)}{1 - r}$.

Lesson development

Later learners were asked to apply these formulae to solve problems on work cards in groups of between three and five. Learners were encouraged to use six steps of comprehension, identification of variables, the question/task, formula to use, make necessary substitutions and then solving the equations formed.

The problem solving tasks on the work cards were thought provoking. The student teacher went round the groups to assess and probe learners' solution strategies as they worked in groups.

During class discussions learners were asked to state the formula to use and the steps involved to find a solution to number one. Group presentation for number three was done theoretically, by stating the formula to use, forming the simultaneous equations to find the values of the two variables a and b, and finally finding S_{100}. There were too many assumptions made by the student teacher which were appropriate to the average and above average learners. Weak learners struggled to follow the discussion on finding the solution of number three. The lesson summary was done through explanations of work covered.

Appendix C2: Researcher and peer assessment reports of in-service teachers in the second round of visits

Christopher: Descriptive Statistics- the variance

Peer's lesson critique

Introduction

The student teacher used the example 2, 4, 5, 6, 8 in the introduction for learners to calculate the mean. This was done fast as most learners made mental computations.

Lesson development

The student teacher explained the mean deviation using the calculated mean of 5. A table was used to show the mean deviations and when they were squared as shown below:

X	2	4	5	6	8
$x - \bar{x}$	-3	-1	0	1	3
$(x-\bar{x})^2$	9	1	0	1	9

It seems the learners had no knowledge of the generalized $\bar{x}$ although they were able to calculate it using real numbers. The sum of the deviations was shown to equal zero.

The sum of the squared deviations was divided by the number of scores to get the mean deviation ie $\dfrac{(x-\bar{x})^2}{5} = \dfrac{20}{5} = 4$. The use of five (5) as a mean ($\bar{x}$) and as the number of scores (n) caused confusion on some learners.

The formula for variance was derived as Var(X) = $\dfrac{\sum(x-\bar{x})^2}{n}$. The learners were given the data 1, 3, 5, 4 to calculate the variance individually. It was proper to make learners calculate the variance in pairs. Through question and answer session the following results were established: $\sum x$ = 13 and $\bar{x}$ = 3, 25. The student teacher should have encouraged learners to check if the column $x - \bar{x}$ = 0 before calculating $(x - \bar{x})^2$.

The meaning of variance was explained as a measure of squared deviations of the mean from each score i.e $\sqrt{variance}$ = standard deviation. The student teacher emphasized that the notation should be clear, Var(x), and explained Var(x) $= \dfrac{\sum(x-\bar{x})^2}{n} = \dfrac{35}{16}$.

An alternative formula for variance was derived in class from the original one as shown below:

$$\text{Var(x)} = \frac{\sum(x-\bar{x})^2}{n} = \frac{1}{n}[\sum(x^2 - 2x\bar{x} + \bar{x}^2)]$$

$$= \frac{1}{n}[\sum x^2 - \sum 2\bar{x}x + \sum \bar{x}^2]$$

$$= \frac{1}{n}[\sum x^2 - 2\bar{x}\sum x + n\bar{x}^2]$$

$$= \frac{\sum x^2}{n} - 2\bar{x}\frac{\sum x}{n} + \frac{n}{n}\bar{x}^2$$

$$= \frac{\sum x^2}{n} - 2\bar{x}^2 + \bar{x}^2$$

$$= \frac{\sum x^2}{n} - \bar{x}^2$$

The student teacher used examples to clarify learners' problems on expressing $\sum \bar{x}^2$ as $n\bar{x}^2$. The general formula of the mean $\bar{x} = \frac{\sum x}{n}$ should have been clarified in the introduction and at the stage where learners professed ignorance of $\bar{x}$ so that learners could easily make the connection in the deduction for the second formula of variance. Some learners faced problems to find the standard deviation using the new formula that connects standard deviation and variance as the square root of $\frac{\sum x^2}{n} - \bar{x}^2$.

Researcher's assessment critique

Learners were asked to find the mean of 2, 4, 5, 6, 8 using their prior knowledge. The learners quickly found the mean as 5. At 'A' Level learners are expected to have scientific calculators and would seem that the figures given were too small to invoke the use of calculators. It seemed as though some learners calculated the mean mentally. A problem solving task could have been appropriate for learners to see the application of means in the real world, invoke learner thinking and use calculators as a catalyst for making fast calculations of challenging computations.

Lesson development

Detailed explanations for getting the mean could have been done by a learner because they were aware of how to calculate the mean since they made correct calculations from the set of data given earlier. The student teacher could have summarised the procedure by introducing the summation sign $\sum$. The calculated mean was used to find the deviations of each score from the mean. A table was used for learners to calculate the deviations and deviations squared as follows:

X	2	4	5	6	8	$\sum$
$X - \bar{x}$	-3	-1	0	1	3	0
$(x - \bar{x})^2$	9	1	0	1	9	20

The sum of deviations of zero ascertained the accuracy of the calculations and the student teacher emphasized that this sum should always be zero.

The sum of squared deviations was found to be 20 and the mean standard deviation was $\frac{20}{5} = 4$.

Some learners had confusion on the denominator of 5, whether it was emanating from the mean or number of terms, which were also 5. This can be a sign of a poor choice of example. The mean squared deviation of 4 was referred to as the variance. A formula for calculating variance was expressed as Variance = Var(X) $= \frac{\sum (x - \bar{x})^2}{n}$. A practical problem similar to the ones usually found in the summative examination questions could have been useful for learners to conceptually grasp the concept of variance rather than comprehend it theoretically as

Var(X) = $\frac{\sum (x - \bar{x})^2}{n}$.

For consolidation exercise learners were asked to find the variance of 1, 3, 5, 4. During class presentation a learner who was asked to find the variance summarised the data as $\sum x = 13$, n = 4 and $\bar{x}$ = 3, 25 = $3\frac{1}{4}$. The formula for calculating variance derived earlier was used to calculate thus: Var(X) $= \frac{\sum (x - \bar{x})^2}{n} = \frac{1}{4}(\frac{140}{16}) = \frac{35}{16}$. It was at this point that the formal definition of variance was given as the standard deviation squared. Numerically it was expressed as $\sqrt{\frac{(x - \bar{x})^2}{n}}$ = standard deviation $= \sqrt{variance}$. An alternative formula for calculating variance was derived through question and answer session as follows:

$$\frac{\sum (x - \bar{x})^2}{n} = \frac{1}{n}[\sum (x^2 - 2x\bar{x} + \bar{x}^2)] - (1)$$

$$= \frac{1}{n}[\sum x^2 - \sum 2\bar{x}x + \sum \bar{x}^2] \text{ -by the distributive rule}$$

$$= \frac{1}{n}[\sum x^2 - 2\bar{x}\sum x + n\bar{x}^2], 2 \& \bar{x} \text{ are constants, summation of } \bar{x} \text{ n times}$$

$$= \frac{\sum x^2}{n} - 2\bar{x}\frac{\sum x}{n} + \frac{n}{n}\bar{x}^2$$

$$= \frac{\sum x^2}{n} - 2\bar{x}^2 + \bar{x}^2$$

$$\therefore Var(X) = \frac{\sum x^2}{n} - \bar{x}^2.$$

The use of the distributive rule to remove the brackets in (1) was not familiar to most learners. A common answer for $\sum \bar{x}^2$ was $(\bar{x}^n)^2$ from learners. Using an illustration of a constant number the student teacher provided a counter example $2.2.2.2 = 4.2 = 2^{n-1}$. For $2.2.2.2.2 = 5.2 \neq 2^{5-1}$. These generalizations helped learners to understand that 5.2 can be generalized to $n.2$. The student teacher did not probe learners' responses as he tended to interpret their misconceptions and demonstrated the correct conception without asking them to justify their solutions.

Learners' alternative conceptions in the derivation of the second formula for calculating the variance consumed more time than planned that the lesson ended abruptly.

Appendix C3: Samples of pre-service teachers' lesson assessment critiques in the first round of visits

Munashe: Solution of linear equations involving one unknown

Peer's assessment critique on

Introduction

The lesson was introduced through a review of a question from the previous exercise. The learners actively participated because it was a revision exercise. The new concept on linear equations was introduced through the use of learners' prior knowledge.

Lesson development

The student teacher showed good questioning techniques. Whenever, a learner gave a wrong answer he asked other learners to evaluate the answer. This allowed all learners to participate in the lesson even those who lacked confidence to raise their hands. This increased student teacher-learner and learner-learner interactions. The student teacher randomly chose learners to answer questions, this enhanced teacher checking of learner understanding. The student teacher showed clear evidence of a good content mastery and confidence to handle the content under review.

The learning environment was conducive to learning as learners were actively involved in what they were doing. The level of learner participation was high. The learners shared ideas. This could be evidence of understanding what they were learning. A variety of questions were asked for the learners to consolidate the concepts on linear equations.

The researcher's assessment critique

Introduction

The lesson started with finding the solution of $xy + x^2 = 15$ when $x = (-1)$. A learner came to the board to find the value of y. After making the substitution for x she found that $y = 14$. The student teacher asked a question "Is it correct?" and there was a chorus answer "No." A boy was asked to come forward to the board to solve the equation. He also got $y = 14$. The boy showed problems on simplifying directed numbers. The student intervened and obtained the solution $y = -14$.

Lesson development

It was not clear how different the work on solving linear equations in the introduction was different from the content of the lesson because the new work started with a definition of an equation. Later the learners were asked to solve (i) $2x + 1 = 24$ and (ii) $5(m + 20) = \frac{1}{4}$. Two learners were asked to separately solve the two equations at the same time on the board whilst the rest of the class was asked to find their own solutions on pieces of paper.

The first equation was solved correctly and a different learner was asked to come to the board to explain the solution. Despite the fact that the learner picked explained the steps in the equation well, the student teacher repeated the explanations. This was not necessary because the learners seemed to have understood the explanations from their peer.

The second equation was problematic to the first learner who solved it on the board. He solved it thus: $5(m + 2) = \frac{1}{4}$, $5m + 10 = \frac{1}{4}$, $15m = \frac{1}{4}$, $\frac{15m}{4} = \frac{4}{1}$, then 4 in the denominator of 15m and the numerator of 1 were cancelled and the learner ended there. The student teacher realized that the equation was solved wrongly and started to solve it afresh without analyzing the learner's errors such as $5m + 10 = 15m$ and $15m = \frac{1}{4} \Rightarrow \frac{15m}{4} = \frac{4}{1}$. Probing and error diagnosis was necessary in order for learners to know the source of their errors. When a solution x = 1.95 was obtained, the learners were not sure whether it was correct or wrong. Rather than the student teacher explaining each step in the solution as he did during demonstration, direct substitution could have been done in a shorter time rather than reworking the solution and explaining each step. Learners should be encouraged to verify their solutions by substituting them in the original equation or use a different approach rather than repeat the same method of solving an equation.

After solving the equation again, a girl interjected that the step $5m + 10 = \frac{1}{4}$ could be rearranged to obtain $5m = \frac{1}{4} - 10$, after grouping like terms together. This could then lead to $m = -\frac{39}{4}$. The student teacher then changed signs in one step of his solution in order to accommodate this new development. This could have been noticed early if the student teacher had verified the correctness of m = 1.95 by direct substitution in the original equation.

The learners were later given the equations (i) $\frac{3}{2x} - \frac{1}{x} = \frac{1}{4}$, (ii) $\frac{l}{4} = 16$, (iii) $2y + \frac{1}{3} = 0$,

(iv) $3m - 4 = 0$ to solve in pairs.

There was group presentation after ten minutes of solving the problems in pairs. The first equation was problematic to the first presenter. He solved it this way $\frac{3}{2x} - \frac{1}{x} = \frac{1}{4}$, $\frac{2x - 3x}{x.2x} = \frac{1}{4}$, $\frac{(2x)(x)}{2} = \frac{1}{4} - 2$, $x^2 = \frac{1}{8}$. The learner who solved this equation showed problems on common denominator and subtraction of a whole number from a fraction. The student teacher did not diagnose the learner's errors and started to solve the equation afresh. The solution x = 2 was verified through substation in the original equation and found to be viable.

A learner were actively involved in the lesson by solving equations on the board and on pieces of papers in groups but the student teacher was not attentive to their alternative conceptions. Instead of diagnosing learners' errors on their solutions displayed on the board the student teacher started to solve the equations afresh. Probing of learners' solutions could have enabled the learners to identify their own errors and correct themselves.

The lesson ended without conclusion because there were too many equations planned for the lesson. Equations that were solved during class presentation were to be presented as homework the next day.

Appendix C4: Samples of pre-service teachers' lesson assessment critiques in the second round of visits

Tendai: Similarity of triangles

The peer's assessment critique

Introduction

The student teacher introduced the lesson by drawing two rectangles with different lengths and widths. Using the ratios of the lengths and widths of the two rectangles the concept of similarities of two shapes was developed.

Lesson development

One learner was asked to read a problem from the text book and the student teacher translated the words into diagrams of two triangles, ΔFDE with length FD = 6cm, angle D = 90^0 and angle F = 53^0, ΔXYZ is right angled at Y with XY = 3cm, YZ = 4cm, ZX = 5cm and angle Y= 37^0. From calculations the learners found out that from the first triangle, angle E = 37^0 and from the second one Z = 53^0. The learners concluded that ΔXYZ = ΔEDF because the triangles had three equal angles though the sides were different. The student teacher then corrected them that the two triangles were not equal but similar. He summarised the relationship between the triangles as ΔXYZ /// ΔEDF.

The learners were later asked to work out in pairs to show which triangles were similar. The triangles had sides XY = 4, YZ = 7 & ZX = 6. In the second triangle GH = 3, HK = 2 & KG = 3.5. The student teacher went round the class to attend to learners who were finding problems to solve the tasks given. One learner was asked to present her working on the board. She wrote ΔXYZ = ΔHKG using the angles. The student teacher helped to explain using ratios of two triangles with sides 4, 7, 6 and 2, 3.5, 3. It was deduced that the ratios of the sides of the triangles are in the ratio 2: 1. The student teacher did not realize that the learner used = instead of /// that is to say, the triangles are not equal but similar.

The researcher's assessment critique

Introduction

Two rectangles with dimensions 3 by 2 and 6 by 4 were used to illustrate similar shapes. The constant ratios of sides (1: 2) were used to conclude that the rectangles were similar. Pictures of triangles were used to illustrate similarity of triangles. The triangles should have corresponding angles equal in order for the triangles to be similar. To enable learner thinking the problems given for consolidation had two angles given and the learners were to calculate the third angles.

Lesson development

A text book question was used to show that ΔEDF was similar to ΔXYZ. ΔXYZ had dimensions XY = 5, YZ= 4, ZX = 3 & angles Y and Z are 37^0 and 90^0 respectively, while ΔEDF had dimensions ED = 6, angles D and E are 37^0 and 90^0 respectively. Learners calculated angle X and found it to be 53^0, and angle F was found to be 37^0. They concluded that ΔXYZ /// ΔEDF. The reason for similarity was not given as AAA.

Instead of student teacher demonstrations and questioning, learners should have got the opportunity to reason out on their own which triangle was similar to ΔXYZ using the equiangular property. This was going to make them use their prior knowledge on scalene triangles. More challenging work for the bright learners could have been to find the lengths EF and DF. This was going to involve learners' understanding of similarity.

Later the learners were asked to show which triangle was similar to ΔXYZ. The triangles had sides XY = 4, YZ = 7 & ZX = 6. In the second triangle GH = 3, HK = 2 & KG = 3.5. The student teacher went round the class to attend to learners who were finding problems to solve the problems given. One learner was asked to present her working on the board. She wrote

ΔXYZ = ΔHKG based on the angles. The student teacher helped to explain using ratios of sides of triangles of dimensions 4, 7, 6 and 2, 3.5, 3. The student teacher did not realize that the learner used = instead of /// ie the triangles are not equal but similar. It was deduced that the ratios of the sides of the triangles are 2: 1 making the triangles similar.

After the second example the learners were drawn back to example 1. The relationship $\dfrac{YZ}{XZ} = \dfrac{DF}{XZ}$

$\Rightarrow \dfrac{DF}{6} = \dfrac{4}{3}$ was used to calculate the missing sides of ΔEDF of example 1. The learners were also asked to calculate EF. The bell rang before the lesson was concluded.

Appendix C5: Pre-service teachers' lesson assessment critiques in the third round of visits

<u>Richard: Fractions and percentages</u>

Peer's assessment critique

Introduction

The lesson started by defining the meaning of fractions. Learners demonstrated that they were familiar with the concept.

Lesson development

The discussion method was employed for learners to fill in the gaps in the equivalent fractions $\frac{1}{2} = \frac{2}{\underline{}} = \frac{\underline{}}{100} = \frac{500}{\underline{}} = \frac{450}{\underline{}}$. The first learner to be picked up to fill the gaps did it wrongly. The student teacher asked the learner whether she had noticed her errors.

In reducing $\frac{10}{50}$ to its lowest term, a learner explained the process saying " we divide $\frac{10}{50}$ by 10 to get $\frac{1}{5}$." This was not quite correct although the student teacher commented it as correct. (*The solution is correct but the understanding of the procedure that obtains the solution is wrong*).

In filling the denominator of $\frac{450}{\underline{}}$ to its equivalent form of $\frac{1}{2}$ a learner worked it as follows:

$\frac{450}{900} \div \frac{450}{450} = \frac{1}{2}$. Another learner wrote the answer as $\frac{450}{900}$.

Conclusion

The lesson closure was a summary of the concepts covered in the lesson.

Researcher's assessment critique

Introduction

The learners were asked to define a fraction. One girl gave the answer as a number with a numerator and denominator. This definition could have been analysed further.

Lesson development

Learners gave examples of fractions pictorially and numerically. For instance, a circle cut through the diameter as representing a half. When learners represented fractions pictorially, there was need to give a broader definition of a fraction. Later the learners were asked to comment on the fractions $\frac{3}{4}$ and $\frac{75}{100}$. The learners provided answers such as "they are the same" and "they are equal". They were asked to provide one word that describes the fractions and one of them

said that they were equivalent. The concept of equivalent fractions was then discussed followed by examples.

Learners were asked to fill in the gaps in equivalent fractions given below:

(i) $\dfrac{1}{2} = \dfrac{2}{} = \dfrac{}{100} = \dfrac{500}{} = \dfrac{450}{}$ (ii) $\dfrac{2}{3} = \dfrac{4}{} = \dfrac{20}{} = \dfrac{}{6} = \dfrac{}{900}$ (iii) $\dfrac{1}{5} = \dfrac{}{10} = \dfrac{4}{} = \dfrac{}{100} = \dfrac{24}{}$.

The student teacher went round the classroom to assess learners' approaches and reasoning when filling the gaps. The learners obtained correct answers in (i) but their reasoning were not correct. For instance, the last part of (i) was reasoned in this way $\dfrac{450}{900} \div \dfrac{450}{450} = \dfrac{1}{2}$.

A learner who was asked to answer (ii) wrote $\dfrac{2}{3} = \dfrac{4}{12} = \dfrac{20}{60} = \dfrac{2}{6} = \dfrac{300}{900} = \dfrac{8}{24}$. The student teacher should have asked the learner to simplify any of the fractions to its lowest term in order to assess whether it reduces to the first fraction. This was going to help the learner to identify her error and correct it. The student teacher asked another learner to provide an alternative answer. Only girls seated in the front rows of the class were picked up to answer the questions on the board.

Later the lesson dwelt on reducing given fractions to their lowest terms using the HCF of the numerator and denominator. The division by 5 in $\dfrac{25}{100}$ does not involve HCF until when repeated and the fraction was at its lowest.

Conclusion

Learners were asked to summarize the concepts learnt in the lesson as if explaining to a parent who is not knowledgeable of fractions. Learners' explanations were factual showing that they grasped the concepts covered in the lesson.

APPENDIX D: SAMPLES OF SELF-WRITTEN POST-LESSON REFLECTIVE TEXTS

Appendix D1: Charles: The sigma (Σ) notation, infinite geometric progression and problem solving on series

The groups were rather too large, they possibly created passiveness among some learners. Learners should work on group tasks in pairs. I should have moved around the classroom helping learners to construct their meaning of the sign Σ. I was not also responsive and not sensitive to learners' needs and solutions. I should have identified learners to work on the chalk board. Learners should get time to explain their answers and ask different learners to critique the methods used or the solution obtained.

The lesson was rather teacher-centred. I should allow more students to participate in class in order for them to construct their mathematical knowledge. Other group work tasks were not looked at. If time runs out is strongly urged to concentrate on few concepts and ensure learners' understanding on the concepts. However, the lesson was particularly a good one.

Reflection category awarded by a peer: level one

Supporting comments

There is pre-occupation with the identification of mistakes. After a lengthy narration of weaknesses, there is audacity to say that the lesson was "a particularly a good one". This is a contradiction which shows a fleeting reflection.

Reflection category awarded by the researcher: level one

Supporting comments

The reflection exposes the weaknesses of the student teacher eg using large groups, not responsive to learner needs etc. These weaknesses are narrated without explaining the circumstances that warranted them no intervention measures to limit them in future teaching.

Appendix D2: Post-lesson reflective texts written in the second round of visits

Nyasha: Parametric equations

The lesson was challenging enough to enable learners develop critical thinking skills. Learners could find the Cartesian equations of given curves and equations of tangents and normals to given curves. Finding the gradient of a chord was easy for most learners. However, more practice is needed on finding the coordinates of the point of intersection of curves. Factorization of polynomial equations of higher order was difficult for most learners. I exposed learners to various techniques of factorizing polynomials and this enabled them to revive their factorizing skills.

The tutorial approach used in this lesson enabled me and learners to explore a variety of methods to solve problems. This benefited learners since individual learners could comment on the effectiveness of each method used. Some learners had sufficient prior knowledge (gradients of tangents & normals, differentiation of explicit functions, etc) and this made the lesson content covered without deviations to some missing gaps. There was ample time for some consolidation exercises on the concepts covered in the lesson. I led learners to correct themselves on mistakes they exhibited rather than providing them with correct answers. Worksheets reduced excessive use of the board rendering the lesson learner-centred.

Reflection category awarded by a peer: Level two

Supporting comments

Emphasis was put on narrating exposure of learners to various techniques of factorizing polynomials. This portrays the student teacher as surviving teaching practice by exposing to learners various methods to solve mathematical problems.

*Reflection category awarded by the researcher***:** Level two

Supporting comments

The reflection is mainly narrations of events of the lesson. Missing is an evaluation of the pedagogical approaches and suggestions for improving practice. Concentration on technical skills and clarifying content goals are level 2 skills.

Appendix D3: Pre-service teachers' self written post-lesson reflective texts in the first round of visits

Michael: The Maclaurin Series and its application to approximations of logarithmic and trigonometric functions

The lesson was covered well. Both content and pedagogical objectives were achieved. I managed to successfully use learners' knowledge to develop the idea of getting d_i (i = natural number) in x leading to the Maclurin's series.

Learners were able to find the Maclaurin's series for the trigonometric and exponential functions in class discussions. This enabled me to introduce more challenging problems for fast learners while the rest of the learners worked at their own pace on the less challenging tasks.

The most challenging task was using Maclaurin's expansion on $f(x) = e^{x^2}$. This exposed the learners' inadequacies in differentiation of a product. More practice is necessary for learners on differentiation of a product. However, some learners discovered that the shorter method of working standard expansion like that of e^{x^2} was substituting x² by u. More work on Maclaurin's theorem will be done in the next lesson.

Reflection category awarded by a peer: Level one

Supporting comments

The student teacher analysed pedagogy and the desire to improve teaching. He narrated learner performance by differentiating fast and slow ones without evidence.

Reflection category awarded by the researcher: level one

Supporting comments

There is a lot of emphasis on personal survival in statements like "the lesson was well covered, learners were able to find Mclaurin's series and the tasks were challenging." The strengths and weaknesses of the lesson were not identified so were the suggestions to improve future teaching.

Appendix D4: Pre-service teachers' self written post-lesson reflective texts in the second round of visits

Mavis: Form 3: Solution of fractional simultaneous linear equations

Post-lesson reflection

During planning I believed that learners had some prior knowledge on solving simultaneous linear equations involving two unknowns. To verify this assumption learner individual work on the board and on pieces of papers was conceived to be ideal to identify their current state of knowledge on solving simultaneous linear equations.

A learner was asked to solve $x + y = 4$ and $2x + y = 3$ on the board using any one of the substitution and elimination methods. The learner solved the simultaneous equation using both methods. This revealed the reasonableness of the assumption that learners had some prior knowledge on solving some simultaneous linear equations. A different learner was asked to verify the viability of the solutions obtained.

Problems involving fractions such as $x + 3y = 0$ and $\frac{1}{2}(y + 4) = x$ were thought to challenge learners' current knowledge on solving simultaneous linear equations. After some time of working in pairs a learner was randomly selected to come to the board to solve the simultaneous equations. The learner's realization that brackets in the second equation should be removed was appropriate. However, the learner faced challenges to use the distributive law to remove the brackets. In removing the brackets the learner approached the task as $\frac{1}{2}(y + 4) \frac{1}{2} = x \Rightarrow y + 4 = x$. This learner failed to realize that to remove $\frac{1}{2}$ from the left, the equation should be multiplied both sides by 2. A different learner was picked to remove the brackets after the first one failed. The second learner correctly removed the brackets.

I should have probed the learner who wrote $\frac{1}{2}(y + 4) \frac{1}{2} = x$ in order to get insight into how he understood the process of removing brackets. Probing learners' alternative conceptions on mathematical procedures was a glaring weakness of the lesson. The learner might have wanted to cross multiply by 2 but got confused on carrying out the operation. Another weakness of the lesson was my failure to ask learners to present their group work in class discussions. That could have allowed different groups to present solutions in multiple ways. For instance, some groups might have used the distributive law to remove the brackets in $\frac{1}{2}(y + 4) = x$ whilst others might have cross multiplied. Both methods were to yield identical solutions if the computations are correctly carried out.

From this lesson I realized that learners' responses should be probed in order to understand the methods they rightly or wrongly use. Conclusions to group work should be done by group members presenting group solutions on the board during class discussions. This is necessary in order to capture learners' diversity in approaching the problems. To enhance the development of pedagogical skills on probing learners' responses and allowing them to present work in multiple ways that could be generated in cooperative groups, the approaches used in this lesson will be repeated in the next one and weaknesses noted in the present lesson reduced.

Reflection category awarded by a peer: level two

Supporting comments

There was narration of teaching and learning events of the lesson. The weaknesses of the lesson were highlighted and some possible suggestions to improve the lesson were made.

Reflection category awarded by the researcher: level three

Supporting comments

The student teacher analysed learners' prior knowledge and how this helped him to develop new concepts. The student teacher also reflected on learners' problems and suggested strategies for helping them to correct themselves such as probing them. He admitted instructional errors and omissions and suggested ways of overcoming them. He showed a broad understanding of the learning environment and improvises in order to improve practice.

Reflection category awarded by a third opinion: level three

Supporting comments

The reflection shows a broad understanding of the learning theories and learning environment by challenging personal conceptions in the learning enterprise.

Agreed reflection category: level three

Appendix D5: Pre-service teachers' self written post-lesson reflective texts in the third round of visits

Tendai: Form 1 A & B: Addition and subtraction of directed numbers using the number line.

The student teacher believed that learners were aware of addition of directed numbers using the number line. Using this belief the student teacher used discovery method for learners to subtract directed numbers in groups. Learners were asked to simplify -4 – 2 using a number line. After a minute of working, the learners were asked to present their solution(s) to the class. A boy chosen illustrated the solution on the number line perfectly on the board. After learners showed competence to use the number line they were asked to simplify directed numbers of the form -2 – (-2); -3 + (-4). Learners found difficulties to work out the two problems. They failed to interpret the operations on the number line. Group work was not effective to resolve learners' difficulties.

The student teacher demonstrated the two fundamental principles that were applicable in solving the two problems. These were - $1 \times -1 = +1$ and $+1 \times -1 = -1$. Most learners found difficulties to understand these two principles that they were given some work to work in groups in order to consolidate the two concepts. After working five problems in groups most learners seemed to have understood the operations based on the correct solutions they produced.

From this lesson I realized that consolidation of problematic operations in groups enable learners to master the concepts involved. For this to work there should be a lot of problems of different levels of difficulty so that learners can pose, think and discuss the way the problems are to be solved. This normally creates debates among group members that promote discussions that clarify some learners' misconceptions. Also the use of teacher exposition is necessary when concepts become incomprehensive to learner. In such circumstances the integration of absolutist and constructivist strategies promote learner understanding of concepts under review.

The operations on directed numbers are usually problematic to learners. Though in this lesson learners appeared to have understood the two principles applicable on evaluating directed numbers, it is not guaranteed that they will remember them tomorrow. To revive their memories, a chart that summarizes the two principles and their applications on typical problems will be hang in the classroom so that learners can crosscheck their methods with the problems on the chart as they work on new problems involving operations with directed numbers.

Class B

Since learners in an earlier class faced problems in evaluating -2 – (-2) this problem became the focal point in this class. In the earlier class the discovery method was not useful to make learners understand how to solve the problem, so in this lesson the exposition method was used. Group work was given after explaining the two principles used to evaluate addition and subtraction operations of directed numbers. A learner asked to present the solution to -2 – (-2) on the chalk board produced a well reasoned correct answer that made other learners nod their heads in concordance with the steps.

The rest of the text was similar to the one written for class A.

Reflection category awarded by a peer: level three

Supporting comments

The student teacher improved in class B the instructional errors experienced in class A. He chronicled the weaknesses in class A but does not suggest the way forward- the suggestions for improvements as is required in critical reflection.

Reflection category awarded the researcher: level three

Supporting comment

The reflection makes conclusions that are supported. It critically analyses pedagogy, theories of learning and considers learners' interests. The reflection admits errors and omissions, succinctly suggests ways of overcoming them and trying the suggestions for improvement in another class.