PERCEPTIONS OF PRE-SERVICE TEACHERS IN FOUNDATION PHASE MATHEMATICS ABOUT THEIR PROFESSIONAL DEVELOPMENT

by

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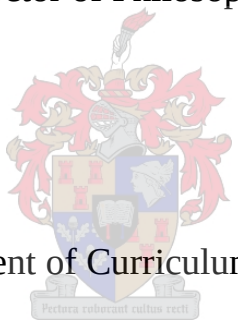

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DECLARATION

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ABSTRACT

This study investigated 3rd-year pre-service teachers' (PSTs) professional development (PD) in Foundation Phase Mathematics., The study specifically elicited the PSTs' perceived improvement in their beliefs, content knowledge (CK) and pedagogical content knowledge (PCK), while learning to teach from the teaching expertise of an expert teacher educator (ETE). There is a paucity of research regarding the effects of ETEs' teaching expertise on the PD of PSTs. A model of teaching expertise comprising eight distinct attributes was identified in the literature, namely:

> Enthusiasm in teaching; Motivating/stimulating students' interest and engagement with learning experiences; Positive relationships with students and approachability; Understanding of students' learning needs and creating a productive learning climate; Humour in teaching; Articulation of subject knowledge expertise; Clarity in lesson presentations/teaching; and Preparations for and organisation of teaching.

The effects of the eight attributes of teaching expertise on the PSTs PD were assessed. PSTs' own assessments of their PD could be considered as important as the formal tests, quizzes, and assignments on which their PD is assessed during their course.

A mixed-method research design was used in which the 3rd-year PSTs' PD was assessed. Data were collected at the beginning (Phase A) and at the end of the 3rd year (Phase B). The purpose was to ascertain the differences between their perceived PD after the first two years (Phase A) and at the end of the 3rd year (Phase B). In Phase A, 71 and 6 PSTs participated in the survey and interviews respectively, while 59 and 5 PSTs participated in Phase B. In both phases, PSTs' perceived improvement in their beliefs, CK, and PCK and the affordances of those improvements were assessed. In both phases, the same questionnaires and interview protocols were used. Data obtained were analysed separately and finally merged for the interpretation and conclusion of the findings.

The findings show that the PSTs in their 3rd year perceived notable improvements in their PD. **They perceived** significant improvements in

> overcoming their feelings of incompetence to engage in problem-solving activities; understanding of how to assist learners to make connections between ideas and strategies in solving problems; and understanding of how to access and assess learners' thinking and comprehension.

The PSTs perceived they **can**

> select appropriate instructional activities and resources; effectively explain concepts and procedures to learners; implement a problem-centred instructional approach; as well as facilitate learners' thinking and meaningful understanding of contents.

The findings further showed that the

> ETE's articulation of subject knowledge expertise and preparations for, and organisation of teaching were the attributes with the most impact on the PSTs' PD, while humour in teaching had the least.

The PSTs' views suggest that their undergraduate training in mathematics education is effective. The findings seem to differ from the claims that PCK only develops in real classroom settings. The findings support Levin's (2014: 51) claim that PSTs' pedagogical beliefs are transformed through observing ETEs. Equally important, the findings argue that a possible turning point for the successful transition of PSTs from learners of mathematics to effective teachers of mathematics is in transforming PSTs' beliefs.

ABSTRAK

Hierdie studie het die professionele ontwikkeling (PO) van voorgraadse studente (VGS'e) in Grondslagfase Wiskundeonderwys ondersoek. Die spesifieke fokus was die VGS'e se persepsies van die verbetering in hul oortuigings, vakinhoudskennis van wiskunde (VIK) en die pedagogiese inhoudskennis (PIK) te ontlok terwyl hulle van 'n ekspert onderwyser-opvoeder (EOO) leer om te onderrig. Daar is 'n skaarste van kennis in hierdie spesifieke veld – die effek wat EOO's op die PD van VGS'e het. 'n Model vir uitgelese onderrigkundigheid wat bestaan uit agt onderskeie eienskappe is in die literatuur geformuleer, naamlik

> Entoesïasme in onderrig; Motivering/stimulasie van studentebelangstelling en betrokkenheid by leerervaringe; positiewe verhoudings met studente en toeganklikheid; Die verstaan van studente se leerbehoeftes en die skep van 'n kreatiewe leerklimaat; Humor in onderrig; Artikulasie van kundige vakinhoudskennis; Duidelikheid in lesaanbieding en onderrig; en Voorbereiding en onderrigorganisasie.

Dit word aanvaar dat die meeste EOO's hierdie kenmerke besit. Die effek van hierdie agt kenmerke van onderrig-uitnemendheid op die VGS'e se PO is geassesseer. Die selfassessering van VGS'e se eie PO is net so belangrik as die formele toetse, *quizzes* en werkopdragte wat hul PO gedurende die kursus meet.

'n Literatuurondersoek is gedoen waarmee die PO van VGS'e gedefinieer is. Ter aanvulling van die literatuurondersoek is die gemengde metode navorsingsontwerp gebruik waarin die 3de jaar VGS'e se PO assesseer is. Data is eerstens aan die einde van hul eerste twee jaar van opleiding (Fase A) en tweedens aan die einde van hul 3de jaar (Fase B) van hul BEd studie ingesamel. Die doel was om hul persepsies van hul PO se groei na die eerste twee jaar en dan aan die einde van die derde jaar vas te stel. Dieselfde vraelyste en onderhoudskedules is in albei gevalle gebruik. Die data is geanaliseer en saamgroepeer om die verskille tussen die VGS'e se waargenome PO in Fase A en Fase B te bepaal.

Die bevindinge wys dat die VGS'e in hul 3de jaar merkbare verbeterings in hul PO waargeneem het. **Hulle beleef dit** dat daar betekenisvolle verbeterings in die volgende was:

> oorwinning oor hul gevoelens van onbevoegdheid om betrokke te raak by probleemoplossing; verstaan van hoe leerders bygestaan word om konneksies te maak tussen idees en strategieë by probleemoplossing; verstaan van hoe om toegang te kry tot en assessering te doen van hul denke en die verstaanproses.

Hulle voel **hulle kan nou**

> die toepaslike onderrigaktiwiteite en bronne kies; konsepte en prosedures verduidelik om leerders se verstaan te bevorder; 'n probleemgesentreerde onderrigbenadering implementeer; leerders se denke en betekenisvolle verstaan van die inhoud fasiliteer.

Die bevindinge wys verder dat

> die VGS se artikulasie van vakinhoudskennis en kundigheid, en voorbereiding vir en organisasie van onderrig, die twee belangrikste kenmerke is wat 'n impak gemaak het op die VGS'e se PO, terwyl humor in onderrig die minste aanduiding gegee het.

Die VGS'e se sieninge beklemtoon dat hul voorgraadse opleiding in wiskundeonderwys daarop gerig is om hulle goed voor te berei vir uitdagings in die wiskundeklaskamer. Hierdie bevindinge wys uitsprake dat PIK net in egte klakamersituasies ontwikkel uit as vals. Inteendeel, dit word wel ontwikkel tydens opleiding van leer om te onderrig. Hierdie bevindinge ondersteun Levin (2014: 51) se aanspraak dat VGS'e se pedagogiese oortuigings getransformeer word deur EOO's dop te hou. Ewe belangrik is die feit dat die bevindinge argumenteer dat 'n moontlike omdraaipunt vir die suksesvolle oorgang van VGS'e as leerders van wiskunde na effektiewe wiskundeonderwysers geleë is in die transformering van VGS'e se vakoortuigings en persepsies.

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BACKGROUND AND MOTIVATION

1.1. PROSPECTIVE TEACHERS' SCHOOL MATHEMATICS EXPERIENCES

Prior to experiencing learning to teach mathematics formally in teacher education modules, most pre-service teachers (PSTs) are reported to have been taught mathematics by elementary school teachers who lack in-depth mathematical knowledge (Shulman, 1986: 8; Kinchin & Cabot, 2010: 161) to transfer "principled mathematical knowledge" to their students (Sowder, 2007: 158; Ball, 1988: 38; Ball, 1990: 11). These students would have developed limited conceptual understanding of mathematics, because their mathematics teachers lack the "rich and flexible" understanding of mathematics subject matter knowledge (Borko, 2004: 5). Not only do such students have limited conceptual understanding, their beliefs and attitudes towards mathematics also seem to be counter-productive (Kesicioğlu, 2015: 84).

The students taught by such teachers could grow up with the defective or surface mathematical understanding they got from their teachers, but the consequences are that they strongly believe that to be "what mathematics is" and that to be "what is worthwhile knowing mathematics" (Borko, Eisenhart, Brown, Underhill, Jones & Agard, 1992: 218; Lampert & Ball, 1999: 33; Thomson & Palermo, 2014: 59; Ambrose, 2004: 91). Beyond the consequences noted above, Ball (1990: 11) notes that PSTs would most likely know mathematics in a way that will not enable them to address the challenges in teaching effectiveness. Akyeampong, Lussier, Pryor and Westbrook (2013: 276) reveal another serious consequence of the above situation, saying that PSTs tend to develop "misplaced confidence" by thinking that teaching is just about recalling facts and following procedures; just about the right or wrong answer (Ball, 1988: 11; Ball, 1990: 10).

The experiences or situations described above gradually develop into a system of beliefs and understanding of mathematics over 12 years of school mathematics learning experiences (Ball, 1990: 10; Bronkhorst, Koster, Meijer, Woldman & Vermunt, 2014: 81; Ingram, 2014: 52; Kinchin & Cabot, 2010: 161; Akyeampong *et al*., 2013: 277). Kagan (1992: 154) has noted that PSTs seem not to compromise on those beliefs, even if their legitimacies are genuinely

challenged. For example, they tend to cling to their beliefs that their future students would have the same learner and learning qualities as themselves when they were young learners (Kagan, 1992: 154). This could amount to informal apprenticeship learning from their school mathematics experiences composed of what their teachers do and say; PSTs' learning experiences as children; and what PSTs think should be taught (Kagan, 1992: 154/159; Da Ponte & Chapman, 2008: 238). Unfortunately, PSTs find it extremely challenging to unlearn the surface understanding and relearn in-depth mathematical knowledge from the teacher educator (Kinchin & Cabot, 2010: 161; Adler, Hossain, Stevenson, Clarke, Archer & Grantham, 2014: 4; Ambrose, 2004: 91; Levin, 2014: 53; Akyeampong *et al*., 2013: 280). This unfortunate situation has been noted by Ball (1990: 11), saying that most mathematics PSTs who seem to be doing well in mathematics tend to believe that the mathematics learning experiences they went through would not need any alternative to better understand the most effective way to teach and learn mathematics. It is now apparent that their apprenticeship learning experiences, for example, influence their preferences about how to teach, how they should learn and how they should be taught mathematics (Ball, 1990: 11; Bronkhorst *et al*., 2014: 81). Those are the school mathematics learning outcomes or experiences most PSTs bring with them into their chosen initial teacher preparation programmes.

1.2. CHALLENGES IN THE INITIAL PREPARATION OF PROSPECTIVE MATHEMATICS TEACHERS

It has been noted that the problems above are compounded by some teacher educators' over reliance on PSTs' school mathematics understanding as sufficient knowledge for teaching for conceptual understanding, but their assumptions have not been productive in PSTs' professional preparation (Ball, 1988: 38; Borko *et al*., 1992: 217-218). Unfortunately, the fundamental mathematics which the PSTs will be teaching after their training also are not taught in detail or critically examined by the teacher educators, in the preparation modules and mathematics courses offered by the university (Buchholtz, Leung, Ding, Kaiser, Park & Schwarz, 2013: 108; Borko *et al*., 1992: 217; Akyeampong *et al*., 2013: 278; Zerpa, Kajander & Van Barneveld, 2009: 70). The seriousness of this situation has been noted by Buchholtz *et al*. (2013) who point out that in most cases elementary PSTs may learn some academic mathematics which are not

taught in the elementary school (Kagan, 1992: 154-158; Bezzina, Bezzina & Stanyer, 2004: 45) and they also learn some mathematics courses which do not enhance their conceptual understanding of the mathematics they are going to teach (Zerpa *et al*., 2009: 70). Therefore, PSTs find themselves trying to teach the mathematics they have departed from learning about for at least three years. Shulman (1986: 8) envisages the negative cumulative effects of all the above and warns that, if the prior education, experiences, or competences of the PSTs are highly deficient in content knowledge (CK) (i.e. the conceptual understanding), then PSTs would end up developing ineffective methodologies to the disadvantage of their future students.

Many researchers in mathematics teacher education have expressed the view that our initial teacher education programmes need more challenging tasks and/or orientations. Lampert and Ball (1999: 33) and Ball (1990: 11), for example, emphasise that, mathematics teacher education should focus on improving the knowledge of PSTs concerning "what it means to know mathematics and what is worthwhile knowing about mathematics". These ambitions support Ball's (1990: 10) idea that PSTs need to experience learning mathematics differently and much better than their school mathematics experiences (i.e. the acquired knowledge and skills), which have been noted as lacking the desired in-depth understanding and beliefs or orientations.

This knowledge of mathematics means in-depth or conceptual understanding of mathematical principles and thorough explanations of mathematical procedures (why they work the way they work) and demonstrating the understanding of explicit and implicit connections between mathematical concepts, facts and procedures (Borko *et al.*, 1992: 195; Ball, 1990: 14). Kagan (1992: 162) contends that it is in this kind of understanding that the developmental needs of PSTs are rightly positioned.

Borko *et al*. (1992: 195) further explain desired knowledge about mathematics to mean the understanding of the "… nature and discourse of mathematics and to understand what it means to know and do mathematics", thus knowing mathematics in task-oriented contexts and situation-oriented context (Wedege, 1999: 206-207; Ball, 1990: 14-15). Experiences of this kind or knowing mathematics within such frameworks can help PSTs to revisit and reconstruct or reinterpret their school mathematical experiences for better and deeper understanding of the mathematics they are going to teach, hence, enhancing their understanding of it (Ball, 1990: 14).

Da Ponte and Chapman (2008: 238) propose that the preparation of PSTs should consider exposing them to learning opportunities, coupled with reflection, which will help them to relearn and correct their wrong perceptions about the nature of mathematics and the teaching of mathematics. Similarly, Ball (1990: 11) says that there is an urgent need for teacher educators to address or challenge the continuous connections and influences of school mathematics experiences on the present learning experiences of PSTs in teacher education. This was due to Ball's (1988: 37) observations that "…without revisiting the "simple" mathematical content they will teach – to revise and develop correct understandings of the underlying principles and warrants, of the connections among ideas – prospective teachers may be wholly unprepared…". Additionally, Levin (2014: 51) proposes that more research is needed regarding the sources through which PSTs develop their pedagogical belief and the influences of those sources (such as learning from the expert teacher educator's (ETE's) knowledge, skills, and beliefs) on their emerging beliefs. Kagan (1992: 154) confirms the views about the influences of expertise in teaching on learning, claiming that it is one of two very important factors which are shaping the PST's entry beliefs or PST images about the teacher and teaching. Those proposals underpin what could be meant by developing knowledge of mathematics and knowledge about mathematics (Borko *et al*., 1992; Lampert & Ball, 1999), and could also be emphasising that teacher educators need to pay more attention to the mathematical preparation of PSTs, because PSTs need to develop the competence and confidence to improve instructional quality in the classroom (Hill, Rowan & Ball, 2005: 372; Ball & Forzani, 2010: 40).

1.3. OVERCOMING THE CHALLENGES

Given the above ambitious vision, propositions, and expectations, the ETE's role is becoming increasingly significant (Bronkhorst *et al*., 2014: 74; Haydn, 2014; Ball & Forzani, 2010: 41, Hativa, Barak & Simhi, 2001: 699; Kagan, 1992: 154; Levin, 2014: 51). Witt, Goode and Ibbett (2013: 20), Hativa *et al*. (2001: 699), and Da Ponte and Chapman (2008: 228) share the view that PSTs, in learning to teach, need to access the teaching beliefs, pedagogical knowledge and teaching expertise of ETEs (Glass, Kim, Evens, Michael & Rovick, 1999: 43**)**. Levin (2014: 51) claims that the pedagogical beliefs of PSTs are transformed through observing the teaching

expertise of ETEs (Kagan, 1992: 154). This is important because, in Shulman's (1986: 8) view, the holistic knowledge that PSTs possess in their discipline are characterised by their beliefs, understandings, and conceptions. Shulman's (1986) view buttresses the suggestions of the authors mentioned above regarding what and how PSTs should be assisted to improve their professional development (PD) as mathematics teachers (Kinchin & Cabot, 2010: 153). For example, PSTs have been reported to have confirmed that the expertise of their university educators is one of the most influential factors helping them to develop their confidence and feel well prepared for the tasks of teaching information communication technology (ICT) (Haydn, 2014: 3).

The ETE, according to Chi (2006: 22), is the "…one who has special skills or knowledge derived from extensive experience with sub-domains". More specifically, an ETE is the one who continuously engages in self-regulating his learning about teaching to develop expertise in teaching (Kreber, 2002: 12). According to Shim and Roth (2008: 6), "expert teaching in higher education" is uniquely characterised by the following components of teaching expertise:

> ... clarity of presentation; enthusiasm of teaching; command of subject knowledge; preparation and organisation; interpersonal relationship; humour and approachability; stimulating the interest of students for engagement in learning; and understanding of students and creating a positive environment (Shim & Roth, 2008: 6).

In connection with ETE's preparation and organisation, Hativa *et al*.'s (2001: 701) investigations show that ETEs carefully plan their lessons, with clear learning goals, and set ambitious targets for their students (Chae, Kim & Glass, 2005: 28). Chae *et al*. (2005) say that "goal-setting is a way to communicate procedural knowledge in what is mostly a problem solving activity" (P. 28). It is important to note that preparation and organisation is among the factors that distinguish the ETE from non-experts (Berliner, 1988: 62-63). Hativa *et al*. found that ETEs value regular flow of feedback to monitor their students' improvement (Helterbran, 2008: 125), they address inadequacies in students' development through intensive remedial learning opportunities, and they involve themselves deeply in achieving students' learning outcomes (Murray, 2006: 388-389). These could be consistent with the ETE's clarity of presentation; stimulating the interest of students for engagement in learning; understanding of students; and creating a positive environment as identified by Kreber (2002: 9) and Shim and Roth (2008: 6).

Hativa *et al*. (2001) explain further that ETEs respect individual diversities; encourage students' active participation in intellectually demanding learning tasks; and use effective teaching strategies to sustain students' interests in an enabling learning environment (Chae *et al.*, 2005: 28). ETEs have developed strong joy in teaching (Kreber, 2002: 10), which translates into the high sense of enthusiasm and humour incorporated in their teaching (Hativa *et al.*, 2001). These confirm Shim and Roth's interpersonal relationship, humour and approachability, and enthusiasm in teaching. Other distinguishing constructs, consistent with the ETE's command of subject knowledge (Shim & Roth, 2008: 6; Kreber, 2002: 9) that have been observed by Hativa *et al*. (2001) include the ETE's deliberate efforts to engage students by using questions and discussions to promote active learning, effective presentations and communications, and motivations of student learning (Kreber, 2002: 9). In particular, the ETE's presentations in teaching have been found to be very clear, well organised, and highly interesting for promoting effective students learning. ETEs' positive communication with their students (Kreber, 2002: 9) build trust and good interpersonal relationships, which create a productive learning environment and foster desired learning outcomes (Hativa *et al*., 2001).

1.4. EMPHASIS ON KNOWLEDGE TRANSFER IN HIGHER EDUCATION

In connection with the researchers' propositions for improving the PST's optimum development as introduced above (as in the views of Lampert & Ball, 1999; Borko *et al*., 1992; Da Ponte & Chapman, 2008; Wedege, 1999; Ball, 1988; Hill *et al.*, 2005; Ball & Forzani, 2010), university education is now placing more emphasis on knowledge transfer in teaching and learning as opposed to knowledge transmission (Dineke, Diana, Ineke & Cees, 2004: 253; Devlin & Samarawickrema, 2010: 111-112). The notion of knowledge transfer is that teaching should focus on the learners and their learning experiences (Ho, Watkins & Kelly, 2001: 144). Unfortunately, as Akyeampong *et al*. (2013: 275) report, this concept (i.e. knowledge transfer in teaching), according some teacher educators, is under potential threat or may be "washed out", the reason being that the increasing number of student teachers is compelling university administrators to economise on staff and student time. Others think that knowledge transfer could be time consuming and extra teachers will need to be hired (Murray, 2006: 387).

However, the call for knowledge transfer to develop competent teachers (Berliner, 1988: 63), still reserves the motivation for excellent teaching and quality pedagogical practices in the work of teacher educators evidenced in the increasing concerns of most universities (Kinchin & Cabot, 2010: 153; Korthagen, Loughran & Lunenberg, 2005: 107). Levin (2014: 61), for example, observes that teacher educators oriented towards the philosophy of knowledge transfer are focusing on preparing future teachers who can "... sustain themselves when competing expectations challenge their beliefs". This confirms the views that the shifts towards knowledge transfer in teaching and learning as opposed to knowledge transmission have further motivated universities' interests in the effectiveness of the teaching practices of teacher educators (Hativa *et al*., 2001; Mosoge & Taunyane, 2012).

Knowledge transfer in teaching and learning could not be said to be perfect despite the positive accounts about it. According to Shim and Roth (2008: 7) the quality of the transfer of expert teaching knowledge, for example, requires systematic ways to access to it, and Sadler (2012: 731) and Levin (2014: 50) agree that the knowledge transfer is challenging for some teacher educators, and it sometimes may not be adequately transferred (Berliner, 1988: 60). This could be due to Hativa *et al.*'s (2001: 700) observations that non-expert teacher educators mostly have fragmented pedagogical knowledge and erroneous beliefs about what makes teaching effective (Hativa, 1998: 375). It seems clear that some teacher educators could be more successful than others in transferring expert teaching knowledge to PSTs (Levin, 2014: 50; Akyeampong *et al*., 2013: 279). This could suggest that the teaching expertise of teacher educators might be instrumental in this new teaching and learning environment.

1.5. OVERVIEW OF RESEARCH ON TEACHING EXPERTISE

From the background presented above, there are indications that the effectiveness of the teaching expertise of teacher educators has been recognised (Superfine & Li, 2014: 1). However, it appears that dominant issues in the field of expert knowledge and teaching expertise have been about **who the expert is** (Chi, 2006); **the nature of expert knowledge** (Hativa *et al*., 2001); **the complexities and** "**… descriptions of the pedagogical and affective attributes of the expert teachers** …" (Smith & Strahan, 2004: 360); **the distinguishing practices and performances of the expert** (Maxwell, Vincent & Ball, 2011; Lu, Di Eugenio, Kershaw, Ohlsson & Corrigan-

Halpern, 2007: 456); and **comparing experts' performances with novices' performances** (Bereiter & Scardamalia, 1993; Berliner, 1988: 39; Smith & Strahan, 2004: 358; Di Eugenio, Kershaw, Lu, Corrigan-Halpern & Ohlsson, 2006: 503; Glass *et al.*,1999: 43). In the field of mathematics education, researchers, for example, have been focusing on **investigating and explaining the nature of mathematics teaching expertise** (Yang & Leung, 2011: 1008) and the **improvements in teachers' mathematics teaching expertise** (Li & Even, 2011: 760).

Clearly, research or knowledge about the impacts of the ETE's teaching knowledge on the PST's PD is rare in literature about effective teaching in higher institutions (Lunenberg, Korthagen & Swennen, 2007: 588; Korthagen *et al*., 2005: 111; Shim & Roth, 2008: 6-7, Murray, 2006: 384; Berliner, 2004: 208). This could probably be due to the fact that research on the expertise of teacher educators has received very little attention (Smith, 2005: 178; Celik, 2011: 79; Berliner, 1988: 39) and likewise there have not been extensive investigations about the attributes of teacher educators' expertise and professionalism (Murray, 2006: 384; Korthagen *et al*., 2005: 111).

In the interest of improving teacher education, it would be justifiable to agree with the propositions or recommendations presented by Bereiter and Scardamalia, (1993), Yang and Leung (2011), Smith (2005), Celik (2011) and Berliner (1988) that research in the field of expertise, especially teaching expertise, should begin considering possibilities of advancing this field from different perspectives, so as to broaden our knowledge about expertise in general and teaching expertise in particular. For example, Bereiter and Scardamalia (1993) are concerned about renewing and redirecting research interest from the traditional expert-novice comparisons to investigating how the novices will become experts in their chosen careers for the benefits of their communities. Bereiter and Scardamalia (1993) are passionate about this significant shift in research focus, because they claim that this is how the development of the society can be influenced by our research.

Yang and Leung (2011) also call for investigations to be carried out on the "… influence and the nature of mathematics teaching expertise and its development" (p. 1014). All the above evidence show that the impact of mathematics ETEs' teaching expertise on prospective teachers' professional knowledge and emerging competencies for their future work of teaching have

received insufficient attention in this field of research (Murray, 2006: 433). This could be seen as a major gap in knowledge in this field which needs researchers' attention.

1.6. RESEARCH INTEREST IN VIEW OF KNOWLEDGE GAPS

In the light of the identified knowledge gap above, the researcher deemed it viable and timely to contribute to or improve knowledge in this field by investigating the impact of teacher educators' expert teaching on PSTs' learning outcomes (PD). The reasons for considering PSTs' PD were obvious, as in the views of Witt *et al*. (2013: 20), Hativa *et al*. (2001: 699), and Da Ponte and Chapman (2008: 228) and explained in section **1.3.** besides these researchers, Levin (2014: 51) has also called for the need to conduct research into the sources through which PSTs develop their pedagogical beliefs and the influences of those sources on their emerging beliefs. More generally, Kaiser, Schwarz and Tiedemann (2010: 433) have observed that investigations into the influences of initial teacher education programmes or systems on prospective teachers' professional knowledge and emerging competencies for their future work of teaching have received insufficient attention in this field of research. Kaiser and her colleagues backed their claims by saying that prospective teachers' beliefs about mathematics, mathematical knowledge and mathematics pedagogical knowledge are among the important issues of concern in the evaluations and comparisons of the effectiveness of initial teacher education programmes. The teacher educator is an important factor in this system, and what teacher educators in the field of initial teacher education are trying to accomplish is to prepare expert teachers who are well-equipped with content knowledge, pedagogical knowledge, and pedagogical content knowledge (Jegede, Taplin & Chan, 2000: 288).

Specifically, this study investigated PSTs' perceived PD in Foundation Phase mathematics from their interactions with ETE's teaching expertise. According to Shim and Roth (2008), most ETEs have been identified as articulating their teaching expertise as ways through which their expert knowledge becomes apparent and shared with their students (Haydn, 2014: 3; Hativa *et al.*, 2001). Since PSTs are learning to teach mathematics from the ETE and the ETE is mainly preparing the PSTs to teach mathematics with some degree of expertise, it was justifiable to investigate the influences of their teaching expertise on the PSTs' PD. The PSTs' PD was defined in terms of three fundamental learning outcomes, namely, transformations/improvements

in PSTs beliefs about the mathematics they are going to teach and the teaching and learning of it; improvements in their understanding of mathematics CK, and the development of their PCK for mathematics (Ball, 1988: 10; Kaiser *et al.*, 2010: 433; Da Ponte & Chapman, 2008: 225). This was supported by Monroe, Bailey, Mitchell and AhSue (2011: 2) who are of the view that teachers' professional development should address changes in beliefs, knowledge, and practice. The framework of the PST's PD used in this study could be consistent with San's (1999: 20) definition of teachers' PD as the changes in knowledge, skills and attitudes for the improvement of professional practice. Schwarz, Leung, Buchholtz, Kaiser, Stillman, Brown and Vale (2008: 795), interestingly, have stated categorically that mathematical content knowledge – understanding of the school mathematics (Buchholtz *et al.*, 2013: 108); pedagogical content knowledge (i.e. understanding of the mathematics curriculum and analysis of learners' mathematical abilities); and beliefs (i.e. about mathematics, and the teaching and learning of it) are the main dimensions of prospective mathematics teachers' professional knowledge (Borko *et al.*, 1992: 194).

The focus of this research could be considered indispensable in promoting teacher education and professional development of teachers, especially for promoting the PD in mathematics education of PSTs (Da Ponte & Chapman, 2008: 224). Jegede *et al.* (2000: 288) argue that the PSTs' PD is attracting more and more attention from teacher educators and teacher education policy makers in order to achieve desired educational reforms. Similarly, the PD of PSTs (becoming novice experts in their disciplines) is regarded by Shulman (1986) as one of the transitional issues in initial teacher education which provoke numerous crucial concerns that need urgent attention, for example

- How does the successful college student transform his or her expertise in the subject matter into a form that high school students can comprehend?
- When this novice teacher confronts flawed or muddled textbook chapters or befuddled students, how does he or she employ content expertise to generate new explanations, representations, or clarifications?
- What are the sources of analogies, metaphors, examples, demonstrations, and rephrasing?
- How does the novice teacher (or even the seasoned veteran) draw on expertise in the subject matter in the process of teaching?

- What pedagogical prices are paid when the teacher's subject matter competence is itself compromised by deficiencies of prior education or ability? (Shulman, 1986: 8).

1.7. PSTs' PERSPECTIVES CONSIDERED

The research focus declared above could be undertaken in different ways in initial teacher education; this investigation focused on the perspectives of the PSTs' themselves (Bezzina *et al.*, 2004: 39-40) concerning their experiences in learning to teach to improve their PD from the ETE's teaching expertise. This was supported by Jegede *et al.*'s (2000: 304) argument that teacher educators as well as teacher education policy makers have to consider the **"voice"** of PSTs in determining their own PD. Jegede *et al.* (2000: 290) lament that research in initial teacher education has failed in eliciting the **"perceptions"** of PSTs about what they think they have acquired and developed to address the current crisis in teaching and learning, especially in mathematics and science, and above all the **extent to which the teaching they are experiencing** during their training in initial teacher education has or is contributing to the development of their expert teaching knowledge. Therefore, Jegede *et al.* are strongly convinced that PSTs' awareness of their own "personal sense of development" in learning to teach can provide the pathway towards developing the desired teaching expertise for their future work of teaching (p. 290). Similarly, Helterbran (2008: 124) is convinced that awareness, among other equally important issues, can enhance the teacher's continuous growth in professionalism. On this point we, as teacher educators, should be convinced that we urgently need to analyse and pay attention to teachers as well as PSTs' own accounts of their PD in terms of the areas in which they have adequately developed their confidence and knowledge, as well as to where they definitely need expert support for quality instruction in their classrooms (Jegede *et al.*, 2000: 290). San (1999: 19) argues that (in-service and pre-service) teachers' perceptions of their skills are important and could provide a framework for making decisions towards improving learning to teach in teacher education ecologies. It is also important to note that, in terms of the most efficient contexts for understanding teachers' perceptions of their own PD, the researcher agrees with Jegede *et al.* (2000) that initial teacher education is one of the contexts that would provide a practical opportunity to get valuable knowledge about such perceptions, when PSTs are learning to acquire and develop expert teaching knowledge from university teachers or professors.

In summary, this study was centred on two very important curriculum issues, namely, **PSTs' perceptions about their PD** and **knowledge about the impacts of the ETE's teaching expertise on PSTs' PD**. As pointed out earlier, the literature shows that student teachers' perceptions regarding their own professional development have not been adequately investigated (Jegede *et al.*, 2000), and that the influence of the ETE's teaching expertise on student teachers' professional development has not received much attention (Shim & Roth, 2008; Smith, 2005; Celik, 2011: 79). These considerations motivated this study's interest in investigating PSTs' own views about their PD in learning to teach from the ETE's teaching expertise.

This research was therefore undertaken to meet the realised need to contribute to closing the knowledge gaps evidenced from literature concerning the influence of the ETE's teaching expertise with special reference to addressing concerns about PSTs' PD (Yang & Leung, 2011: 1014), namely, beliefs about mathematics and the teaching and learning of mathematics (Levin, 2014: 61); content knowledge (CK); and pedagogical content knowledge (PCK). Levin (2014) recommends that researchers interested in investigating PSTs' beliefs should explicitly clarify the aspects of beliefs they are focusing on, as declared in this research report (i.e. PSTs' beliefs about the subject matter of mathematics and their beliefs about teaching and learning of mathematics). The author (i.e. Levin, 2014) also argues that investigating PSTs' developing beliefs, as proposed in this research, should be the initial concerns of researchers, including mathematics education researchers.

This investigation is focused on explaining the views, voices, thinking, beliefs and feelings of PSTs regarding their achievements (PD) in learning to teach Foundation Phase mathematics from the ETE: what/how they perceive "their on-going development as teachers of mathematics" (Da Ponte & Chapman, 2008: 242). As Da Ponte and Chapman (2008: 225) have said, it is "important to examine where we are and where we could be heading to in order to facilitate the development of competent mathematics teachers", and the researcher believed that a possible way would be to elicit the PSTs' own perceptions about their PD during their interaction with the teaching expertise of the ETE in Foundation Phase mathematics education. Thus**,** this study was set to discover, from PSTs' perspectives, the improvement in the dimensions of their PD during

their learning experiences in the third year Foundation Phase mathematics module in interaction with the ETE's teaching expertise. As explained by Da Ponte and Chapman (2008: 246), PSTs' relationships and interactions with professionals in their fields of learning can contribute to the development of their professional identities.

1.8. PROBLEM STATEMENT

This study was concerned with PSTs' perceptions about the transformation in their beliefs about mathematics and the teaching and learning of it; improvement in their understanding of mathematics CK; and development of their PCK during their interaction with the teaching expertise of the Foundation Phase mathematics teacher educator in the 3rd year (Levin, 2014: 51; Witt *et al*., 2013: 20; Hativa *et al*., 2001: 699; Da Ponte & Chapman, 2008: 228).

1.9. THE GENERAL STRUCTURE OF PRE-SERVICE TRAINING IN SOUTH AFRICA

South African universities generally provide two kinds of teacher preparation qualifications or programmes: a four-year Bachelor of Education (BEd) and a one-year Post-Graduate Certificate in Education (PGCE) (Green, 2014: 113; Wessels, 2008). These initial teacher preparation qualifications are offered by all twenty-one (21) public universities, while some universities offer both the BEd and the PGCE, as in the case of the university at which this study was undertaken. Green (2014: 113) adds that only 13 of the 21 universities offer Foundation Phase teacher preparation programmes. In addition, Wessels (2008) notes a third option for teacher training called the Advanced Certificate in Education aimed at assisting teachers to upgrade from a three-year to a four-year qualification whereby teachers further specialise in teaching a specific school subject like mathematics. According to the Integrated Strategic Planning Framework for Teacher Education and Development in South Africa, 2011–2025, it would be highly unlikely that all the universities would be offering a single national model of Foundation Phase teacher education, partly due to historical, socioeconomic and cultural contexts in which such programmes emerge, and the political (Provincial needs) and epistemological (Course organisation/design) differences, as well as what the trainees bring with them (Stuart & Tatto, 2000).

The Foundation Phase is a field of specialisation under the BEd (General Education) programme offered by the university where this study was conducted. PSTs follow Foundation Phase Mathematics modules throughout their preparatory phases (i.e. from the second year to the fourth year). The module prepares PSTs to teach mathematics from Grade R to three (3) (Integrated Strategic Planning Framework for Teacher Education and Development in South Africa, 2011–2025: 17). It focuses on improving or developing the PSTs' conceptual understanding of CK and mathematical teaching knowledge. In their interaction with the facilitators of the modules, PSTs are required to or are engaged in explaining, representing, and understanding and reacting to mathematical thinking that is different from their own (Superfine & Li, 2014: 4). Classroom observations, micro-teaching practices, teaching internship in their community schools, assessment and feedback from off-campus teaching practice, reflections, use of technology in teaching, etc. are among experiences PSTs undergo in the Foundation Phase mathematics module. The nature of the learning environment is collaborative and interactive.

The PSTs usually focus on complete Foundation Phase modules from the second year of their training. At this stage of their training, they study different modules under different teacher educators. Surprisingly, this course is predominantly liked by women PSTs, and sometimes a few men PSTs, despite the widespread idea that "women/girls are math phobia" (Ball, 1990: 10/11). Although it is encouraging that more female PSTs are enrolled in this programme, the number of Foundation Phase teachers required to match the need for Foundation Phase teachers on a national level, and on the provincial level, could be very low (Integrated Strategic Planning Framework for Teacher Education and Development in South Africa, 2011–2025: 15).

1.10. RESEARCH AIM

This research elicited perceived improvements in the beliefs, content knowledge, and pedagogical content knowledge of 3rd-year Foundation Phase mathematics PSTs while they were learning to teach from an ETE's teaching expertise.

1.11. RESEARCH QUESTIONS

This study attempted to answer the questions that follow:

a) What are the viewpoints of the PSTs concerning the impact of their preceding two-year training in Foundation Phase mathematics on their PD? (Phase A)
   i. What transformations do the PSTs perceive in their beliefs about mathematics and teaching and learning of mathematics?
   ii. What affordances do the PSTs perceive from the improvements they perceive in their beliefs about mathematics and teaching and learning of mathematics?
   iii. What improvements do the PSTs perceive in their understanding of the mathematics CK and the development of their PCK for Foundation Phase mathematics?
   iv. What affordances do the PSTs perceive from the improvement they perceive in their understanding of the mathematics CK and the development of their PCK for Foundation Phase mathematics?
   v. Which of the three dimensions of their PD (i.e. beliefs, CK and PCK) is/are most or least enhanced?

b) What are the viewpoints of the PSTs about their PD during their interaction with the ETE's teaching expertise in the third-year Foundation Phase mathematics module? (Phase B)
   i. What transformations do the PSTs perceive in their beliefs about mathematics and teaching and learning of mathematics?
   ii. What affordances do the PSTs perceive from the improvements they perceive in their beliefs about mathematics and teaching and learning of mathematics?
   iii. What improvements do the PSTs perceive in their understanding of the mathematics CK and the development of their PCK for Foundation Phase mathematics?

iv. What affordances do the PSTs perceive from the improvements they perceive in their understanding of the mathematics CK and the development of their PCK for Foundation Phase mathematics?

v. Which of the three dimensions of their PD (i.e. beliefs, CK and PCK) is/are most or least enhanced?

vi. Which of the attributes of the ETE's teaching expertise impacted most or least on the components of the PSTs' PD?

c) Which of the two experiences (Phase A or Phase B) impacted more/less on the dimensions of their PD?

1.12. RESEARCH DESIGN AND METHODOLOGY

This study used a mixed-methods design in which both quantitative and qualitative methods were used for data collection, analysis and interpretation (Hativa, 1998: 357). The aim was to generate adequate information to adequately answer the research questions (Creswell, 2013: 4; Hativa, 1998: 357; Rowley, 2014: 310). While the quantitative method helped to reduce errors and increased objectivity, the qualitative method was used to gather information that could not be ascertained through the use of the quantitative method (Guest, 2013: 142). For the quantitative method, the researcher used a survey (i.e. administered questionnaires) in order to elicit the views of all the third-year PSTs about their PD (i.e. PD from preceding two-year training and PD in the 3rd-year experiences with the ETE) (San, 1999: 20). For the qualitative method, semi-structured interviews were conducted by the researcher to collect data in order to get further insight on their viewpoints about their PD.

All third-year PSTs who attended the Foundation Phase mathematics module for the 2015 academic year were invited to voluntarily participate in the survey (Hativa, 1998: 359). Then the researcher conducted the interviews with one of the existing English-speaking groups among the third-year PSTs, usually with about eight PSTs in a group, who would volunteer for this purpose (i.e. to generate the qualitative data) (Hativa, 1998: 357).

The researcher designed the questionnaires for the survey phase of the study. The items in the questionnaires were based on the three components of the PSTs' PD: transformation in PSTs'

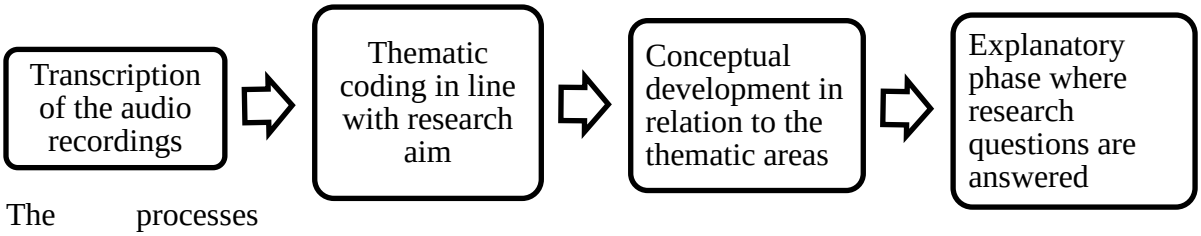
beliefs about mathematics and teaching and learning of mathematics; improvement in PSTs' understanding of mathematics CK; and development of PSTs' PCK for Foundation Phase mathematics. The development of the items in the questionnaire for the survey in this research were guided by the research problem, aim, questions, relevant literature and an existing validated survey framework (Rowley, 2014: 312) designed by Hudson (2009) and Hudson and Ginns (2007). Before the survey, the questionnaire was pretested to ascertain its reliability and validity for the actual population under study. The questionnaire was administered to PSTs in a similar BEd programme in mathematics who volunteered to respond to the questionnaires.

The survey was conducted twice in the main study, because the use of data from the different periods have been found to be very effective in providing means for analysing changes that occurred in a phenomenon, such as teaching and learning, over a period of time (Hudson & Ginns, 2007: 889). Thus, data were collected first at the end of the 2nd year and, second, at the end of the 3rd year (i.e. learning from the ETE). The questionnaires that were used had the same response-eliciting items in both surveys. However, the second questionnaire for the second survey had an additional section meant exclusively for the "the PSTs' perceptions about the most impacting teaching expertise" on their PD. Responses were analysed using descriptive statistical techniques and inferential statistical techniques for both questionnaires.

As with the survey phase above, the researcher conducted two interview sessions with the PSTs in the English-speaking group who volunteered for the interviews. The first interview followed the administration of the first questionnaire and the second interview followed the administration of the second questionnaire. The interview data were analysed by using the framework of analysis or approach shown in Figure **1.1** below.

Figure 1.1. Qualitative data analysis procedure

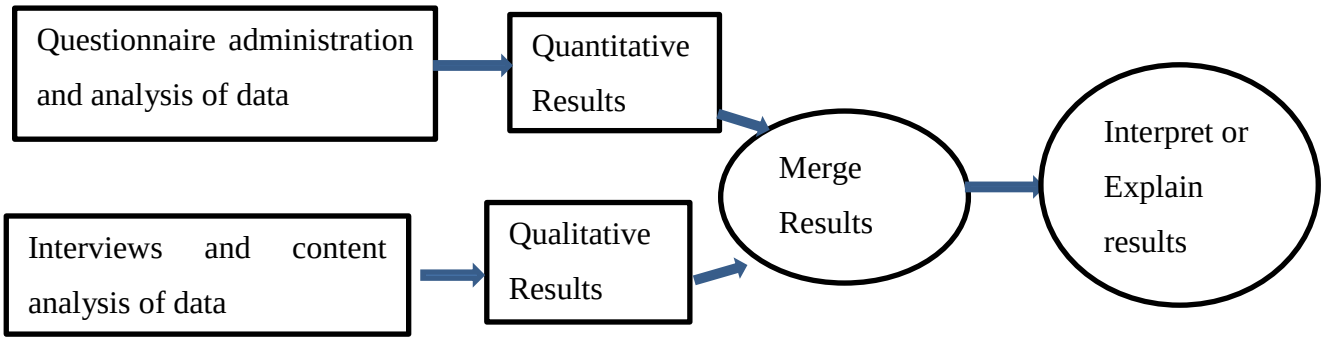
Source: created by the researcher



The processes described above showed that this study used a convergent parallel design in collecting, analysing and interpreting the data from both methods (Creswell, 2013: 40). The main focus was on merging all the results for comprehensive understanding of the research problem and questions (i.e. find out where these viewpoints converge, diverge, or contradict one another) (Hativa, 1998: 358; Guest, 2013: 148). Figure **1.2** below shows how the researcher utilised the convergent parallel design in collecting or generating and analysing the data, and interpreting the results that emerged.

Figure 1.2: Convergent Parallel Design

Source: Creswell (2013: 40)



The researcher strictly followed the ethics guiding the conduction of research in the context of the specific university. More especially, the researcher adhered to the ethical principles of confidentiality, anonymity and voluntary participation. Regarding times and venues, for example, the interviews were conducted at the convenience of the interviewees.

Table **1.1** below shows the working schedule for the entire data collection and analysis phases of the study.

Table 1.1: The research working schedule

MONTH	YEAR	ACTIVITY
FEBRUARY to MARCH	2015	First data collection - survey and interviews
APRIL to SEPTEMBER	2015	Analysing first data: data from survey and interviews Writing research reports on the first phase of the research
OCTOBER to NOVEMBER	2015	Second data collection - survey and interviews Analysing data from second survey and interviews Finalise data processing (integrating quantitative and qualitative)
NOVEMBER	2015	Final write-up and submission of thesis

Source: Created by the researcher

1.13. PROVISIONAL CHAPTERING

Chapter 1: Background and motivation

Chapter 1 provides the background to the problem under study. It highlights the purpose and rationale for this investigation. The study's aim is also provided in this chapter. A brief description of the empirical phases of the study is also highlighted.

Chapter 2: Model of teaching expertise and its role in promoting teaching and learning effectiveness in higher education

Chapter 2 provides perspectives on the attributes of teaching expertise in general and teaching expertise in mathematics education in particular. This chapter identifies eight distinct attributes of teaching expertise from diverse perspectives concerning exemplary teaching strategies, especially in higher education. It discusses the roles of the eight attributes of teaching expertise in promoting teaching and learning effectiveness. It highlights distinguish teaching performance which sets expert teacher educators apart.

Chapter 3: Effects of teaching expertise on the prospective teachers' professional development

The framework of prospective teachers' professional development was determined through the literature survey presented in Chapter 3. The effects of the attributes of teaching expertise on the prospective teachers' professional development are presented in this chapter. This chapter also describes the conceptual framework which guided the empirical phase of this investigation.

Chapter 4: Research design and methodology

Chapter 4 describes the empirical phase of this investigation. It describes the mixed-method design used in collecting and analysing data and interpreting findings of this study. It justifies the suitability of the mixed method design used.

Chapter 5: Presentation, discussion, and interpretation of results

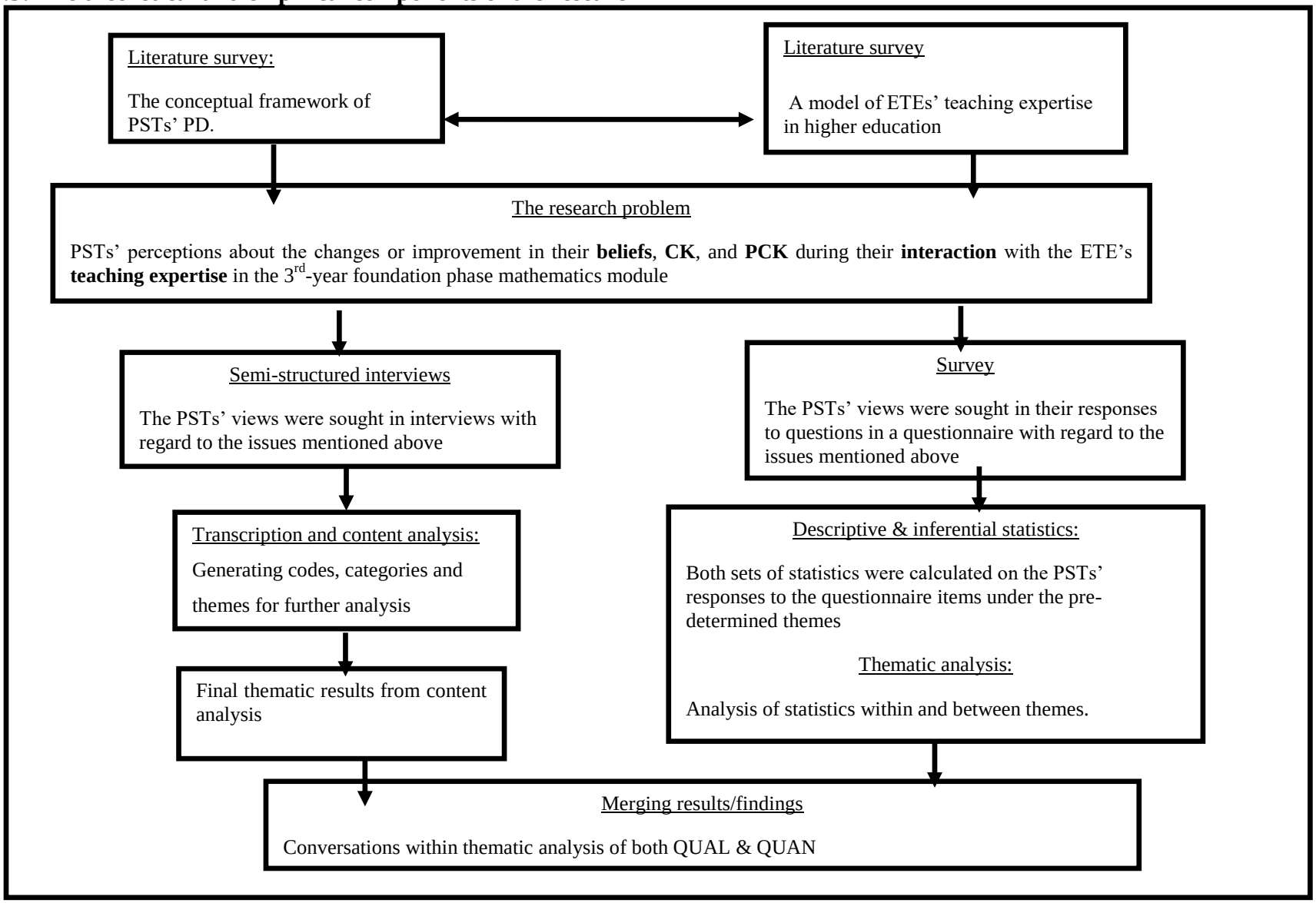
Chapter 5 presents the results from the empirical phase of this study. It explains how the data were analysed. It shows how the quantitative and qualitative results were merged to ensure meaningful findings from the different merged data sets. It discusses the findings in the light of the research questions and relevant literature.

Chapter 6: Conclusion and recommendations

Chapter 6 draws conclusions from the merged findings in the light of the research questions that guided this study. It ends by highlighting important recommendations for improving future research on similar problems.

The theoretical and empirical components of this study are summarised in Figure **1.3** below.

Figure 1.3: The theoretical and empirical components of the research



1.14. ETHICAL CONSIDERATIONS

In compliance with research ethics in the context of this study, the researcher submitted the research instruments (the questionnaire and interview questions) to the appropriate authorities in charge of research in the University of Stellenbosch and sought permission from the Institutional Research and Planning, Department Ethics Screening Committee and the university's Research Ethics Committee before the researcher used these instruments in the study.

The survey processes were conducted in strict compliance with the university's research ethics. The researcher sought ethical clearance and permission from the university's departmental ethics committee and the university's ethics committee to administer the two sets of questionnaires to all the PSTs, for them to complete anonymously and voluntarily.

In compliance with interviewing ethics, the interviews were conducted at the convenience of the interviewees regarding times, venues, and duration of the interviews. The researcher furthermore assigned anonymous identities to interviewees throughout the study to ensure privacy and confidentiality.

In compliance with research ethics, the researcher ensured that all recorded conversations (audio and written) like the hard copies of data were kept in the promoter's office in a safe cabinet and scanned copies of data were kept in a password-locked file on the researcher's laptop. Following the final transcription and validation exercises, the data have been kept as explained earlier, to be destroyed after about five years.

1.15. ACCRONYMS AND ABREVIATIONS

CK – Content Knowledge refers to the understanding of mathematics concepts, facts, and procedures and how they are connected – commonly known as the subject knowledge of a subject, like mathematics.

ETE – Expert Teacher Educator here refers to the expert educator of the PST, in an institution for teacher education, who is responsible for assisting PSTs to develop teaching expertise to enhance their teaching effectiveness in the classroom (Koster, Korthagen & Wubbels, 1998: 76).

PCK – Pedagogical Content Knowledge refers to a combined understanding of the mathematics content, effective teaching practices, and learning difficulties that can help teachers to facilitate meaningful understanding of mathematics (Shulman, 1986).

PD - Professional Development refers to changes in knowledge, skills and attitudes for the improvement of professional practice (San, 1999: 20). Schwarz *et al*. (2008: 795) have stated categorically that mathematical content knowledge (i.e. understanding of the school mathematics) (Buchholtz *et al*., 2013: 108); pedagogical content knowledge (i.e. understanding of the mathematics curriculum and analysis of learners' mathematical abilities); and beliefs (i.e. about mathematics, and the teaching and learning of it) are the main dimensions of the professional knowledge of prospective mathematics teachers (Borko *et al*., 1992: 194).

PST- Pre-service Teacher is also synonymous with terms like student-teacher and prospective teacher. It is a student in training to be a teacher.

2. CHAPTER 2
MODEL OF TEACHING EXPERTISE AND ITS ROLE IN PROMOTING TEACHING AND LEARNING EFFECTIVENESS IN HIGHER EDUCATION

2.1. INTRODUCTION

As explained in Chapter 1, the aim of this research was to elicit PSTs perceptions about and their interpretations of the changes/improvement in their PD in connection with the teaching expertise they were exposed to in learning to teach mathematics, in their 3rd-year Foundation Phase mathematics module. This goal was supported by the views held by Thomas and Beauchamp (2011: 767) that perceptions about their PD and their potential success in their future classrooms are worth investigating in the initial teacher education of PSTs. San (1999: 19) added that, in general, teachers' perceptions of their PD inform teacher educators' strategies in preparing novice expert teachers. In line with these views, the researcher elicited the views of PSTs regarding the changes/improvements perceived in their beliefs about mathematics and the teaching and learning of it; understanding the CK; and the development of their PCK. In addition, the PSTs' views of the perceived affordances of those changes/improvements were to be surveyed. The details are given Chapters 4, 5 and 6.

Having explored the literature in the field of teaching expertise towards understanding teaching expertise in depth, the researcher derived a comprehensive framework or model of attributes of expert teaching from the diverse perspectives and conceptions about teaching expertise to guide further investigation towards achieving the research aim stated above. The literature review further extended the initial understanding of the concept of teaching expertise by explaining the tacit nature of expert teaching; ways of sharing expert knowledge; and descriptions of the ETE. Following the sections above, the levels of teaching expertise in the work of teaching, are also explained to widen our notion of teaching expertise. With reference to the research problem and research questions guiding this study, this review ended by exploring the literature to ascertain why teaching expertise matters in teacher education. The development of this chapter is presented in the sections below.

2.2. EXPLANATION OF TEACHING EXPERTISE

This section covers the following issues related to understanding teaching expertise: concepts or perspectives about teaching expertise; models/frameworks of mathematics teaching expertise; foundations of mathematics teaching expertise; development of the researcher's model of teaching expertise; descriptions of the attributes of expert teaching constituting the developed model; discussion of the complementary roles of the attributes of expert teaching in the new model; comparison of the developed model with constructivists' perspectives about teaching expertise; comparison of the developed model with Leinhardt and Smith's (1985) model mathematics of teaching expertise; the new model in engendering the modern teaching and learning theories; descriptions of the nature of expert teaching knowledge; ways of sharing expert teaching knowledge; and description of an ETE.

2.2.1. Perspectives on teaching expertise in higher education

The main focus of this section is to present the perspectives of researchers, teacher educators and university students on teaching expertise in higher education, to serve as the pool or provide a framework for further explorations to derive a comprehensive model of teaching expertise. The term teaching expertise has been described using a variety of terminologies such as teaching excellence; the scholarship of teaching; effective faculty practices; good teaching at university; variables of teaching effectiveness (Kreber, 2002: 7). According to Tyagi and Vashisth, (2012: 30) teaching expertise means "... the ability of a teacher to relate the learning activities to the developmental process of a learner and to their current and immediate interests and needs". Bulger, Mohr and Walls (2002) have added that variables of teaching effectiveness to describe teaching expertise were terms used by Rosenshine and Furst in 1973. These comprised "Clarity, Variability, Enthusiasm, Task-oriented and/or Businesslike Behaviours, and Student Opportunity to Learn Criterion Material". Both views seem to highlight one central issue: deliberate and intellectual exploration of exemplary teaching strategies and activities towards improving desired learning outcomes.

About two decades later, educators as well as researchers began to show interest in affection-driven teaching methodologies of teacher educators as one of the characteristics of teaching expertise in higher education (Weston & McAlpine, 1998: 151). The justifications for this emerging interest in educators' effective personal qualities for teaching (Dineke *et al*. 2004: 255) include the view that teacher educators, for example, are using personal qualities such as empathy, care, humour, respect, commitment, and the ability to regulate frustrations and impatience as a mechanism for drawing PSTs much closer to their personalities and to the learning experiences to ensure optimum learning outcomes for building the PSTs' PD (Devlin & O'Shea, 2012: 395; Garner, 2006: 177). For example, Friedman, Friedman and Amoo (2002), Weston and McAlpine (1998: 151), and Powell and Andresen (1985: 80) have shown with evidence that students find the classes of ETEs who integrate their personal characteristics with other teaching expertise to be friendly places and they seem to enjoy their teaching. To this extent, it could perhaps be justified that Mitchell, Knobloch and Ball (2004: 281) define expert teaching as "… the relationship between instructional activities of the instructor and the educational changes that occurs in students (i.e. both behavioural and conceptual changes)" is consistent with the new conceptions of teaching expertise. In support of the above views, Mitchell *et al*. (2004) are convinced that expert teaching promotes the development of deep knowledge of the discipline, improves problem-solving skills of students, motivates students to engage with the learning tasks, and increases students' appreciation of their own competence and professional strengths.

2.2.2. Perspectives pertaining to mathematics teaching expertise

Researchers in the field of teaching expertise have acknowledged the complexity of understanding the nature of mathematics teaching expertise because of its cultural dependence and context orientations (Yang & Leung, 2011: 1008; Li & Even, 2011: 760; Smith & Strahan, 2004: 360; Berliner, 2001: 467; Berliner, 1988: 60). Yang and Leung are of the view that mathematics teaching expertise combines both complex attributes of teaching: teaching expertise is specific to the context of teaching practice and teaching mathematics, on the other hand, is a cultural activity (Berliner, 2001: 467). Mathematics teaching expertise has been conceptualised in varied forms, but broadly speaking the various concepts could either be consistent with the

cognitive/knowledge perspective or with the personality/socio-cultural perspective (Yang & Leung, 2011; Berliner, 2001: 467).

The cognitive/knowledge perspective recognises that mathematics teaching expertise should include ‘‘... mathematics-specific analysis ability ...’’ of the expert (Pang, 2011: 778-779; Yang & Leung, 2011). In Pang’s (2011) view, a teacher’s expertise in mathematics-specific analysis is different from his/her expertise in general teaching analysis. An example of a teacher’s mathematics-specific analysis is when he or she specifically focuses on a students’ own mathematical thinking when this teacher asks the students “to find out the area of a trapezoid by using that of a parallelogram”. On the contrary, the teacher’s general analysis expertise will be focusing on students’ “mistakes or misconceptions” that “are natural in the process of learning” (p. 779).

Clearly, the nature of mathematics teaching expertise understood from this perspective (mathematics-specific analysis ability) focuses on the expert’s subject-matter knowledge in mathematics and PCK in mathematics, which include “… mathematics knowledge for teaching (mathematics content, mathematics and pedagogy) and mathematics (itself), and students’ learning” (Yang & Leung, 2011: 1008). In the view of Yang and Leung, this attributes of mathematics teaching expertise refers to the teacher’s repertoire of mathematics subject-matter knowledge and it is unanimously agreed that teacher’s command of subject-matter knowledge (Shim & Roth, 2008; Berliner, 2001: 469) is equated with his expertise in that knowledge domain (Yang & Leung, 2011: 1009). Yang and Leung (2011) seem to be convinced that the ETE’s command of mathematics subject-matter knowledge is the pivot of the teaching expertise (p. 1009). They claim that, irrespective of the expert’s discipline, “a profound knowledge base in the subject matter, PCK and other fields” are necessary requirements to refer to him/her as an expert teacher (p. 1009). In supporting the above views, Smith and Strahan (2004: 358) pointed out that ETEs are identified on the basis of their mathematics subject-matter knowledge in their own discipline.

The cognitivists further argue that, beyond the ETE’s mathematics subject-matter knowledge, other equally complementary attributes of teaching expertise which need to be recognised are the ETE’s “… ability to select and implement cognitive challenging tasks” (Boston & Smith, 2011:

965-966; Yang & Leung, 2011). From the cognitivists/knowledge perspective, mathematics teaching expertise is said to be developing when the teacher's knowledge is changing or there is improvement in understanding of mathematics subject-matter knowledge, and when the teacher is becoming "more skilful in designing lesson plans" (Yang & Leung, 2011: 1010). According to Yang and Leung (2011: 1010), the mathematical expertise of a teacher evolves through the "… stages of novice, advanced beginner, competent, and proficient teacher" (Berliner, 1988: 40; Kinchin & Cabot, 2010: 154).

The personality/socio-cultural perspective on the other hand considers teaching expertise to include "content knowledge, pedagogical knowledge, affective attributes, and comparative teaching outcomes" (Smith & Strahan, 2004: 358). Unlike the cognitivists, the socio-culturalists believe that acquiring/developing extensive experiences is essential in the development of mathematics teaching expertise (Yang & Leung, 2011: 1011; Berliner, 2001; Berliner, 1988: 39; Kinchin & Cabot, 2010: 154). In Yang and Leung's (2011) view, for example, a teacher needs at least 10,000 hours or a minimum of 10 years of instructional experiences to develop his/her mathematics teaching expertise (Berliner, 2001; Kaiser & Li, 2011: 346; Smith & Strahan, 2004: 358-59).

2.2.3. The foundations of mathematics teaching expertise

In 1985, prior to Shulman's PCK and Ball's mathematical knowledge for teaching (MKT) concepts of teaching expertise, G. Leinhardt and D. A. Smith identified two broad interrelated but basic categories of teaching expertise in mathematics education. According to Leinhardt and Smith (1985), teaching in general and teaching mathematics in particular, should be regarded as cognitive skills. They believe that these special skills guide the articulation of the expert's knowledge of his/her mathematics lesson structure and subject matter (Leinhardt & Smith, 1985: 247). In other words, the teacher's command of subject matter knowledge becomes a manifestation of his expert knowledge while his or her knowledge of lesson structure becomes a manifestation of his expertise in the work of teaching. Leinhardt and Smith explain the above cognitive skills as quoted below:

> Expert teacher's lesson structure knowledge includes the skills needed to plan and run a lesson smoothly – planning and organisation of the lesson, to pass easily from one segment to another –

> progressive transition maintaining connections between aspects of seemly different lessons, and to explain material clearly.
>
> Expert teacher's subject matter knowledge includes concepts, algorithmic operations, the connections among different algorithmic procedures, the subset of the number system being drawn upon, the understanding of classes of student errors, and curriculum presentation.

As it will be made very clear later, Leinhardt and Smith (1985) seem to be placing more emphasis on the cognitive perspectives over against personality teaching qualities. Their model of teaching expertise seems to focus more on the ETE's authoritative knowledge and his/her ability to display teaching skills. To this extent, it seems to ignore the personal teaching qualities which have been proven to be effective or productive in teaching and learning (Dineke *et al*., 2004: 255).

2.2.4. Relationship between the two foundations of teaching expertise in mathematics

The complementary roles or relationships between the two components (subject matter knowledge and lesson structure knowledge) of teaching expertise in mathematics education cannot be under estimated (Leinhardt & Smith, 1985: 247). The authors explain that subject matter knowledge mechanises the expert's lesson structure knowledge entirely (Ambrose, 2004: 92; Frykholm, 1999: 81; Ball, 1988: 6/11; Shulman, 1986: 7). This knowledge helps the expert to select appropriate examples, formulate explanations of concepts and procedures, and demonstrate effective understanding (Shulman, 1986: 7; Da Ponte & Chapman, 2008: 226). Shim and Roth (2008) describe this expertise as command of subject matter. It is clear that lesson structure knowledge will not be successful when subject matter knowledge is deficient, because a teacher's content knowledge is the main pre-requisite for success in teaching (Faulkner & Cain, 2009: 24; Shulman, 1986: 8; Kinchin & Cabot, 2010: 161; Sowder, 2007: 158; Ball, 1988: 38; Borko *et al*., 1992: 218; Lampert & Ball, 1999: 33; Thomson & Palermo, 2014: 59; Ambrose, 2004: 91).

Skills in lesson structure are needed similarly for the successful transfer of content knowledge in teaching (Da Ponte & Chapman, 2008: 235; Buchholtz *et al.*, 2013: 108). Thus, both are complementary components of teaching expertise, therefore their development should be balanced during the PSTs' PD process (Schwarz *et al*., 2008: 795; Borko *et al*., 1992: 194; Buchholtz *et al*., 2013: 108). It is essential to note that inadequacies in one of these dimensions

of teaching expertise affect the effectiveness of the other in the work of teaching (Leinhardt & Smith, 1985: 247).

2.2.5. The emerging model of teaching expertise in higher education

The preceding sections have presented the conceptions of or perspectives on teaching expertise in general education and mathematics education in particular. The main focus here is to derive a comprehensive model from the literature about expert teaching.

In this approach, the researcher categorised preceding perspectives on attributes of expert teaching in higher education into two broad themes, namely personal qualities for effective teaching and cognitive competence/ knowledge of the discipline. Then the researcher explored the diverse attributes to find emerging themes which seemed to harmonise or provide the most representative concepts for a cluster of attributes, especially with regard to the degree of occurrence of such attributes. This is shown in the Tables **2.1**, **2.2**, **2.3** and **2.4,** below:

Table 2.1: Emerging themes of attributes of teaching expertise (a)

Personal qualities for effective teaching	**Emerging themes**	**Cognitive competence/ knowledge of the discipline**	**Emerging themes**
The person as teacher using his/her empathy and the ability to regulate frustrations and impatience (Dineke *et al*., 2004: 255)	Understanding of students and attending to their learning needs	Expert in Content Knowledge; Facilitator of Learning Processes; Organiser and Scholar/Lifelong Learner (Dineke *et al*., 2004: 255)	Articulation of subject knowledge expertise
Enthusiasm for teaching; interpersonal relationship; humour and approachability; understanding of students and creating a positive environment (Shim & Roth, 2008: 6)	Positive relationships with students	Clarity of Presentation; command of subject knowledge; preparation and organisation; stimulating the interest of students for engagement in learning (Shim & Roth, 2008: 6)	
Enthusiasm for teaching; modelling leadership roles in teaching; motivating students to engage with the learning experiences; and professionalism in dealing with students' concerns and interests (Tyagi & Vashisth, 2012: 30).	Enthusiasm/interest/passion for teaching	Command of the content knowledge; clarity and presentation of the material for students; advanced organisation, preparation, and managing effective teaching and learning (Tyagi & Vashisth, 2012: 30).	Clarity in lesson presentation or teaching.
Humour (Chesebro & McCroskey, 2001: 61; Friedman *et al*., 2002; Powell & Andresen, 1985: 79; Torok, McMorris & Lin, 2004: 14; Garner, 2006: 177)	Motivating/stimulating students' engagement with learning experiences	Smith and Strahan (2004: 358), content knowledge, pedagogical knowledge	
Enthusiasm for their subject, stimulating students' emotion, and building interpersonal rapport (Mitchell *et al*., 2004: 280)	Humour in teaching	their clear and systematic delivery of material, preparedness in providing organisation (Mitchell *et al*., 2004: 280)	Preparation for and organisation of teaching

Source: Created by the researcher

Table 2.2: Emerging themes of attributes of teaching expertise (b)

Personal qualities for effective teaching	Emerging themes	Cognitive competence/ knowledge of the discipline	Emerging themes
personality/socio-cultural qualities (Yang & Leung, 2011; Berliner, 2001: 467); affective attributes (Smith & Strahan, 2004: 358)		repertoire of mathematics subject matter knowledge e.g. ‘‘mathematics-specific analysis ability: focusing on a students’ own mathematical thinking’’ (Pang, 2011: 778-779; Yang & Leung, 2011; Berliner, 2001: 467); general analysis expertise: focusing on students’ “mistakes or misconceptions” that “are natural in the process of learning” (Pang, 2011: 778-779779); “… mathematics knowledge for teaching and students’ learning” (Yang & Leung, 2011: 1008); “ability to select and implement cognitive challenging tasks” (Boston & Smith, 2011: 965-966; Yang & Leung, 2011); “more skilful in designing lesson plans” (Yang & Leung, 2011: 1010); Smith and Strahan (2004: 358), content knowledge, pedagogical knowledge	Articulation of subject knowledge expertise Motivating/stimulating/promoting learning effectiveness. Preparation for and organisations of teaching
			Clarity in lesson presentations/teaching Understanding of students’ learning needs and creating a productive learning climate

Source: Created by the researcher

Table 2.3: Emerging themes of attributes of teaching expertise (c)

Personal qualities for effective teaching	Emerging themes	Cognitive competence/ knowledge of the discipline	Emerging themes
Weston and McAlpine (1998: 151) and Lowman (1996: 35): Interpersonal rapport: e.g. caring for students and passion for the discipline, motivating students, concern, respect, approachable, "love of the subject"; "enthusiasm and knowledge"; and enthusiasm for the subject matter discipline	Positive relations with students Enthusiasm in teaching Motivating students	Weston and McAlpine (1998: 152) - course design e.g. using their command of subject matter to connect with their PSTs' own learning experiences; clarity and preparation and organisation; Lowman (1996: 33) - knowledgeable, stimulating, dynamic	Articulation of subject knowledge expertise Motivating/stimulating/promoting learning effectiveness
Instructor-group interaction, instructor-individual student interaction and enthusiasm; respectful and interested in students, encouraged student participation, and regularly monitored student learning to provide feedback, interest in teaching (Kane, Sandretto & Heath, 2004: 285)	Approachable Engaging students Monitoring students' progress and giving positive feedback	Command of the subject, clarity, enthusiasm, clarity, preparation, organisation, stimulating interest and thinking about the subject matter, love of knowledge", in-depth knowledge of their subject area, demonstrated knowledge of and use of a variety of teaching techniques (Kane, Sandretto & Heath, 2004: 285)	Clarity in lesson presentation or teaching Preparation for and organisations of teaching

Source: Created by the researcher

Table 2.4: Emerging themes of attributes of teaching expertise (d)

Personal qualities for effective teaching	**Emerging themes**	**Cognitive competence/ knowledge of the discipline**	**Emerging themes**
motivation in studying the material through their enthusiasm or expressiveness, having positive rapport with students, showing high expectations of them, encourage them, and generally maintain a positive classroom environment' (Hativa *et al*., 2001: 701–702)	Enthusiasm in teaching Positive relations with students Understanding students' learning needs and creating productive learning climate	Prepared and organised, presenting the material clearly, stimulating students' interest, engagement (Hativa *et al*., 2001: 701–702)	Preparation for and organisation of teaching Clarity in lesson presentation/teaching Motivating/stimulating/promoting learning effectiveness
		Teaching clarity, e.g. showing transparent instructional approach and goals; providing examples and summary of key points in lectures; promoting PSTs' understanding of subject matter content and instructional expectations (BrckaLorenz, Cole, Kinzie & Ribera, 2011: 2)	Understanding students' learning needs and creating a productive learning climate .

Source: Created by the researcher

The researcher's reason for considering the two broad categories above was that emerging conceptions by researchers and teacher educators alike are advocating for holistic conceptual frameworks of teaching expertise in higher education to encompass exemplary productive personal teaching qualities in addition to the traditional delineation of teaching expertise to the lecturer's cognitive teaching qualities only.

Regarding personal teaching qualities pertaining to expert teaching, all the perspectives considered above seem to focus on the following themes which could be considered as central to all the perspectives: *Enthusiasm in teaching; Motivating/stimulating students' interest and engagement with learning experiences; Positive relationships with students and approachability; Understanding of students' learning needs and creating a productive learning climate;* and *Humour in teaching*. Similarly, the perspectives on cognitive competence/ knowledge of the

discipline pertaining to expert teaching seem to commonly converge on the following themes: *Articulation of subject knowledge expertise*; *Motivating/stimulating/promoting learning effectiveness*; *Clarity in lesson presentations/teaching*; and *preparation for and organisation of teaching*. It should be pointed out that theme *Motivating/stimulating/promoting learning effectiveness* apparently is common both to personal teaching qualities and cognitive competence/ knowledge of the discipline.

Drawing from these themes, the researcher believes that an ideal personal teaching quality or cognitive competence/knowledge of the discipline pertaining to expert teaching should be affiliated to one of the themes to merit the universal status of expert teaching attributes. Hence, these themes constitute the dimensions of expert teaching pertaining to both personal teaching qualities and cognitive competence/knowledge of a discipline in the model of expert teaching derived for the purpose of this study.

It is important to point out the most frequently recognised attributes pertaining to expert teaching from the majority of the perspectives, which include *enthusiasm in teaching* (Hativa *et al*., 2001: 701–702; Mitchell *et al*., 2004: 280; Kane, Sandretto & Heath, 2004: 285; Weston & McAlpine, 1998: 151; Lowman, 1996: 33; Tyagi & Vashisth, 2012: 30; Shim & Roth, 2008: 6), *motivating/stimulating students' interest and engagement with learning experiences* (Hativa *et al*., 2001: 701-702; Mitchell *et al*., 2004: 280; Kane *et al.*, 2004: 285; Weston & McAlpine, 1998: 151; Lowman, 1996: 35; Tyagi & Vashisth, 2012: 30; Shim & Roth, 2008: 6; Pang, 2011: 778-779; Yang & Leung, 2011; Berliner, 2001: 467); *positive relationships with students and approachability* (Dineke *et al*., 2004: 255; Hativa *et al*., 2001: 701–702; Shim & Roth, 2008: 6; Mitchell *et al*., 2004: 280; Kane *et al.*, 2004: 285; Weston & McAlpine, 1998: 151; Lowman, 1996: 35; Smith & Strahan, 2004: 358; Tyagi & Vashisth, 2012: 30); *understanding of students' learning needs and creating a productive learning climate* (Hativa *et al*., 2001: 701–702; Kane *et al.*, 2004: 285; Smith & Strahan, 2004: 358; Weston & McAlpine, 1998: 151; Lowman, 1996: 35; Tyagi & Vashisth, 2012: 30; Dineke *et al*., 2004: 255); *articulation of subject knowledge expertise* (Dineke *et al*., 2004: 255; Shim & Roth, 2008: 6; Tyagi & Vashisth, 2012: 30; Pang, 2011: 778-779; Yang & Leung, 2011; Berliner, 2001: 467; Smith & Strahan, 2004: 358; Weston & McAlpine, 1998: 151; Lowman, 1996: 33; Kane *et al.*, 2004: 285; BrckaLorenz *et al*., 2011: 2); *clarity in lesson presentations/teaching* (BrckaLorenz *et al*., 2011: 2; Hativa *et al*., 2001:

701–702; Mitchell *et al*., 2004: 280; Kane *et al.*, 2004: 285; Weston & McAlpine, 1998: 152; Tyagi & Vashisth, 2012: 30; Shim & Roth, 2008: 6); and *preparation for and organisations of teaching* (Shim & Roth, 2008: 6; Tyagi & Vashisth, 2012: 30; Pang, 2011: 778-779; Yang & Leung, 2011; Berliner, 2001: 467; Weston & McAlpine, 1998: 152; Kane *et al.*, 2004: 285; Mitchell *et al*., 2004: 280; Hativa *et al*., 2001: 701–702). The researcher believes that the above being the most frequently recognised personal teaching qualities and cognitive competence/knowledge of a discipline could mean that they are the attributes of teaching expertise universally shared or articulated by most ETEs. Therefore, including these attributes of expert teaching in the model derived here could enhance the reliability and validity of this model, and it could merit universal status as well.

It is equality important, in the researcher's view, to note the least mentioned attribute of expert teaching. The researcher noted that *Humour in teaching* (Chesebro & McCroskey, 2001: 61; Shim & Roth, 2008: 6; Boston & Smith, 2011: 965-966; Yang & Leung, 2011) pertaining to the personal teaching qualities of the ETE, was the least mentioned expertise. Being the least mentioned in the wide range of perspectives above would not necessarily mean that it is insignificant. For this reason, the researcher included it the model derived for this study to ascertain this assumption.

The emerging themes in Tables **2.1**, **2.2**, **2.3** and **2.4** above consolidate the attributes of teaching expertise from the different and wide perspectives identified by the acknowledged researchers. Based on the evidence that the themes represent clusters of attributes of expert teaching, the researcher believed that these emerging themes were suitable for the context of this research. The researcher also believed that they are consistent with the context of ideal teaching effectiveness in initial teacher education. For these reasons, the researcher considered *articulation of subject knowledge expertise in teaching*; *clarity in lesson presentation/teaching*; *preparation for and organisation in teaching; enthusiasm in teaching*; *positive relationships with students and approachability*; *motivating/stimulating students' interest and engagement with learning experiences; understanding of students' learning needs and creating a productive learning climate* and *humour in teaching* in combination as a model of expert teaching in higher education which could be articulated by an individual lecturer (i.e. the ETE). It would, therefore, be worthwhile ranging beyond just identifying the experts' exemplary teaching strategies, to

investigate the influence (Berliner, 1988; Kinchin & Cabot, 2010; Bereiter & Scardamalia, 1993; Da Ponte & Chapman, 2008: 242; Witt *et al*., 2013: 20; Hativa *et al*., 2001: 699) of articulating them in the ETE;s work of teaching to enhance the PD of PSTs. In other words, this research aimed to investigate the impact of PSTs' exposure to these attributes of teaching expertise on their PD, via their own perceptions.

2.2.6. Description of the attributes of expert teaching

The main focus of this section is to concisely describe or explain what each attribute of expert teaching means in the work of teaching, especially to make explicit the complementary connections between them. What was desired most from this discussion was to make it clear that all the attributes could be perceived as integrated components of a holistic model of expert teaching.

In their article, Shim and Roth (2008), for example, only mention or list the attributes of teaching expertise similar to the perspectives of teaching expertise shared by other researchers in this field. In the researcher's view, mere listing of the attributes of teaching expertise does not adequately enhance our understanding of them, not withstanding that fact that most of the attributes in the list could apparently be understood. Even with this, a deeper or conceptual understanding particularly regarding the work of teaching would be extremely helpful. In what follows, the researcher attempts to give succinct descriptions or explanations of the eight attributes of expert teaching listed above. For clarity of the explanations and to articulate possible connections between the attributes of expert teaching, the following order is followed: the ETE's *articulation of subject knowledge expertise in teaching*; *clarity in lesson presentations/teaching*; *preparation for and organisation in teaching*; *enthusiasm in teaching*; *positive relationships with students and approachability*; *humour in teaching*; *motivating/stimulating students' interest and engagement with learning experiences*; and *understanding of students' learning needs and creating productive learning climate.*

2.2.6.1. Articulation of subject knowledge expertise in teaching

Experts in their respective disciplines are first and foremost known or identified by their enormous accumulation of knowledge and skills in those fields (Yang & Leung, 2011: 1009; Smith & Strahan, 2004: 358). For example, the initial development of both teachers' and

students' expertise in an academic discipline like mathematics is determined by the level of in-depth mathematical knowledge they have acquired. The development of the mathematics teacher's teaching expertise from the level of novice, through advanced, competent, proficiency, to the expert level (Yang & Leung, 2011: 1010; Berliner, 1988: 40; Kinchin & Cabot, 2010: 154) specifically is continuously evaluated against the teacher's *articulation of subject knowledge expertise* or command of the mathematics subject matter knowledge (Pang, 2011: 778-779; Yang & Leung, 2011). Naturally, these levels are differentiated on the basis of performance, mostly in problem solving (Berliner, 1988: 39; Berliner, 2001: 464; Chi, 2006; Leinhardt & Smith, 1985: 247; Kreber, 2002), and performance is also based on the teacher's command of the knowledge in that discipline (Kreber, 2002: 13; Chi, 2006). It could, therefore, be evident that command of subject knowledge is the lifeline of expert teaching (Tiberius, Smith & Waisman, 1998: 129; Kinchin & Cabot, 2010: 153; Berliner, 1988; Kreber, 2002).

Beyond the scope of this attribute as described above, Tyagi and Vashisth, (2012: 31) have documented that subject knowledge expertise means an amalgam of cognitive and affective knowledge domains which include specific content and general knowledge, knowledge of students' diversities, knowledge of students' achievements and educational expectations, knowledge of effective teaching strategies or methods and communication, and knowledge of engaging and stimulating students' learning activities (Hativa, 1998; Berliner, 1988; Kreber, 2002). Thus, the ETE's subject knowledge expertise is not limited to command/in-depth understanding of the CK of a discipline only. The reality is that, *articulation of subject knowledge expertise* is the first attribute most PSTs are expecting to benefit from during their interactions with teacher educators. It gives students the impression of the level or degree of expertise of their educators. Some researchers have shown that students' academic achievements are highly dependent on their teachers' in-depth understanding of the knowledge in the discipline (Borko, 2004; 5; Borko *et al*., 1992: 195/218; Lampert & Ball, 1999: 33; Thomson & Palermo, 2014: 59; Ambrose, 2004: 91; Sowder, 2007: 158; Ball, 1988: 38; Shulman, 1986: 8; Kinchin & Cabot, 2010: 161). If the teacher lacks in-depth mathematical knowledge, for example, his/her students' conceptual understanding would be deficient (Ball, 1990: 11; Shulman, 1986: 8; Kinchin & Cabot, 2010: 161). This study is yet to identify some of the contributions of this

attribute of the ETE in shaping the PD of PSTs, especially, in connections with conceptual changes such as improving their CK and helping them to develop their PCK.

2.2.6.2. Clarity in lesson presentations/teaching

It is evident that clarity in the work of teaching has been reiterated extensively in the models of teaching expertise above (Bulger *et al*., 2002; Weston & McAlpine, 1998; Lowman, 1996). In terms of teaching effectiveness and addressing the challenge of a learning-centred approach in university education, some researchers, including BrckaLorenz, Cole, Kinzie and Ribera (2011: 2), Helterbran (2008: 124), Hativa (2000: 52-55) and Pierce and Kalkman (2003: 128) have argued that university teaching practices should focus on teaching clarity.

According to Hativa (1998: 354), models of teaching expertise have not defined teaching clarity explicitly. However, Chesebro and McCroskey (2001: 62) define teacher clarity

> … as a variable which represents the process by which an instructor is able to effectively stimulate the desired meaning of course content and processes in the minds of students through the use of appropriately-structured verbal and nonverbal messages.

Chesebro and McCroskey (2001: 62) also add that "To be clear, teachers need to make their organisation of content explicit so students are able to integrate lecture material into their schemata effectively". This suggestion shows that clarity in teaching necessarily requires that educators have command of subject matter knowledge (Hativa, 1998: 355) and demonstrate effective preparation and organisation in their work of teaching, which could mean that all three attributes of expert teaching (i.e. *articulation of subject knowledge expertise in teaching*; *clarity in lesson presentation/teaching*; *preparation for and organisation in teaching*) are strongly interrelated.

According to BrckaLorenz *et al*. (2011: 2), teaching clarity encompasses several key components in teaching which include transparent instructional approach and goals; providing examples and summary of key points in lectures; and promoting PSTs' understanding of subject matter content and instructional expectations.

Clearly, not every teacher can teach others to understand the content satisfactorily, even though s/he might have command of the subject knowledge. This could mean that an educator's command of the knowledge alone does not make him/her an ETE (Kreber, 2002: 13; Ball, 1990: 1; Bereiter & Scardamalia, 1993; Tiberius *et al*., 1998: 128), because his/her students could be

expecting him/her to be able to present the mathematical knowledge clearly for their understanding. Hence, *clarity in lesson presentation/teaching* could be, at this point, the difference between an ETE and a non-ETE (Ramsden, 2003: 112-113). Teaching and learning experiences have shown that clarity of presentations really matters in enhancing students' understanding of anything worth learning.

More often than not, students complain when a lesson is not clearly presented to them. On the contrary, when the lesson is well presented, students are satisfied and it is evidenced in their achievements or performance. Most especially, prospective teachers do not hesitate to adopt or adapt their educators' succinct explanations or presentations in their future work of teaching (Hativa, 1998: 357). It is important to note that, as compared to other disciplinary domains like the humanities, clarity in teaching is highly necessary in teaching mathematics and other sciences (Hativa, 1998: 357). This study was set up to identify some of the contributions of this attribute of the ETE in shaping the PD of PSTs, especially in connection with conceptual changes such as improving their CK and helping them to develop their PCK.

2.2.6.3. Preparation for and organisation in teaching

From the discussion above, it may be clear that preparation and organisation in the work of teaching is part of the professional identities of effective teachers. ETEs, especially, have been reported as planning their lessons carefully, with clear learning goals, and setting ambitious targets for their students (Hativa *et al*., 2001: 701; Chae *et al.*, 2005: 28). In Berliner's (1988: 62-63) view, preparation and organisation are among the attributes of teaching effectiveness that distinguish the ETE from non-expert teacher educators. Berliner's view draws our attention the fact that an educator's command of the subject knowledge and clarity of presentation, for example, may be incomplete without effective preparation for the lessons and organisation of the instructional activities. The teacher educator's knowledge and skills at this stage could increase or give diverse meanings to the subject knowledge and clarity of presentation at his/her command in the work of teaching. Thus, preparation and organisation in the work of teaching could enhance the ETE's performance. The ETE having an important professional identity, it could be expected that PSTs would benefit from their educators' preparation and organisation to improve their instructional practice, e.g. in selection of content and context and setting realistic instructional aims and objectives This is perfectly within the aim and objectives of this study: to

discover the contribution of this attribute of the ETE in shaping the PD of PSTs, especially in connection with both behavioural and conceptual changes such as transforming beliefs about mathematics and teaching and learning of it; improving their CK; and helping them to develop their PCK.

2.2.6.4. Enthusiasm in teaching

Enthusiasm in teaching represents the teacher's passion for teaching, the energy invested in the teaching showing deep interest/love for the intellectual power (subject matter knowledge) driving teaching work, and dedication to or commitment in teaching (Howitt, 2007: 49-50). In the researcher's view, this attribute could be seen as the backbone of teaching effectiveness, aside from the fact that it has been noted as an attribute of teaching expertise. Dineke *et al*.'s (2004: 256) argument that expertise in teaching is a combination of good personal characteristics or qualities and sound disciplinary knowledge, confirms the explanations presented above. Clearly, enthusiasm in teaching could be an aspect of the educator's personal qualities. From Lunenberg *et al*.'s (2007: 589) belief that teacher educators constantly influence the learning of their students, even when they are displaying inadequate behaviour, it could be expected that this attribute of the ETE could influence or shape PSTs' PD.

Hence, this study set out to identify some of the contributions of this attribute of the ETE in shaping the PD of PSTs, especially, in connection with both behavioural and conceptual changes such as transforming beliefs about mathematics and teaching and learning it; improving their CK; and helping them to develop their PCK.

2.2.6.5. Humour in teaching

Humour in teaching is also in the category of personal qualities constituting teaching expertise. According to Hativa (2000: 274-279), humour incorporated in teaching can be verbal (e.g. using jokes, anecdotes, language play) or non-verbal (using cartoons, caricature, photos visual pun), or a combination of both verbal and non-verbal (e.g. using impersonation, parody, satire, monologue, skit). It is important to note that incorporating humour in teaching makes the lecturer approachable and likable to students, because humour eases the "master and slave" relationship between student and lecturer. Students find their lecturers approachable because there is no unnecessary tension between them (Hativa, 2000: 273). Very significantly, though sometimes

unnoticed, lecturers use humour to bring about behavioural changes in students who exhibit unacceptable behaviour like laziness, disrespect, and inattentiveness, without openly confronting the students (Hativa, 2000: 274).

Aside from the fact that humour makes the lecturer approachable and lecturers use it to correct unacceptable behaviour, it has been proven that humour is greatly appreciated by students because they find lessons incorporating humour to be presented effectively, and lecturers also value the effectiveness of humour in engaging students' attention and generating their interest to deliver their best (Hativa, 2000: 274).

From the evidence presented above, the researcher is of the opinion that humour is a teaching expertise that can enhance the ETE's *articulation of subject knowledge expertise in teaching*; *clarity in lesson presentation/teaching*; *preparation for and organisation in teaching*; *enthusiasm in teaching*; *positive relationships with students and approachability*; *motivating/stimulating students' interest and engagement with learning experiences*; and *understanding of students' learning needs and creating a productive learning climate.* Hativa's (2000: 274) assertion that incorporating humour in teaching is an indication of the lecturer's confidence in himself and the expert knowledge s/he is sharing with the students; assurance in the effectiveness of his/her teaching approach; and command over his/her work of teaching supports the researcher's opinion here. In line with the learning outcomes resulting from lessons incorporating humour reported above, this study set out discover the contributions of this attribute of the ETE in shaping the PD of PSTs, especially, in connection with both behavioural and conceptual changes such as transforming beliefs about mathematics and teaching and learning of it; improving their CK; and helping them to develop their PCK.

2.2.6.6. Positive relationships with students and approachability

Like enthusiasm in teaching, *positive relationships with students and approachability* is another one of the personal characteristics constituting expertise in teaching. According to Hativa (2000: 255), insensitive lecturers' overt behaviour and feelings towards students are able to destroy their student's learning potential because it develops bad feelings in students such as an increase in anxiety towards the lesson; instilling deep fear; developing less confidence in themselves; causing feelings of inferiority; and dislike for the discipline as a whole. In Hativa's view, such

lecturers themselves eventually lose control over their work, due to lack of interpersonal relationships, or they become ineffective in articulating some very important teaching expertise, including those aspects discussed here. This is because they are mostly filled with anger towards students; impatience with students' characteristics and contexts; and ill feelings or frustration. This is exactly the opposite of humour in teaching as discussed above.

ETEs who exhibit *positive relationships with students and approachability* as a teaching strategy have been reported to be appreciative of the value of effective communication with their students and building trust and good interpersonal relationships, with the view of creating a productive learning environment and fostering desired learning outcomes for their students (Hativa, 2000: 255). It seems clear that all other attributes of expert teaching cannot be articulated sufficiently without the lecturer incorporating a good interpersonal relationship with students. by The researcher finds confirmation for this argument in Hativa's (2000: 256) assertion that "… a pleasant classroom climate that is conducive to learning is a necessary condition for effective teaching" towards promoting the sharing of expert teaching knowledge.

Hativa (2000: 255) notes that students' learning outcomes are maximised when the lecturer is positively sensitive to his/her students' characteristics or contexts, by showing respect for the students and their capabilities; drawing the students closer to his personality and competencies; accommodating students' responses or viewpoints or mistakes; showing interest and care for their learning; encouraging students to attend, think and learn even complex content; encouraging students to practise their own trial and error strategies in learning; and showing concern for learning difficulties. The attribute of *positive relationships with students and approachability* can, beyond all reasonable doubt, allay the counterproductive learning environment or climate created by insensitive behaviour (Hativa, 2000: 255). This study set out to discover some of the contributions of this attribute of the ETE in shaping the PD of PSTs, especially in connection with both behavioural and conceptual changes such as transforming beliefs about mathematics and teaching and learning of it; improving CK and helping students to develop their PCK.

2.2.6.7. Motivating/stimulating students' interest and engagement with learning experiences

Motivating/stimulating students' interest and engagement with learning experiences are synonymous to situations when ETEs focus on arousing students' interest; making especially difficult contents genuinely interesting to students; or making students enjoy learning the subject matter knowledge. Stimulating the interest of students for engagement in learning is an attribute of expert teaching that furthers the distinction between ETEs and non-ETEs (Ramsden, 2003: 113). In Paul Ramsden's view, this attribute of expert teaching is one of the "six key principles of effective teaching in higher education" (2003: 93). The author explains, that to bring about significant behavioural and conceptual changes in PSTs' PD, the ETE would be stimulating the interest of students for engagement in learning by incorporating reflective practices (Berliner, 1988: 40-43; Kreber, 2002: 10 & 12; Ambrose, 2004: 95); the modelling of teacher and teaching effectiveness (Ball, 1990: 13; Korthagen *et al*., 2005: 111; Haydn, 2014: 3; Levin, 2014: 51); and scaffolding strategies, for example when facilitating mathematics modules, especially methodology modules. Ramsden sees it as mandatory for teacher educators to improve the quality of students' engagement in learning by stimulating their interest and offering clear explanations of complex subject matter. The main concerns of the ETE here is that it is very important for students to be convinced that it is worthwhile learning the particular material while making it pleasurable for them to be learning that material (Ramsden, 2003: 93). Students' engagement with learning experiences requires reaching the ultimate purpose of enabling them to understand what they are learning; to work at their own pace and to the level of their own understanding; to make them responsible for their own learning or to become independent learners; to facilitate the development of their own expertise; and to develop their own skills inquiry in learning (Ramsden, 2003: 97). It should be mentioned that the strategies listed above are mostly articulated by teacher educators who value sharing their expertise with their students. Furthermore, stimulating the interest of students for engagement in learning could be seen as the expertise that requires the interplay of the ETE's *articulation of subject knowledge expertise in teaching*; *clarity in lesson presentation/teaching*; *preparation for and organisation in teaching*; and *enthusiasm in teaching*, which are closely related and apparently complementary. The benefits of such teaching expertise have motivated the current inquiry into some of the contributions of this attribute of the ETE in shaping the PD of PSTs, especially in connection

with both behavioural and conceptual changes such as transforming beliefs about mathematics and the teaching and learning of it; improving their CK; and helping them to develop their PCK.

2.2.6.8. Understanding of students' learning needs and creating a productive learning climate

Understanding of students' learning needs and creating a productive learning climate could mean showing interest in students' contexts and their learning characteristics or needs; compassion for their characteristics and their learning; or diagnosing and addressing students' misconceptions (Ramsden, 2003: 98). *Understanding of students' learning needs and creating a productive learning climate* is an expertise which could be figured out when ETEs value the role of positive communication with PSTs; respect for diversity in PSTs' abilities; remediation and regular feedback to PSTs (Ramsden, 2003: 94). Ramsden is convinced that understanding of students and creating a positive environment is an essential quality of a "very good teacher", because very few teacher educators in universities articulate this attribute of expert teaching. This teaching expertise appears to be neglected by many university educators, and this negligence has been debunked by reliable research findings showing the worth of understanding students and creating a positive environment. Ramsden (2003: 95), for example, shows that research by Feldman (1976) and Entwistle and Tait (1990) have shown that university students value highly those educators who respect them and consider their needs or contexts in interacting with them. Ramsden (2003: 95) laments that educators who do not articulate this expertise in their work of teaching consciously or unconsciously make the subject-matter unnecessarily demanding for their students. On this note, this investigation set out to examine Ramsden's claims concerning some of the contributions of this ETE attribute in connection with shaping the PD of PSTs, especially behavioural and conceptual changes such as transforming their beliefs about mathematics and the teaching and learning of it; improving their CK; and helping them to develop their PCK, which could result from it.

2.2.7. Complementary roles of the attributes of expert teaching

The researcher is arguing that merely listing the attributes of teaching expertise would not promote the golden understanding that they are integrable components or that they complement the roles of one another, but rather would continue to deepen our understanding of them as discrete components of a single individual's teaching expertise. In the researcher's view, understanding the attributes of expert teaching as integrable or complementary components would be very helpful and would also show or articulate their combined efforts towards promoting the agenda of the constructivists' perspectives on quality teaching and learning. The researcher believes that the explicit or implicit connections between these attributes of teaching expertise need to be revealed, because the teacher educator might in one way or another exhibit or articulate the attributes in an integrable fashion in the work of teaching, which may or may not be noticed. Discussing the explicit or implied complementary relations or connections between the attributes of teaching expertise would be equally helpful towards enhancing our conceptual understanding of these expert teaching constructs. To proceed from this point, the researcher attempts to discuss possible complementary relations or implied connections between the attributes of expert teaching described above.

It has been shown that *articulation of subject knowledge expertise in teaching* is the foundation of the teacher educator's teaching expertise in his/her discipline. And it has further been shown that displaying this expertise alone is not enough to claim expertise, especially in the preparation of future teachers. To this extent, it is undeniable that the mathematics teacher educator's *clarity in lesson presentation/teaching* would be needed to enhance the transfer or sharing of subject-matter knowledge, thus both would be necessary to enhance sound and in-depth understanding of mathematics subject matter knowledge. The teacher educator's *clarity in lesson presentation/teaching* could be seen as a means of communication with PSTs, therefore the better its quality, the more meaningful and beneficial the other attributes of expert teaching become in enhancing the PD of the PSTs.

Furthermore, it can be seen that the teacher educator's *preparation for and organisation in teaching* is a very important and necessary attribute of expertise in teaching since it serves as the framework guiding the teaching and learning activities. It could be inferred that the teacher educator's *preparation for and organisation in teaching may* coordinate the successful

articulation of the other attributes of expert teaching. This should be forcefully emphasised in initial teacher education modules like Foundation Phase mathematics. Similarly, *enthusiasm in teaching* could also immensely influence the extent to which the ETE articulates all other attributes of teaching expertise.

To some extent, the degree of the articulation of the ETE's command of subject knowledge; clarity in lesson presentation/teaching; enthusiasm in teaching; positive relationships with students and approachability; and humour in teaching, among others teaching attributes are evidenced in the ETE's incorporation of his/her understanding of students' learning needs and in creating a productive learning climate. This argument is strengthened by Ramsden's (2003: 95) claim that incorporating understanding of students and creating a positive environment "… requires developing a keen interest in what it takes to help other people to learn; it implies pleasure in teaching and associating with students, and delight in improving". Thinking about all these attributes of expert teaching as compatible or complementary dimensions of an individual's teaching qualities or tools and evaluating them within the frameworks of teaching theories or models of teaching expertise would project them as constituents of one complete model. The following sections address this interest.

2.3. THE NATURE OF EXPERT TEACHING KNOWLEDGE

Shim and Roth (2008) explain that expert knowledge in teaching cannot be separated from the teaching situations in which it becomes apparent (p. 14). ETEs blend their teaching knowledge (their theoretical knowledge) with the practice of teaching (practical knowledge) to the extent that there is no apparent difference between the two (Shim & Roth, 2008). Shim and Roth note that expert teaching knowledge could be accessed through "... the art of teaching, situational teaching, habitual teaching, and unconscious or subconscious teaching practices" (p. 14). The authors refer to the knowledge expressed through the contexts discussed above as tacit knowledge (Ball, 1988: 14-15; Kreber, 2002: 15). The tacit knowledge of experts has become the central theme of many investigations in this field (Kinchin & Cabot, 2010: 154).

Expert teaching knowledge has also been described as "a form of art" in the views of Yang and Leung (2011: 1008). Shim and Roth (2008) interpret this nature of expert teaching saying experts' skills are developed through intuition and experience and not by following a prescribed set of rules, or facts (Kreber, 2002: 13; Berliner, 1988: 42-43). In Shim and Roth's (2008) study, an ETE for example claims "teaching is a mixture of art and science". This was evidenced in an excerpt from interviews with an ETE saying "That's why people say [expert teaching knowledge is] a mixture of art and a science" (p. 11).

Researchers like Yang and Leung (2011), Li and Even (2011), Smith and Strahan (2004), Berliner (2001), and Berliner (1988) unanimously agree that expert teaching knowledge is situational because it is best articulated in a specific situation, since it might not be separated from the situation. To illustrate this nature of expert teaching knowledge, Shim and Roth (2008) documented an ETE saying that expert teaching knowledge "… can only really exist there when I'm in the classroom with the students" (p. 11).

According to Shim and Roth (2008), most experts may not be aware (i.e. unconscious or subconscious teaching expertise) of their expertise in teaching though observers around them are well informed of the expertise they possess (Kinchin & Cabot, 2010: 155). This was described by an ETE saying: "I knew that I was doing that, but I didn't know that this was part of an educational process ..." (Shim & Roth, 2008: 12).

Ball (1988: 15) shares the view of Shim and Roth that expert teaching knowledge can also be habitual in nature. According to Shim and Roth's (2008) observations, expert teaching knowledge usually is "an innate ability of the expert, because it was so quick and deep". Shim and Roth (2008) illustrate this nature of expert teaching knowledge, quoting an observer describing an expert's teaching knowledge:

> ... when she's conducting a session, she picks up on cues from the audience obviously and from individuals. The other thing that she's really good at is thinking in depth quickly, so you can watch her engage in maybe a one-on-one session with a student and the student presents a draft of something. She can respond to such a level of depth to get the person moving along in terms of her questioning, just brain-storming, whatever it takes in order to move the person forward (Shim & Roth, 2008: 12-13).

The evidence presented above shows that the expert knowledge could be implicit in nature and very distinct in the process of teaching, because there does not seem to be any clear distinction between the knowledge itself and the expertise facilitating it.

2.4. SOME WAYS OF TRANSFERRING EXPERT TEACHING KNOWLEDGE

The nature of expert teaching knowledge has been described as a form of art, situational, habitual, and articulated unconsciously/subconsciously in teaching practice. Shim and Roth (2008: 14) note that ETEs share their teaching expertise with their students through modelling and observation, reflecting on actions, metaphors, storytelling, and helping learners to reconstruct beliefs in the work of teaching.

Firstly, Lunenberg *et al*. (2007: 589) define modelling by ETEs as "…the practice of intentionally displaying certain teaching behaviour with the aim of promoting student teachers' professional learning". In sharing teaching expertise between ETEs and their students, Ball (1990: 13), Korthagen *et al*. (2005: 111), Haydn (2014: 3), and Levin (2014: 51) have acknowledged the effectiveness of employing modelling and observation in an integrated fashion. In support of the views discussed above, Berliner (1988: 62) and Lunenberg *et al*. (2007: 586) argue that tacit knowledge, which some teacher educators think are difficult to articulate (Shim & Roth, 2008: 6), can be shared with the observer through intensive modelling by the expert teacher. A case in point is the evidence gathered by Shim and Roth in their research, of both the ETEs and their mentees endorsing the productiveness of the modelling and observation methods of sharing teaching expertise. In Haydn's (2014) investigations, it is likewise noted that the ETEs regularly model how PSTs could use ICT in teaching to foster students' understanding. Lunenberg *et al*. (2007: 589) also emphasise that "… modelling by teacher educators can contribute to the professional development of student teachers". Lunenberg *et al*. explain that

PSTs derive three benefits from the ETE's modelling, namely hearing, reading, and experiencing teaching effectiveness. The authors also add that modelling by ETEs influences behavioural and attitudinal/belief changes in PSTs. In Lunenberg *et al*.'s view, effective modelling requires effective teaching expertise. The reason, according to Lunenberg *et al*., is that teacher educators who have problems modelling teacher roles and teaching effectiveness are lacking the desired knowledge and skills to model effectively. It appears that modelling effective teacher and teaching effectiveness requires a great deal of teaching expertise, such as the eight attributes of teaching expertise (see section **2.2.5**).

Secondly, Lunenberg *et al*. (2007: 589) argue that learning outcomes are maximised in modelling and observation when prospective teachers are encouraged to incorporate reflections in the learning process (i.e. while they are observing the modelling by the ETEs). Da Ponte and Chapman (2008: 247) describe reflection on actions as a practice that includes:

> considering the appropriateness of the teaching and learning materials and strategies; PSTs and the ETE considering their interactions processes and outcomes; PSTs considering instances where they find it difficult understanding and making sense of the learning processes and opportunities; and considering unusual or rare occurrences that can enhance future improvements.

In the view of Berliner (1988: 40-43), Kreber (2002; 10/12), Ambrose (2004: 95), Da Ponte and Chapman (2008), and Shim and Roth (2008), incorporating reflection on action plays a central role in transferring or sharing expert teaching knowledge, especially due to the complex nature of expert knowledge. Shim and Roth (2008) have reported that expert teacher educators deliberately focus on reflecting about teaching over a prolonged period of time. Da Ponte and Chapman (2008: 247) claim that reflection on teaching distinguishes expert teachers from non-expert teacher, especially in mathematics teacher education. These arguments seem to support the view that, to a greater extent, the development of PSTs' reflective skills during their interaction and sharing in the ETE's expert teaching knowledge is as valuable as knowledge of the discipline (Da Ponte & Chapman, 2008: 247).

Thirdly, "metaphor" is one of the methods used by ETEs to share teaching expertise with students (Shim & Roth, 2008: 19). This is reverted to "when something [is] impossible to be

described in a direct way in words", and experts introduce "something else which [is] the same in a particular way". By way of illustrating this expert approach, Shim and Roth (2008) quote an ETE's description of the approach: "I tend to give a lot of examples. I tend to sort of go through an example or say it's like, create a metaphor, it's like this, I sort of metaphorically think or give a visual example because I think visually" (p. 19). The effectiveness of employing metaphor in teaching has also been documented by Da Ponte and Chapman (2008: 239). In their view, some teacher educators use metaphors to facilitate PSTs' understanding of problem solving and its teaching. The integration of metaphors has been found to promote the development of "a more flexible view of problem solving and its teaching that reflected a learner-centred approach" to enhance PSTs' PD (Da Ponte & Chapman, 2008: 239).

Fourth, expert teacher educators adopt the storytelling approach to facilitate knowledge transfer, especially when their aim is to communicate a "feeling" that can enhance the learning goals (Shim & Roth, 2008: 20). According to Shim and Roth (2008), an ETE described this expert method, saying "… I would tell that kind of story to my student if there was a sad moment in the piece of music…" (p. 20).

Fifth, sharing and learning expert teaching knowledge can be very effective if the learner reconstructs his/her beliefs and opens up to new ideas about teaching knowledge (Shim & Roth, 2008: 9-10). An ETE, according to Shim and Roth (2008) said: "... she knows that her teaching style is greatly different from mine. … She came with the openness to observe and to look for things that she thought were effective…that she could do" (p. 9-10).

2.5. TOWARDS DESCRIBING AN ETE

Several definitions of teacher educators are presented in the literature, including those by Ben-Peretz, Kleeman, Reichenberg and Shimoni (2010), who explain that teacher educators are

- …the people who instruct, teach and provide support to student-teachers, thus making a significant contribution to the development of future teachers (p. 113);
- Everyone who trains teachers' or 'Everyone who teaches, mentors or guides teachers in the pre-service as well as in the in-service teacher education arenas (p. 119);
- Everyone who teaches in a teacher education institute (p. 119).

Mitchell *et al*. (2004: 280) and Kreber (2002) describe teacher educators as "... those who motivate students, convey concepts, and help students overcome learning difficulties". More specifically, Ben-Peretz *et al*. (2010: 113) and Korthagen *et al*. (2005: 110) perceive ETEs as those who were or might have been "good-school teachers" and have acquired and developed special teaching knowledge and skills (i.e. expertise) in their discipline.

According to Ben-Peretz *et al*. (2010) teacher educators engage numerous and diverse, but very challenging, day-to-day responsibilities by lecturing in a specific field of expertise; making the learning process accessible to student teachers; encouraging reflective processes in the trainees; and being involved in research and in developing research skills in their students (p. 113). Interestingly, Ben-Peretz *et al*. (2010: 113) point out "role-modelling" how to teach to facilitate PSTs' PD effectively as very prominent among the responsibilities of the teacher educator.

In the view of Ben-Peretz *et al*. (2010: 119), teacher educators' identities and their roles in the work of teaching are intertwined. The authors describe this unique relationship based on three working theories of the teacher educator: "the model pedagogue; the reflective, self-studying practitioner; and the developer of professional identity".

Being a model pedagogue implies that the teacher educator sees himself/herself as a role model setting the stage for PSTs to easily access teaching knowledge from his or her exemplary teaching knowledge and skills (Ben-Peretz *et al*., 2010: 119). Most centrally noted is the idea that the model pedagogue is enabled to bridge the gap between theory and practice in teaching. This is explained by Ben-Peretz *et al*. (2010) as the ability of the teacher educator to:

- teach young adults and adults, understanding their needs and ways of thinking
- learn how to guide and mentor their students for their future roles as teachers, by mediating and modelling sound and updated pedagogies
- integrate the theories they have learned into their practice
- review their former field experience and adapt it to their new practices
- create and *implement* new practices. (p. 120)

Ben-Peretz *et al*. (2010: 121) describe the reflective, self-studying practitioner as the teacher educator investigating his/her own teaching, "in order to improve it". Ben-Peretz *et al.* (2010: 121), quoting Kreber (2002: 12), explain that "reflection and self-study are perceived as vehicles for self-and-action improvement and are looked upon as core processes that motivate and direct

the professional development of teacher educators" Mitchell *et al*. (2004: 281) add their voice to this important attribute highlighted by Kreber, saying that teacher educators develop their exemplary teaching and professionalism through reflection and self-regulation.

In describing the teacher educator as a developer of professional identity, Ben-Peretz *et al*. (2010) declare that teacher educators engage in sharing teaching and learning experiences with their teacher educator colleagues and students in particular in the form of qualitative narratives so as to help PSTs to "understand themselves and uncover their own desired ways of teaching and being teachers" (p. 123). Through such opportunities, teacher educators were able to help PSTs in diverse ways to "discover their personal professional strengths by themselves".

Ben-Peretz *et al*. (2010) found that the working theories of teacher educators lead to the following remarkable achievements in their teaching:

- Caring about the teacher educator's students' growth, being emphatic, promoting their autonomy, promoting their inter-relationships … promoting their sense of belonging to their profession and so on.
- Freely sharing their experiences, attitudes, concepts, with PSTs which might allow them to find their own professional voices and identities.
- Encouraging reflection among PSTs. (p. 123)

All of the above can be summarised in Korthagen *et al*.'s (2005) pronouncement that "… being a teacher educator requires dealing with a complex dual role" (Lunenberg *et al*., 2007: 588). Teacher educators not only take on the role of supporting student teachers' learning about teaching, but in so doing, through their own teaching, model the role of the teacher" (p. 111).

As role models, ETEs are perfect examples of teachers and what teachers do or should be doing. This study set out to identify the contributions of the ETE's characteristics described above in shaping the PD of PSTs, especially in connection with both behavioural and conceptual changes such as transforming belief about mathematics and teaching and learning of it; improving their CK; and helping them to develop their PCK (Lunenberg *et al*., 2007: 588).

2.6. SOME DIFFERENCES ETEs MAKE IN THE PREPARATION OF PSTs

The fundamental goal of this section is to discuss the significance of teaching expertise in the work of teacher educators. This discussion aims to identify the difference that teaching expertise

makes in the preparation of prospective teachers. The discussion here is directly linked to the research problem and research questions guiding this study. Significantly, this section could serve as the link between this chapter and. Chapter 3.

Tyagi and Vashisth (2012: 32) have shown that teaching clarity affords the ETE to be highly explicit in providing students with the necessary direction and explanations regarding the organisation and content of the course. These authors add that teaching clarity enables ETEs to use effective alternative approaches to transfer knowledge to their students. It also enables ETEs to assist their students in making meaningful connections between old and new concepts they have learnt. This expertise enables the ETE to articulate the subject content; do realistic teaching (real life applications of knowledge); demonstrate preparedness and organisation; incorporate an interpersonal relationship and social interaction with students, and exhibit clarity in teaching (Tyagi & Vashisth, 2012: 31).

Witt *et al*. (2013: 20), Hativa *et al*. (2001: 699) and Da Ponte and Chapman (2008: 228) share the view that, in learning to teach, PSTs need to access ETEs' teaching beliefs, pedagogical knowledge and teaching expertise. Levin (2014: 51) explicitly claims that the pedagogical beliefs of PSTs are transformed through observing the teaching expertise of ETEs.

Empirical researchers have shown, by comparing non-expert teachers with expert teachers, that expert teachers can achieve better and more diverse learning outcomes or gains than non-expert teachers (Lu *et al*., 2007: 456; Chae *et al*., 2005: 28; Glass *et al*., 1999: 43). Others have provided evidence that the expert educator, unlike the non-expert teacher educator, tries to elicit more information (by asking more questions, elicit more materials from students, and engage them in the learning experience) about students' learning, in order to understand them and create a positive learning environment for their learning (Chae *et al*., 2005: 28; Glass *et al*., 1999: 48). In addition, it has been documented that students, when interacting with expert teachers, are engaged in intensive reflection on their own actions and learning experiences, intensively assessing their own understanding of the problem for learning (Di Eugenio *et al*., 2006: 506). Unlike non-expert teachers, expert teachers encourage students to learn to construct their own knowledge by using prompts and scaffolding (Di Eugenio *et al*., 2006: 506).

In contrast with the above, Akyeampong *et al*. (2013: 275) lament findings that seem to reveal the inadequacies of some non-expert teacher educators who facilitate initial preparation programmes. Their findings seem to reveal that facilitators of preparation courses investigated by them, especially the methodology module (i.e. teaching and learning how to teach), lack the necessary expertise and professionalism to promote the development of the PSTs' PCK (Akyeampong *et al*., 2013: 275). The authors perceive that the PSTs ignorantly claim to have developed the confidence and knowledge required to be effective teachers, which the authors believe to be a consequence of the lack of expert qualities in the work of the facilitators (Akyeampong *et al*., 2013: 276).

Akyeampong *et al*. (2013) suggest that the teaching knowledge the PSTs in their study had developed was based on the facilitators' prescribed ways of teaching which lacked richness, reality, flexibility, and adaptability to classroom contexts and learners' perspectives (p. 276). For example, the PSTs experienced learning to teach mathematics as only needing "one correct" teaching approach, according to the tutors in their colleges (Akyeampong *et al*., 2013: 276). Akyeampong and his colleagues noted other consequences of the non-expert teacher educators' lack of teaching expertise that were are manifested in the kind of teachers the PSTs were becoming. Their findings seem to show that the PSTs trained by such teacher educators seem to pay insufficient attention to a learner-centred approach. The seriousness of this situation is encapsulated in Helterbran's (2008: 124) argument that a learner-centred orientation in teaching improves the teachers' professionalism because, if the learner is not the focus of the teaching he/she is experiencing, then of what use is the teaching?

In addition, Akyeampong *et al*.'s findings seem to show that the PSTs were practising mathematical instructions without due focus on teaching for meaningful understanding. The PSTs, for example, were reluctant to engage learners in problem-solving to understand mathematics; they were uncritical about the needs and characteristics of children; gave insufficient assistance to young children for finding answers to problems by using different strategies in their instructional practices; and were unable to explain why mathematical procedures work to young children.

The authors conclude by saying that, to some extent, the teaching characteristics of both PSTs and beginning teachers in their research were predominantly based on transmitting knowledge (i.e. mental mathematics, demonstrations) without attention to learners' understanding. They also seemed to turn a blind eye to the consequences of their own common misconceptions about mathematics and the teaching and learning of it (Akyeampong *et al*., 2013: 277).

The PSTs' experiences in learning to teach from their educators seemed to suggest that the educators could not facilitate the development of the PSTs' PCK by creating opportunities for them to learn mathematics and the challenges in teaching it from the perspective of learners' difficulties (Akyeampong *et al*., 2013: 277; Lu *et al*., 2007: 456). So it might not be surprising that the PSTs lacked the understanding of teaching knowledge (PCK) as integrated with CK and "knowledge of pupil learning needs or misconceptions, their background characteristics, the classroom ecology and resources, and the practical examples that make sense to them" (Akyeampong *et al*., 2013: 276).

2.7. CONCLUSION

The researcher's aim was to derive a model of teaching expertise that would be suitable for the context of this research, the context of initial teacher preparation in general, and Foundation Phase mathematics teacher preparation in particular. The following eight attributes of expert teaching constitute the new model: *articulation of subject knowledge expertise in teaching*; *clarity in lesson presentation/teaching*; *preparation for and organisation in teaching; enthusiasm in teaching*; *positive relationships with students and approachability*; *motivating/stimulating students' interest and engagement with learning experiences; understanding of students' learning needs and creating a productive learning climate* and *humour in teaching.* It may be seen that this model harmonises a fairly wide range of perspectives on teaching expertise. The model has brought together attributes of expert teaching which are believed to be articulated by the majority of ETEs in different disciplines. Berliner (1988: 39) voiced this claim by the researcher by saying that experts found in different domains seem to possess similar skills and attitudes in their performance. A more apparent similarity among experts is that "they use a common mode of perceiving and processing information". According to Shim and Roth (2008:

7), the attributes of teaching expertise represent the type of skills ETEs might be articulating in their teaching practice.

It has been shown that this model represents a coherent set of attributes of teaching expertise which are fairly explicit, rather than tacit, in the work of teaching. In addition, the model presents ideal dimensions of the teaching effectiveness of the teacher educator that deliberately modify students' counter-productive behaviour into the most desirable behaviour. The impact of the attributes on students' effectiveness in learning the subject matter of the discipline, as well as promoting greater achievement of the curriculum's expectations, has also been discussed.

This review further shows that the mathematics teaching expertise discussed in this chapter is explicitly consistent with the eight attributes of teaching expertise in the new model or framework of expert teaching, e.g. *articulation of subject knowledge expertise in teaching* and *clarity in lesson presentation/teaching* are consistent with profound knowledge of the subject matter, mathematics-specific analysis ability, PCK*; enthusiasm in teaching* is consistent with commitment of the teacher; *preparation for and organisation in teaching* is consistent with "ability to select and implement cognitive challenging tasks"*; positive relationships with students and approachability* and *humour in teaching* are consistent with affective attributes; *motivating/stimulating students' interest and engagement with learning experiences;* and *understanding of students' learning needs and creating a productive learning climate* are consistent with knowledge of students' learning.

This review has shown that expertise in teaching comprises progressive development through three distinct stages identified by Tiberius *et al*. (1998) that are similar to the five levels of expertise development in the view of Yang and Leung (2011), Berliner (1988) and Kinchin and Cabot (2010), namely, "novice, advanced beginner, competent, proficient and expert. It has also been shown that distinctive performance, especially in problem solving, are the hallmarks of teaching expertise. In this review, the implications of expert and non-expert teaching in teacher education, especially when the teacher educator is confronted with problems during teaching prospective teachers, have been illustrated.

Strategies of expert teacher educators (ETEs) such as modelling, observation, reflecting on actions, storytelling, metaphors, and critiquing pre-service teachers' beliefs were found to be the

ways of sharing their knowledge with their students. More importantly, this review ended by showing that ETEs are set apart from non-ETEs by the expression of the eight attributes of expert teaching identified in the new model.

The main focus of this study was to investigate this harmonious model of teaching expertise in one context (i.e. teacher education and professional development) (Berliner, 1988: 39), especially in an important curriculum issue (i.e. pre-service teachers' professional development) relating to mathematics education. This bears on the main research question which concerns the effects of those attributes of teaching expertise in the new model on pre-service teachers' professional development. This involves how the researcher further explored the new model of teaching expertise.

3. CHAPTER 3
EFFECTS OF TEACHING EXPERTISE ON THE PROSPECTIVE TEACHERS' PROFESSIONAL DEVELOPMENT

3.1. INTRODUCTION

The interest of this research was to elicit the perceptions of pre-service teachers' (PSTs) on changes/improvement in their professional development (PD) during their interaction with the teaching expertise of the teacher educator who facilitated the 3rd-year Foundation Phase mathematics module on which the research was focused. The attributes of teaching expertise referred to here are those constituting the new model described earlier (see section **2.2.5**). It is also important to reiterate that, in this study, the PD of the PSTs participating in this investigation has been conceptualised in terms of three fundamental learning outcomes which teacher preparation programmes are set to achieve. These learning outcomes include change/improvement in PSTs' beliefs about the subject matter of mathematics and the teaching and learning of mathematics; improvement in their understanding of content knowledge (CK) and development of their pedagogical content knowledge (PCK). Thus, surveying the perceived changes in their beliefs about the subject matter of mathematics and teaching and learning of it; improvement in their understanding of CK; and development of their PCK were investigated.

This chapter begins by exploring the ecological factors which play an unavoidable role in enhancing or shaping the PD of PSTs. The reason for this is that the entire interest of the study fits perfectly in this domain (i.e. the ecology of teacher education). The special factors of interest to this study in this ecology are the teacher educator's teaching expertise and characteristics of the PSTs. The reason for this particular interest is that the researcher was interested in the learning outcomes resulting from interaction between those two special factors. As highlighted above, the expected learning outcomes constitute the components of PSTs' PD.

The second part of this chapter seeks to explore two relevant issues that are closely related to the notion of PSTs' PD, as implied in this study, namely, PD in the landscape of in-service teacher education and teachers' knowledge and teaching effectiveness in South Africa. One reason was to determine from the literature whether the notion of PSTs' PD used in this study was consistent with

a. the targets or achievements of the in-service training for classroom teachers.
b. the desired teacher's knowledge for quality teaching in South Africa.

Another reason was to interpret the implications of findings from the literature under those themes for the future findings of this investigation.

The third section of this chapter attempts to explain the notion of PD in initial teacher education. This attempt is hoped to secure further justification for the notion of PSTs' PD as implied in this study. Specifically, the exploration of the literature in this section, addresses the following issues/questions: what is meant by PSTs' PD in the landscape of initial teacher preparation?; what are the issues of concern in the PD of PSTs or what constitutes the core of PSTs' PD?; what are the bases for determining success, growth, or changes in PSTs' PD?

Having stated the above, it should be remembered that the importance of teaching expertise or expert teaching knowledge to the teacher educator as well as the learner, was discussed towards the end of Chapter 2. That information is directly linked to the main theme of this chapter. Against this background, the final section of this chapter attempts to explore literature to give a detailed account of empirical evidence on the influence of the attribute of teaching expertise explained in **2.2.6** regarding PSTs' PD, thus, the contribution of the instructional behaviour of expert teacher educators to learning effectiveness. This section is entirely related to the research problem and questions guiding this study in focusing on teaching expertise and its impact on the dimensions of PSTs' PD.

3.2. ECOLOGICAL FACTORS IN INITIAL TEACHER EDUCATION

PSTs' PD is influenced by the interplay of numerous factors, under different situations and at different levels during their training (Da Ponte & Chapman, 2008: 254; San, 1999: 19). Lunenberg *et al*. (2007: 588) refer to the collection of these variables as the "ecology of teacher education", while Da Ponte and Chapman (2008) use the phrase "landscape of pre-service mathematics teacher education" (p. 224), to relate the ecological interactions to the field of mathematics education. PSTs' PD could, for example, be shaped by the modules and other curriculum material; teaching practices they experience; their educators as role models (Kagan, 1992: 154); peer influences; and PSTs' learning strategies (Howitt, 2007: 41). Da Ponte and Chapman (2008: 254) also identified "teacher educators' characteristics (e.g. their roles, motives, interest, personal features, conceptions, knowledge); cooperating mentors and students; assessment instruments and procedures"; "pedagogical approaches"; socio-cultural features of the teaching and learning settings; the organisation of the educational systems and teacher education programmes; and the purposes and objectives of teacher education" as the variables which contribute to the PD of PSTs. In addition, the PSTs' entry attitudes, beliefs, knowledge, conceptions, skills, experiences in learning to teach (apprenticeship teaching knowledge), and expectations have also been identified among the ecological factors shaping the PSTs' PD by Ingram (2014: 52), Bantwini (2012) and Da Ponte and Chapman (2008: 254).

Frykholm (1999: 81) similarly identifies PSTs' previous experiences (i.e. school mathematics experiences); knowledge structures (i.e. the mathematics they know and how they know it or how it exists in their minds); and belief systems (i.e. what mathematics is and how it should be taught and learnt) which PSTs bring to the preparation process, as very influential in the training processes. Closely related to the interest of this investigation is Kagan's (1992: 154) explicit claim that the teaching expertise modelled by the teacher educator and the PSTs' own identities as learners are the two main factors in this ecology that significantly shape PSTs' entry beliefs or images about the subject matter of the discipline, teachers and teaching.

Smith (2005) has described how the ecological factors interact in the preparation of PSTs more comprehensively. According to Smith (2005: 178), while initial teacher education programmes or curriculum provides fertile ground for cultivating the "seeds of professionalism in teaching", the teacher educator does the planting and nourishing or nurturing of the professional teaching knowledge so as to produce future independent teachers for quality instruction. The author explains that teacher educators are providing PSTs with the "foundations of professional knowledge" in this endeavour, and are preparing them to be able to adapt to future challenges related to their professional growth (Hume & Berry, 2011: 354). In addition they assist PSTs to "develop the tacit aspects of professional competence" (Smith, 2005: 178). The descriptions given here suggest that the teacher educator as a factor in this ecology is playing a central role in the preparation of prospective teachers.

From among the factors in the ecology described above, this study focused on the effects of the teacher educator's teaching expertise (Lunenberg *et al*., 2007: 588; Kagan, 1992: 154) on PSTs' PD. This factor has been explicitly or implicitly termed teaching practice and educators are referred to as role models by Howitt (2007: 41) and as "pedagogical approaches" and teacher educators' characteristics by Da Ponte and Chapman (2008: 254). The role of the educator's teaching expertise has been recognised as important in facilitating or determining the adequacy of the PSTs' preparation in learning to teach mathematics or any other discipline (Bronkhorst *et al*., 2014: 74; Kagan, 1992: 154). Bronkhorst *et al*. (2014) and Kagan (1992) believe that it has been among the significant environmental factors which have a considerable influence, for example on PSTs' resistance to change. It has been found that PSTs appreciate and learn from the educator's teaching expertise when their learning strategies/needs are adapted to the teaching strategies of educators. Da Ponte and Chapman (2008: 246) also support the views of the authors mentioned above in that PSTs' PD is influenced by "the nature of the relationships that they develop with experienced professionals" (Ingram, 2014: 52).

In this ecology, therefore, given the PSTs' entry attitudes, knowledge, skills, experiences (apprenticeship knowledge gained at school), and expectations, the current study investigated the improvement in PSTs' PD through their interaction with the ETE's teaching expertise, thus investigating their changing beliefs about mathematics and what makes teaching mathematics effective; improving their CK; and developing their PCK.

The explorations of the initial teacher preparation ecology above and the declaration of this study's interest have guided the researcher towards conceiving the conceptual framework below to guide the in-depth understanding and accurate interpretation of the improvement in PSTs' PD. The exploration has shown clearly that the ecological factors continuously interact to shape and reshape the PSTs' PD, and the teacher educator is a very significant factor in this ecology. Hence, the declaration of the research interest is realistic in terms of the idea that ecological factors interact to shape PSTs' PD.

3.3. DESCRIPTION OF THE CONCEPTUAL FRAMEWORK

3.3.1. Motivation

According to Eisenhart (1991: 209), "... a conceptual framework is a skeletal structure of justification…". She explains that it is an argument which harmonises different but coherent viewpoints or perspectives to guide the researcher in suitable ways to collect data in a particular study and enhance data analysis and interpretations or explanations (p. 210). Developing this conceptual framework was further motivated by Eisenhart's (1991: 212) conviction that using a conceptual framework in educational research, for example mathematics education, can lead to authentic (i.e. valid and reliable) research conclusions, because the researcher sources different perspectives or issues that are relevant to the good interest of the study.

Several studies concerning teaching expertise have used conceptual frameworks to articulate their perspectives on investigations. In their case study of teaching expertise Smith and Strahan (2004: 358-359), for example, combined three different prototype models of teaching expertise towards understanding or describing what expert teachers share in common in their instructional practices: what experts teachers do and what experts teachers say. The conceptual framework for the current study could be regarded as an extension of Smith and Strahan's (2004) conceptual framework, because this study has derived the attribute of teaching expertise (see **2.2.5**) (as Smith and Strahan (2004) did) and sought to interpret their impacts in bringing about change in PSTs' PD from the PSTs' perspective, thus investigating the effects of what ETEs do and say with their teaching expertise in the PSTs' PD.

3.3.2. Considerations

Towards developing this conceptual framework, the researcher considered the insights gained from the descriptions of the ecology presented above and through elaboration of the eight attributes of teaching expertise in the new model (see section **2.2.5**). In both cases it became evident that teaching expertise is a major ecological factor and could have a profound influence on learning outcomes. In this conceptual framework, therefore, the assumed independent variables are the eight attributes of teaching expertise in the new model, while the assumed dependent variables are the PSTs' entry attitudes, beliefs, knowledge, conceptions, skills, experiences in learning to teach (apprenticeship knowledge), and expectations. It is important to point out that both the assumed independent and the dependent variables are from the same ecological setting. These considerations could give the researcher more flexibility to provide comprehensive understanding or explanations of the problem under investigation (Eisenhart, 1991: 211) and flexibility in terms of easily identifying the units of analysis and variables of interest. The PSTs have been identified as the units of analysis and the variables are the dimensions of their PD (i.e. PSTs' beliefs, CK, and PCK) which are subject to the influences of the ETE's teaching expertise, which could be similar to the eight attributes of expert teaching in the new model. The PSTs own perceptions and interpretations of changes/improvement in the variables are central in this investigation.

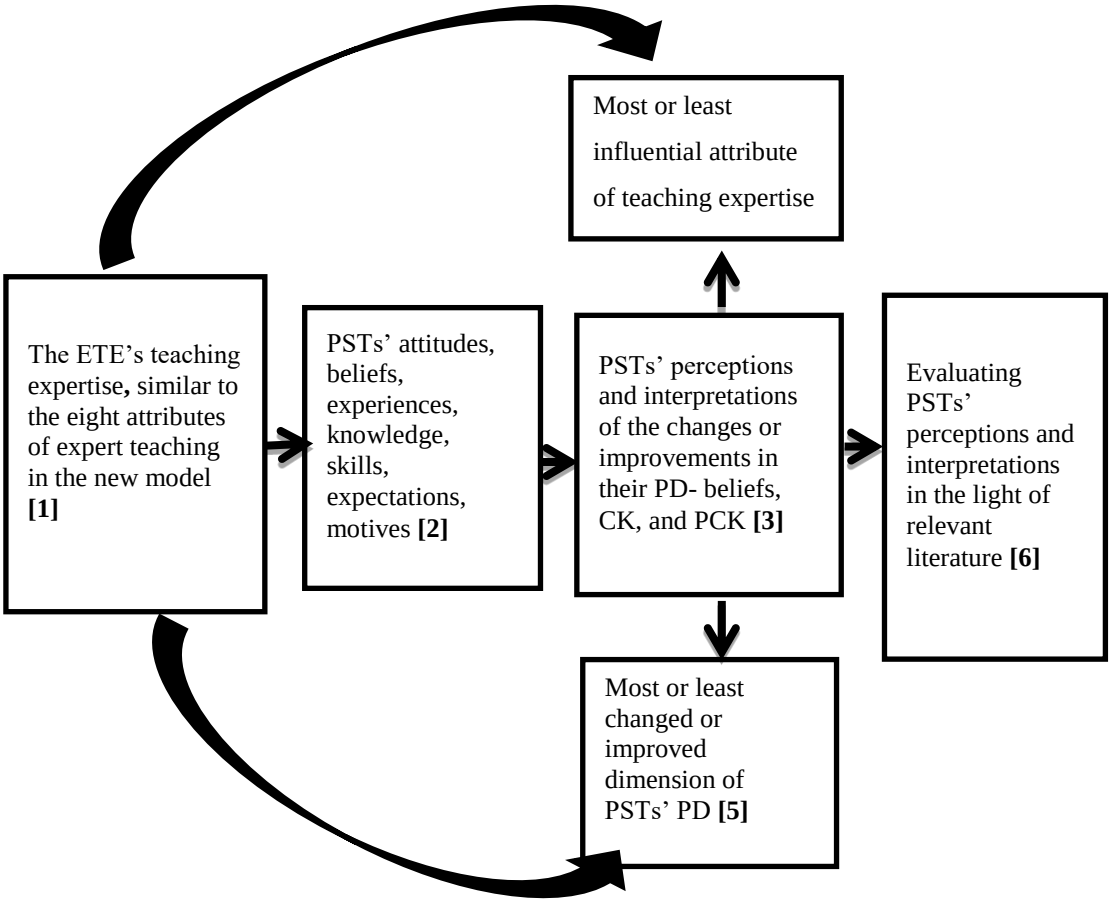
Additionally, this conceptual framework assumed a learning environment in which PSTs are actively interacting with the ETE's teaching expertise, similar to the eight attributes of expert teaching in the new model, to develop their PD. In this respect, the framework can be said to be consistent with constructivist learning theory (Da Ponte & Chapman, 2008: 252). The PSTs thus are actively learning to develop their PD; PSTs are actively interacting with the ETE's teaching expertise, similar to the attribute in the new model; the ETE is oriented towards transferring or sharing his/her expert teaching knowledge with the PSTs; the ETE's teaching expertise is promoting active learning through interaction with the PSTs; and the ETE's teaching expertise is promoting active knowledge construction by the PSTs to develop their PD (Ball, 1990: 12).

3.3.3. The proposed PD evaluation model

At this point the researcher proposed a model for evaluating the PD of PSTs., This conceptual framework specifically guided the processes of eliciting PSTs' perceptions and interpretation of their experiences regarding the influence of teaching expertise on their PD, thus used the PSTs' views to offer satisfactory explanations of what has changed or improved in their PD due to the teaching expertise they experienced. The model is shown in Figure **3.1,** below.

Figure 3.1. The conceptual framework guiding the research study

Source: Created by the researcher



Since this investigation only focused on the effects of the eight attributes of teaching expertise listed in **Box 1** on **Box 2** (PSTs' attitudes, beliefs, experiences, knowledge, skills, expectations, motives), using a one-directional arrow is the most appropriate to show the research interest. **Box 3** guides the researcher's attempt to explain the PSTs' perceptions about what has/have changed in their PD (beliefs, CK, and PCK). It focuses on their reflections and interpretation of the effects

of the teaching expertise they experienced on their PD. While **Box 5** guides the researcher to offer further details of perceived changes/improvement in the subjects' PD, **Box 4** guides the researcher to investigate and provide in-depth explanations of the PSTs' points of view regarding which attribute(s) of the teaching expertise they associated with the perceived changes**.** In **Box 6,** the researcher seeks further interpretations of their perceptions about the improvements in their PD in the light of the literature. **Box 6** more specifically evaluates the PSTs' claims within the framework or models of PSTs' professional growth. **Later,** in Chapter **4,** the researcher explains how data were collected with reference to **Boxes 3, 4** and **5**, and the analysis of and conclusions from the information gathered with reference to **Boxes 3, 4, 5** and **6** are provided in Chapters **5** and **6**.

The proposed model could be aligned with existing PD evaluation frameworks in teacher education and professional development, like Guskey's (2000) model for evaluating teachers' PD. It shares some similarities with the proposed method for evaluating PSTs' PD in **Box 3.** Guskey (2000) succinctly identifies what he calls "The Critical Levels of Professional Development Evaluation", namely

> participants' reactions to the experience; participants' learning experiences and outcomes; information on organisation support and change; participants' abilities to apply the new knowledge and skills they have learnt; and evidence of participants' influences on their students' learning outcomes and achievements.

At any of the levels, Guskey's (2000) model primarily focuses on how to gather information at that level; what to measure at the level; and "how that information will be used". To put into context, Guskey's model evaluates the influence of teacher PD activities based on "participants' reactions to the experience" (**level 1)**; participants' learning experiences and outcomes (**level 2)**; "information on organisation support and change" (**level 3)**; participants' abilities to apply the new knowledge and skills they have learnt (**level 4)**; and evidence of participants' influences on their students' learning outcomes and achievements (**level 5)**.

3.3.3.1. Gathering information at the levels

Compared to the current research, levels **1**, **2** and **4** have direct links to this study in terms of purpose and methodology. The central purpose of **level 1** is to find out whether the participants involved in the PD activities liked these activities. This is similar to the current study's focus on learning from PSTs' views whether their expectations of developing their PD were met, having

been exposed to the eight attributes of teaching expertise in the new model, thus to elicit the views of the PSTs to ascertain the effects on their PD of the teaching expertise they experienced. This can be explained by comparing the PSTs' points of view on improvement in their PD during the two-year training with the improvement in their PD in the 3rd year. The PD assessed on the two-year training of PSTs considers the effect on their PD of all the factors in the context of their training (the ecology). The PD assessed on their 3rd-year training is strictly focused on the effects of the eight attributes of teaching expertise on the PSTs' PD. This serves as a major indicator of any differences the PSTs may perceive. The current study used a questionnaire to gather information from the PSTs, which is similar to Guskey's (2000) methodology in gathering information from participants for evaluation. Guskey's reason for using questionnaires, like the current study's use of Likert scale items for eliciting PSTs' views, is that, as he claims, "... a combination of rating scale items and open-ended response questions allow participants to provide more personalised comments". Further interpretations of the PSTs' PD could be sought for using the perspectives in **Box 6.** Both surveys and interviews are applicable here, but, interviews most likely yield the best expressions of the PSTs' perceptions.

With reference to **level 2**, Guskey claims that these "participants learned something from their professional development experience" to develop their knowledge, skills, and attitudes, which are worth evaluating. The current research likewise assumes that PSTs actively access expert teaching knowledge from the ETE's teaching expertise. This could be evident in the transformation of their erroneous beliefs (as documented in the literature) about what the mathematics they are going to teach is, and what makes teaching and learning of mathematics effective and interesting, and the development of their CK and PCK. The methodology suggested by Guskey (2000) for gathering information at this level of evaluation includes using paper-and-pencil instrument simulations, demonstrations, participant reflections (oral and/or written), and participant portfolios. The methodology for the current study did not include using paper-and-pencil instrument simulations and demonstrations. However, Guskey's method of "participant reflections (oral and/or written)" is similar to the use of semi-structured interviews in the current study. This is the methodology common to the current study and Guskey's model, because the main aim of this study was to explain the PSTs' perceptions, and not to test their knowledge, skills and attitudes.

At **level 4,** Guskey's (2000) model focuses on evaluating the change that is evident in the participants' teaching practice, by showing how the acquired or developed knowledge, skills, and attitudes from the PD activities are applied. The current study similarly prioritises perceived affordances of the changes in the PSTs' PD (Hill *et al.*, 2005: 372; Ball & Forzani, 2010: 40) after their exposure to the teaching expertise experienced in the 3rd-year Foundation Phase mathematics module. From among all the methodologies suggested by Guskey for evaluating the PD of teachers at this level, the use of questionnaires and interviews is similar to the methods of the current study.

3.3.3.2. What to measure at the levels and how to use the information

At **level 1,** Guskey's (2000) model intends to measure teachers' "initial satisfaction with the experience", but the current study measures PSTs' view on achieving their expectations after their exposure to the teaching expertise experienced in the 3rd-year Foundation Phase mathematics module. While Guskey (2000) intended to use the outcomes of the measure at this level to "to improve program design and delivery", the PSTs' views captured in the current study could inform teacher educators of the effects of teaching expertise on PSTs' PD expectations and achievements (Shim & Roth, 2008: 7; Hiebert, Gallimore & Stigler, 2002: 3; Schwarz *et al*., 2008: 791). In addition to teachers' acquisition of new knowledge and skills, which Guskey's (2000) model measures at **level 2**, the current study elicits the views of PSTs about transformation in their beliefs about the subject matter of mathematics and the teaching and learning of it; improvement in their understanding of CK; and development of their PCK. Regarding how the information is used, the current study shares Guskey's suggestion that level **2** will help "to improve program content, format, and organisation" (Da Ponte & Chapman, 2008: 254; Yang & Leung, 2011: 1008; Smith & Strahan, 2004: 358; Levin, 2014: 50).

The current research aims to elicit PSTs' views about what they believe they can do with the transformation in their beliefs about the subject matter of mathematics and the teaching and learning of it; improvement in their understanding of CK; and development of their PCK. Contrary to this, Guskey's (2000) model is emphatic regarding measuring the degree and quality of implementation that teachers can or must do in applying the knowledge and skills they have

acquired from the PD activities at **level 4**. According to Guskey (2000), the evaluation information at this level should be used "to document and improve the implementation of program content". The current study was meant to provide useful information that would benefit teaching effectiveness in preparing novice expert teachers.

3.4. PD IN THE LANDSCAPE OF IN-SERVICE TEACHER EDUCATION

This section is included in this review to ascertain what teacher professional development programmes in general and in South Africa in particular have achieved or set out to achieve and, more importantly, to ascertain the extent to which the framework of PSTs' PD defined in this study matches the required achievement or targets of the workshops for practising teachers. The researcher hoped that this would enable him to articulate well-informed implications of the literature findings in this section to initial teacher preparation in light of the findings of this study.

According to Borko (2004: 3), in-service teacher education or workshops have been part of the measures used for improving practising teachers' knowledge for decades. These have mostly comprised temporal and short-term courses, especially when there has been a need to address emergencies or inadequacies in teaching and learning. Mosoge and Taunyane (2012: 196) have reported that teachers found the workshops in which they participated to be meaningful and useful in assisting them to address instructional challenges experienced in their classrooms (Borko, 2004: 3). Mosoge and Taunyane (2012) also add that the teachers claimed that the workshops helped them to effectively implement the new curriculum. These researchers (2012: 196) remarked that similar positive perceptions have been observed by other researchers, especially when the PD activities were directly related to the classroom work of the teacher. According to Mosoge and Taunyane (2012), Borko (2004: 5), for example, reported that teachers in the United States attend intensive summer workshops in mathematics and science aimed at deepening teachers' knowledge of subject matter in both subjects, and that teachers who participate give positive testimonies about the impact of those workshops. Thus, depending on the intensity of the PD programme, teachers' knowledge and their instructional practices can improve (Borko, 2004: 5).

Borko (2004: 6) adds that, besides enriching the teacher's knowledge of the subject matter in mathematics and science, the workshops also provide opportunities for teachers to come to understand how children think; to become aware of their mathematical and scientific conceptions and typical misconceptions; and to employ such knowledge to promote quality teaching and learning. She also explains that there are significant differences between participating and non-participating teachers, because those who participate are enabled to understand children's problem-solving strategies and understand problems that pose difficulties to children. They also learn how to pose problems to children, and they understand why they must promote effective communication with learners in order to build on their understandings and counter misconceptions (Borko, 2004: 6).

With respect to professional development programmes or workshops for teachers in South Africa, a study by Steyn (2010) identifies two kinds of professional development programmes which teachers attend, namely official programmes offered by the Department of Education/district offices and private PD programmes (i.e. workshops). For reasons similar to those for doing the current study, Steyn (2010) was interested in the relevance of such workshops for the teachers' PD and teaching effectiveness. It is important to note that Steyn's research interest is still being recognised by subsequent researchers like Bantwini (2012: 30), who has suggested that teachers' perceptions of PD programmes or activities relating to their own PD and for addressing teaching and learning problems in South Africa need more attention.

Unlike the outcomes of workshops in America as reported above, Steyn (2010: 170-171) reported that teachers expressed dissatisfaction with the majority of PD programmes offered by their provincial Department of Education. They claimed that the workshops were not relevant for addressing the real challenges of teachers' instructional inadequacies. This seems to confirm Van der Berg *et al.*'s. (2011: 4) observations that the majority of workshops have not proven to be very effective in addressing the challenges of contemporary issues relating to teachers and teaching effectiveness in the classroom. Bantwini (2012: 519) has added that most of the professional development programmes for teachers have not addressed expectations and challenges in South Africa, especially in the teaching and learning of science.

Bantwini (2012) and Steyn (2010) have reported more of those disappointments registered by teachers involved in PD programmes or workshops to present a vivid picture of the South African situation. According to Bantwini (2012), teachers felt that PD activities could not help them to improve their CK and could also not provide them with the teaching materials they needed to be effective in the classroom. In most cases teachers complained they were not given ample time to "assimilate and accommodate" new learning experiences (p. 522). It is obvious that the teachers are more interested in PD programmes that can expose them to new and relevant learning experiences to enrich their CK and pedagogical knowledge and to get to know new policies that have implications for their PD as a whole (Bantwini, 2012: 522). Steyn's (2010:171) report shows that the teachers and principals involved in the workshops find that the "programmes are not up to standard"; are "very fundamental" with "little practical value"; and are "just different sound tracks with the same content". Some referred to the programmes as *"warra-warra"* (slang for "meaningless talk"); some even believed that the programmes were of poor quality because the officials "did not understand what is going on at 'ground level'".

According to Steyn (2010: 171), participants in such PD workshops furthermore noted that the "presenter and officials lack the necessary expertise and skills". Bantwini's (2012: 530) report confirms those findings, noting that the teachers perceive inadequacies in the PD programmes and the facilitators with regard to meeting or realising teachers' expectations around addressing the challenges they face in teaching. Steyn (2010: 171) comments that such inadequacies explain the limitations of such workshops when it comes to empowering teachers with the necessary expertise to articulate the link between theory and practice in teaching and learning. Steyn (2010: 171) categorically stated that participants preferred "knowledgeable" and "competent" presenters who are "top achievers", "experts", "subject specialists", "well cognisant with my world".

Inadequacy of some workshops has also been reported in America. Douglas (2005: 21), for example, laments that PD activities for teachers in America have failed to enrich teachers' teaching knowledge and assist in dealing with other challenges they find difficult to address. Douglas's (2005) findings seem to be confirmed by Helterbran's (2008: 125) report, which indicated that very few teachers in America believed the PD activities they attended were useful to their PD.

From the research reports mentioned above, one can perceive that teachers are willing to learn new, challenging and useful or applicable knowledge to enhance teaching effectiveness and the ultimate goal of effective student learning outcomes necessary to meet the evolving challenges of modern times. It also appears that the entirety of desired goals and achievements and the challenges of PD programmes for practising teachers reported above highlight the necessity of improving teachers' knowledge and teaching practices. In other words, the goals of the workshops for the teachers are set around improving the teachers' knowledge and teaching practice. Hence, successful workshops take pride in improving the teacher's knowledge for quality classroom instruction. Unsuccessful PD activities also seem to be emphatic that the teacher's knowledge for quality teaching should have been addressed by those PD programmes. Clearly, the notion of the PSTs' PD implied in this research is consistent with the aims and achievements of PD programmes for in-service teachers. Thus, changes in PSTs' beliefs about mathematics and the teaching and learning of mathematics; improvement in their understanding of CK and development of their PCK, are indeed the issues of concern in the continuous professional development of the classroom teacher.

3.5. TEACHERS' KNOWLEDGE AND TEACHING EFFECTIVENESS IN SOUTH AFRICA

The researcher deemed it worthwhile to explore the literature on the situation of teachers' knowledge and the quality of teaching which their knowledge affords them, because the current research interest fell in this domain. Through this exploration, the researcher intended to ascertain connections between concerns such as teachers' knowledge and the quality of teaching, and the framework of PSTs' PD defined in this research. The researcher hoped that this could enable him to articulate well-informed implications of findings from the literature here, to teacher preparation in the light of the final findings of this study.

Teaching effectiveness is believed to be dependent on teachers' in-depth understanding of central facts, procedures and concepts in mathematics; teachers' in-depth understanding of how mathematical concepts, facts, and procedures are connected; and teachers' in-depth understanding of how to establish new mathematical knowledge and justify its validity (Borko, 2004: 5; Borko *et al*., 1992: 195/218; Lampert & Ball, 1999: 33; Thomson & Palermo, 2014: 59;

Ambrose, 2004: 91; Sowder, 2007: 158; Ball, 1988: 38; Faulkner, 2009: 24, Shulman, 1986: 8; Kinchin & Cabot, 2010: 161). Borko (2004) refers to those knowledge dimensions as the "rich and flexible subject-matter knowledge" of a discipline that teachers need to assist learners to develop conceptual understanding, especially in mathematics.

The understanding of mathematics teaching effectiveness from the above perspectives has been raising concern in the public domain, as well as in teacher education on the issue of teachers' lack of in-depth knowledge in the disciplines they are teaching, such as mathematics (Van der Berg *et al*., 2011: 4), especially in South Africa. Continuously falling standards in students' achievements in mathematics have been blamed partly on teachers' deficient mathematics subject matter knowledge. In describing the situation, researchers concerned about the falling standards in the South African educational system compared with other countries in the sub-region, have described it as "a crisis, a national disaster, in tatters, inefficient and [making] ineffective use of resources, and essentially dysfunctional" (Letseka, 2014: 4864-4865).

Letseka (2014: 4865) identifies several issues that are convincing enough to be the reasons:

i. Most students are enrolling in dysfunctional public and rural schools.
ii. The quality of teaching in such schools is far below expectations.
iii. Instructional hours are woefully inadequate
iv. Inefficient and ineffective teaching methodologies in the schools
v. Teachers are ill-prepared to critique and adapt the curriculum they are implementing
vi. Teaching practices and performances are completely disconnected from the needs of the beneficiary communities- theory and teaching practices are disjointed.

It is obvious that the last three issues (**iv**, **v**, and **vi**) listed above echo the teachers' lack of subject matter knowledge in their disciplines. It should also be emphasised here that those three issues are among the major concerns which initial teacher preparation programmes or activities seek to address.

Mosoge and Taunyane (2012: 180) are convinced that, to overcome the concerns about teachers' knowledge and improve their teaching effectiveness, the solution to our educational crisis in South Africa lies in promoting the teacher's professionalism in the work of teaching. Mosoge and Taunyane (2012: 180) argue that we cannot rely totally on initial teacher education for the solution to this problem, because PSTs are not adequately prepared to become professionals in their fields of practice and therefore are not able to exhibit professionalism in their work (Kagan,

1992: 154), which could be the reason behind educational reform in most part of the world. These authors therefore do not seem to be convinced that the solution to teacher inadequacy could be sought at the level of initial teacher education.

Mosoge and Taunyane (2012) and Van der Berg *et al*. (2011), among others, therefore suggest that promoting teachers' professionalism requires the development of specialised teaching knowledge in their field of practice. This argument could be seen as provoking Shulman's ideas around the need for teachers to develop prototype expert teaching knowledge called PCK. Towards promoting teachers' professionalism, as suggested by Mosoge and Taunyane (2012), South African educational reforms encourage teachers to redefine, redevelop, reconstruct, or improve their professional identities and practices to address unfolding challenges and standards and expectations at school, national and international levels (Mosoge &Taunyane, 2012: 182).

In Van der Berg *et al.*'s. (2011) view, teachers need help in updating their knowledge through continuously created opportunities for them to see the need for in-depth development of their own content knowledge. They propose that teachers should be encouraged to write tests based in their content domain or the curriculum they are teaching at regular intervals and prizes should be awarded to those who perform well in tests so that they may be motivated to spend adequate time relearning the content knowledge in detail while preparing for the examinations. The proponents argue strongly that this is a better alternative to the 3 to 5-days workshops that mostly fail to address shortcomings in teaching and learning effectiveness (Van der Berg *et al*., 2011: 6). This may be of help in finding solutions to problems regarding teaching and learning. In support of Van der Berg *et al*., Monroe *et al*. (2011) are of the view that teachers can improve their own CK and PCK by revisiting and reinforcing fundamental mathematical knowledge in the curriculum they are teaching. This will give them an opportunity to enrich their CK and PCK with expertise in knowing the how and why of mathematical ideas, multiple ways to solve mathematical problems, and flexibility in making connections between mathematical concepts (Monroe *et al*., 2011: 2).

In opposition to Van der Berg *et al.*'s (2011) view of motivating teachers to relearn deeper mathematical knowledge by rewarding excellent performance in professional examinations, Monroe *et al*. (2011) advocate for non-monetary motivation to get teachers to perfect their

mathematical knowledge. Monroe *et al*. (2011) are of the view that teachers need self-motivating opportunities or enthusiasm to relearn in-depth mathematical knowledge by challenging themselves to understand the mathematics in the way they expect their students to understand it – applying reason to their own thinking, being open to criticism of their way of reasoning, engaging with multiple solutions to a problem, reconstructing their viewpoints about what mathematics is and what is worthwhile knowing about mathematics (Monroe *et al.*, 2011: 2; Borko *et al.*, 1992: 218; Lampert & Ball 1999: 33; Thomson & Palermo, 2014: 59; Ambrose, 2004: 91).

Letseka (2014: 4867), on the other hand, is concerned with changing teachers' beliefs to improve teaching effectiveness in South African school. Letseka (2014) believes that out-dated rules and assumptions held by teachers and other stakeholders are some of potential causes of the falling standards in the South African educational landscape. Letseka (2014: 4867) therefore suggests that teachers need to break away or dissociate themselves from old and ineffective rules, assumptions, thinking and dysfunctional ideas, in their practice and performance towards achieving more modern and quality expectations in education.

It is worth noting that all the suggestions for teachers to improve the quality of their knowledge as well as their teaching practice are explicit about the need for specialised teaching knowledge and changing beliefs and assumptions about teacher and teaching effectiveness. Clearly, all those issues could be seen to be embedded in the notion of PSTs' PD implied in this study.

3.6. PROFESSIONAL DEVELOPMENT (PD) IN THE LANDSCAPE OF INITIAL TEACHER PREPARATION

3.6.1. What PD means in teacher preparation

At the sight of the above caption, the reader might most likely draw his/her own conclusions. Most probably, by drawing on the foregoing discussion, one may think that professional development starts when the practicing teacher begins to attend workshops and engages in other activities for professional development. One of the concerns here is to ask whether or not the term PD is implied in the preparation of future mathematics teachers. Another question concerns when the PST should be aware of his/her own PD, and whether the PST should be aware that

he/she starts to develop it right from and throughout his/her learning trajectory in the initial teacher education model of his/her choice. With these interests, the researcher aimed to explore literature, as much as possible, to briefly address those concerns.

Surprisingly, most people associate the term professional development only with the activities practising teachers do or presentations they listen to or watch. It is hardly associated with learning outcomes from those activities and presentations. It seems that the PD only involves echoing programmes of study for teachers and not learning outcomes, as the latter was implied in the current research project. Secondly, the dominant understanding of PD seems to project aspects of teachers' professional identities and practice over teachers' professional knowledge and the skills relating to the subject matter of the discipline and the curriculum, as the latter is implied in the current research project.

It is important to point out that PD, as it is properly understood, is associated with practising teachers availing themselves of opportunities to advance their knowledge and develop new instructional practices (Borko, 2004: 3). Clearly, therefore, it is not about the name or term but about learning opportunities, processes and their outcomes, in terms of knowledge and skills and attitudes reshaped. It should again be noted that emerging concerns and foci of PD programmes have been to bring about teacher change in terms of increasing, enriching, or improving teachers' subject matter knowledge for teaching; improving teachers' understanding of students' thinking; and improving teachers' instructional practices (Borko, 2004: 5). There is no doubt that the motives and expectations of preparing the future mathematics teacher are explicitly stated in Borko's (2004) argument above. Hence, PD would not be a misplaced concept/issue in the initial preparation of teachers.

3.6.2. The components of the core of PD

This section seeks to bring to light the silent aspects of teachers' PD and, more importantly, to further argue that it is worthwhile for concerned stakeholders (lecturers, PSTs, policy makers) in initial teacher education programmes to intensify the recognition and association of PD with the preparation of the PSTs. Boston and Smith (2011) have observed that "… studies have linked professional development to changes in teachers' knowledge, beliefs, or habits of practice,…" (p. 967). These are evidenced in Yang and Leung's (2011: 1007) observations that there has been

renewed interest, in the field of mathematics education, in three very important qualities of the mathematics teacher, namely teachers' mathematics subject matter knowledge; pedagogical content knowledge; and beliefs about effective mathematics teaching. Wilcox (1992: 25) argues that the professional preparation of the PSTs necessarily needs to focus on assisting them to develop the required intellectual tools, namely, CK and PCK (Buchholtz *et al*., 2013: 108; Shulman, 1986: 7)) and dispositions to engage in mathematical problem solving themselves. These may be seen as consistent with the routine practices during the preparatory phases of the teacher's initial training, whereby teacher educators work hard to challenge, change, or improve the PSTs' beliefs about the mathematics they will be teaching; their misconceptions about teaching and learning of mathematics; and their superficial mathematical understanding, to equip them with the desired mathematics teaching expertise (Schwarz *et al*., 2008: 791; Borko *et al*., 1992: 219/220; Li & Even, 2011: 760).

In addition, Brown and Coles (2010: 377) and Brown and Coles (2011) have documented that a great deal of literature on the mathematics teacher's PD identify three categories of their PD, namely, content, method, and effectiveness. According to Brown and Coles (2010), the content in particular encompasses the teacher's subject matter knowledge in mathematics (i.e. CK, PCK, and MKT) and the teacher's beliefs about mathematics and the teaching and learning of it and how these beliefs can be changed during their preparation or instructional practice or any other learning opportunities (Brown & Coles, 2010: 377). There is no doubt that both pre-service and in-service teachers share the same interest in developing the contents described above. It would therefore be more appropriate and timely when PSTs are aware that they are developing those components of their PD throughout their training period.

Similarly, Schwarz *et al*. (2008: 795) have categorically stated that mathematical content knowledge (i.e. understanding of the school mathematics) (Buchholtz *et al*., 2013: 108); pedagogical content knowledge (i.e. understanding of the mathematics curriculum and analysis of learners' mathematical abilities); and beliefs (i.e. about mathematics, and the teaching and learning of it), are the main dimensions of prospective mathematics teachers' professional knowledge (Borko *et al*., 1992: 194). Buchholtz *et al.* (2013: 108) explain that "It has now been widely acknowledged that both content knowledge and PCK are indispensable components of a teacher's professional knowledge". Borko *et al*. (1992) are also convinced that beliefs about

mathematics subject matter are an important dimension of teachers' subject matter knowledge (p. 195). Kaiser *et al*. (2010: 433) also report that prospective teachers' beliefs about mathematics, mathematical knowledge and pedagogical knowledge of mathematics are among the important issues of concern in the evaluation and comparison of the effectiveness of initial teacher education programmes.

More declarative statements have been made to show that the core issues of the teachers' PD are CK, PCK, and changing beliefs. Monroe *et al*. declare that the professional development of a teacher is evidenced in three dimensions: changes in beliefs, knowledge, and practice (Monroe *et al.*, 2011: 2). Bantwini (2012: 518) also adds to the argument above that the success of a reform depends largely on teachers' functional CK and PCK, which Monroe *et al*. (2011) identify as the indispensable components of the teacher's PD. Further, Bantwini (2012: 517) explicitly explains that the desired dimensions of teachers' PD enshrined in programmes around the world include enhancing teachers' PCK, CK and how to use curriculum materials in their disciplines for quality instructions.

3.6.3. Bases for determining the successes, growth, or changes in PSTs' PD

The reason for surveying the literature under this theme was to align the future findings of the current research with other empirical findings or models of PSTs' PD or growth. Doing this could give the researcher other perspectives from which the PSTs' PD could be interpreted, hence, gaining more insight into the PSTs' perceptions about the effects of the teaching expertise on their PD.

Da Ponte and Chapman (2008: 223) claim that, in the complex processes of preparing future mathematics teachers, the central issues addressed by mathematics teacher educators include bridging or integrating theoretical knowledge with practical knowledge and transforming PSTs' identities from mathematics learners to mathematics teachers. In support of the claim above, and Brown, McNamara, Hanley and Jones's (1999: 301) earlier research, Akyeampong *et al*. (2013: 280) share the views that the success of PSTs' PD in their effectiveness in teaching primary school mathematics, for instance, rests in their complete transition from school mathematics learners to school mathematics teachers. Yang and Leung (2011: 1011) seem to have simplified these claims in their view that effective transition towards turning out effective teachers for our

communities and schools should focus on developing PSTs' knowledge and dispositions for teaching effectiveness.

Brown *et al.* (1999: 302) also suggest that an effective way to ensure this transition during initial teacher education is to expose PSTs to learning processes and opportunities which will challenge them to "unlearn and discard the mathematical baggage both in terms of subject misconceptions and attitudes problems" (Akyeampong *et al.*, 2013: 280). Brown and colleagues are firmly persuaded that teacher educators should consider it vital to assist PSTs to develop expert teaching knowledge (PCK). In their view it is a necessary component of the PSTs' successful transition to becoming effective teachers, which they refer to as "… transition from doer to teacher." (p. 302). All the researchers mentioned above have suggested possible parameters for determining growth in PSTs' PD.

Kagan's (1992: 155/156) research provides a framework for determining PSTs' as well as beginning teachers' professional growth. The author determined this model from his study of 40 research reports on beginning teachers' and prospective teachers' professional development. The researcher presents a comprehensive summary of Kagan's (1992) model of PSTs' PD in Table **3.1**, by creating four column headings in line with the needs of the current review's theme. The first column, "Significant progressive stages", comprises the five stages of PSTs' PD in Kagan's model. The label of a stage is an embodiment of related constructs which contribute to that aspect of PD. The second column, "Challenges at this stage", describes the obstacles to overcome and/or new but challenging ways of learning towards accomplishing a particular stage. The third column, "Learning outcomes at this stage" describes factors which enhance the accomplishment for the stage. Finally, the fourth column, "Category of PD or growth", identifies the change in either behavioural or conceptual attributes of professional growth (Kagan, 1992: 156).

Table 3.1: The developmental stages of PSTs' professional growth

The developmental stages of PSTs' PD (Kagan, 1992)			
Significant progressive stages	**Challenges at this stage**	**Learning outcomes at this stage**	**Category of PD growth**
Enhancement of metacognition	Confronting their preconceived knowledge and beliefs about learners, themselves as teachers and instructional context	Conscious of those illegitimate beliefs and knowledge and the changes taken place in those beliefs and knowledge.	Changes/transformation in beliefs about the subject matter and the teaching and learning of it.
Acquiring knowledge about learners' characteristics OR Challenging their personal beliefs about teachers' roles and who learners are	Reflecting on and correcting their misconceptions about teachers and teaching and learners and learning. Exposure to beliefs of expert educators or mentors in conflict with their illegitimate beliefs	Acquired knowledge guides them to modify, adapt, and reconstruct their misconceptions about their roles as teachers and the uniqueness of learners	Erroneous beliefs begin to change to boost their professional development
Focus on or conscious of own instructional behaviour	Adaptation and reconstruction of personal beliefs about teacher and teaching. Focusing on the learning and the learners in instructions	Develop the desired beliefs about teacher and teaching effectiveness.	Instructional designs are enhanced and instructional decisions are based on the learners' academic needs.
Development of standard procedure in teaching and learning	Learning or re-learning prototype teaching and learning strategies or procedures. How to integrate instructions with classroom management	Acquisition of standardised teaching procedures, e.g. classroom control and discipline.	Improvement in teaching skills.
Evolution of problem-solving skills	Need to improve all inadequacies in knowledge, beliefs, conceptions, instructional behaviour, and fundamental skills	Develops the skill for recognising problem contexts; realistic and contextual thoughts; problem-solving skill	CK and PCK are enhanced

Source: Kagan (1992)

It can be noted from all the researchers above that the indicators of PSTs' successful PD are emphasising the need for PSTs to develop or acquire at least the three constructs of PD as it is implied in this study, which are explained explicitly below.

3.6.3.1. Desired CK and PCK for the success of PSTs' PD

As in the case of in-service teachers, the in-depth subject matter knowledge of PSTs' is attracting the attention of all stakeholders on the education scene (Goulding, Rowland, & Barber, 2002: 689) because the level of a teacher's CK significantly affects what he/she is capable of teaching and how he/she will teach it (Da Ponte & Chapman, 2008: 225). In terms of the desired knowledge, Da Ponte and Chapman (2008: 241) argue that the success of PSTs' professional practice primarily depends on their knowledge of mathematics and knowledge of how to teach mathematics. This could imply the necessity of developing PSTs' CK and PCK in mathematics towards enhancing their PD. Wilcox (1992: 7) and Allen (2003: 4) share the view that PSTs in Foundation Phase mathematics, for instance, should develop a more conceptual level of knowledge about mathematics and the teaching and learning of it towards successful PD.

3.6.3.2. Desired beliefs for the success of PSTs' PD

Notwithstanding that fact that subject matter content has been rated highly as important in promoting teaching effectiveness, there is strong relationship between teachers' beliefs and the structure of their subject matter content and teaching knowledge (Ambrose, 2004: 92; Frykholm, 1999: 81; Ball, 1988: 6/11; Macnab & Payne, 2003: 55). The implication could be that, if teachers' beliefs are productive and generative, they are encouraged to develop or enrich their subject matter knowledge for teaching. Thus, the orientation of the teacher's belief could result in the development of effective teaching knowledge. The implications deduced above have been supported by Ambrose (2004: 92) saying that it is possible that PSTs can maximise their potential for advancing their subject matter content if their beliefs are changed or transformed to assume characteristics that are productive. Ambrose (2004: 97) calls this "generative beliefs for learning mathematics".

One of the components of this belief system concerns PSTs developing the belief that mathematics is a web of interrelated concepts and procedures (Borko *et al*., 1992: 195; Wedege,

1999: 206-207). Ambrose (2004) advocates that PSTs should come to realise that mathematical concepts and procedures are not discrete or compartmentalised (Ball, 1988: 16; Borko *et al*., 1992; Wedege, 1999: 206-207), but are related. However, conceptual understanding forms the foundational knowledge, and can help articulate procedural understanding. The other complementary component of the proposed belief system concerns belief about teaching and learning of mathematics, and Ambrose (2004) suggests that PSTs should develop the belief that "…children bring to school a great deal of informal mathematical knowledge that can be the basis of instruction". They also recognise "… that often the ways children think about mathematics differ from the ways of adults who have been schooled" (p. 98). In Ambrose's (2004: 95) view, this system of belief can empower the PST to make "more principled decisions on the basis of beliefs they believe are important, instead of acting on the basis of the habits of unexamined beliefs and undifferentiated attitudes" (Ambrose, 2004: 95).

Unlike the generative belief system, undifferentiated belief systems have been found to be counterproductive (Ambrose, 2004: 91; Adler *et al.*, 2009: 4; Ambrose, 2004: 91; Levin, 2014: 53). The reason is that PSTs may not recognise and appreciate the significance of preparing and organising stimulating learning experiences; promoting effective communication with learners; and encouraging self-directed learning and discovery learning through learner activeness in knowledge constructions (Kaiser & Vollstedt, 2007: 3-4). Undifferentiated beliefs and attitudes include beliefs that "... teachers should be nice and should present instruction clearly"; teachers should be "more concerned about affective and interpersonal issues"; in the work of teaching teachers should be "exploring experiences that will give them opportunities to connect intimately with children"; "teaching entails presenting information that student will memorise"; teaching involves "mechanical transfer of information"; in the work of teaching offering explanations is just straightforward (Kaiser & Vollstedt, 2007: 4); teaching is just about telling children what to do; and mathematics learning is to acquire the "standard symbolic procedures" (Ambrose, 2004:116; Kaiser & Vollstedt, 2007: 3). In particular, undifferentiated belief systems tend to orient PSTs' beliefs about mathematics itself as a body of knowledge that exists in the form of facts, rules, formulas and procedures to be applied to a problem. This gives rise to their beliefs that instruction in mathematics is just a mastery of didactics, which both teacher and learner need

to follow. Mathematics teachers are transmitting knowledge, assessing students, and providing feedback (Ball, 1990: 12; Wilcox, 1992: 6-7; Ingram, 2014: 52; Kinchin & Cabot, 2010: 161).

Improving the counter productiveness of the belief systems described above, especially in the modern mathematics classroom, has been the concern of many researchers and teacher educators. Ma and Singer-Gabella (2011: 8), for example, are of the view that the desired dispositions for PSTs' future teaching effectiveness should emphasise an instructional environment in which teachers design engaging learning experiences that stimulate learners' reasoning about quantities, empowering learners to create their own strategies, and engaging in discourse about learners' thinking and/or solutions to problems. The authors believe that this belief system would be suitable or can promote a modern reform mathematics classroom instructional framework which is explicit about what teachers should be doing; what learners should be doing; and the role of problems for learning effectiveness, as described below:

- teachers work towards preparing responsible future learners: creating opportunities for using learners' reasoning to promote teaching and learning effectiveness
- learners are "making mathematical sense of problems and communicating their reasoning, not just for producing a correct answer"
- problems are meant for promoting meaningful learning of the mathematics activity in focus, not just for practicing skills and replicating procedures (Ma, & Singer-Gabella, 2011: 8).

3.6.3.3. Harmonising all desired qualities in PD

Just like the need for air, water, and food to be working together to keep us alive, the discussions above seem to be emphatic about the necessity of building the successes of the PSTs' PD in the three fundamental issues, namely developing the desired and productive belief systems; improving in-depth CK; and developing PCK. Thus, the successful changes in PSTs' PD necessarily require that all the three are equally developed or improved or balanced towards the development of effective teachers or teaching qualities. In addressing this, Da Ponte and Chapman (2008) are emphatic that the professional identities of PSTs in mathematics education is well developed when the two knowledge components (i.e. CK and PCK) are well developed and integrated or connected (Li & Even, 2011: 760), in addition to developing the beliefs of what

makes teachers effective in the teaching of mathematics, as explained by Ma and Singer-Gabella (2011).

It appears that effective professional qualities for determining the changes in PSTs' PD, cherish the harmony and integration of their knowledge and belief systems. This is also supported by Brown *et al.'s* (1999) passionate appeal for teacher educators not to fail to realise the strong relationships between these fundamental issues. The reason is that PSTs' experiences as learners of mathematics develop the conceptual framework they hold about the nature of mathematics, and it is manifested in their future teaching practices (p. 301-302). Frykholm (1999: 83) is also of the view that teacher educators can avoid disproportionate changes in PSTs' PD, by paying equal attention to addressing the inadequacies in PST attitudes and beliefs about the mathematics they are going to teach and the teaching and learning of it, as they do to enhance PSTs' subject-matter knowledge. For such reasons, Wilcox (1992: 25) and Da Ponte and Chapman (2008: 225) seem to unanimously agree that, for quality mathematical instruction, PSTs need to develop the conceptual understanding of mathematics, and the knowledge and dispositions with which they can support children to meaningfully engage in mathematical investigations.

The integrated perspective described above could be seen as the emerging model of PSTs' PD gathered from all the discussions presented above, regarding indicators of growth in PD. This model confirms the PSTs' PD defined by the researcher in the previous sections of this chapter. The interesting and significant advancement of our understanding of the evolving definition is that the model, at this stage, has been derived from indicators or views about what and how the growth in PSTs' PD is understood in the literature.

3.7. EFFECTS OF TEACHING EXPERTISE ON LEARNING

This section is at the heart of the entire review, as well as the heart of the study. The aim here was to explore literature for evidence of the kind of learning outcomes exhibited by learners who learn from the expertise of their educators – in other words, to find evidence from the literature about the behavioural and/or conceptual changes which are promoted when PSTs' are exposed to the ETE's *articulations of subject knowledge expertise in teaching*; *clarity in lesson presentations/teaching*; *preparation for and organisations in teaching*; *enthusiasm in teaching*;

positive relationships with students and approachability; *motivating/stimulating students' interest and engagement with learning experiences*; and *understanding of students' learning needs and creating productive learning climate.*

Lunenberg *et al*. (2007: 589) believe that teacher educators constantly influence the learning of their students, even when they are displaying inadequate behaviour. Based on Lunenberg *et al.'s* claim, it can be expected that each of the attributes of teaching expertise identified above could have some impact on PSTs' PD. In what follows, the researcher explores the literature to discover the effects of the attributes of teaching expertise.

3.7.1. Clarity in lesson presentations/teaching and subject knowledge expertise

BrckaLorenz *et al*. (2011) investigated the influences of "teaching clarity and student engagement". They conclude that the majority of the students were of the view that the teaching clarity of the university educators they were exposed to helped them to gain profound understanding, both of course materials and of abstract concepts (BrckaLorenz *et al.*, 2011: 9). BrckaLorenz *et al*. (2011) also claim that early research work with the same interest provided proofs of the significance of clarity in teaching, such as increasing students' motivations to learn and challenging their understanding; promoting the kinds of deep learning and educational gains desired for all students; and enhancing students' abstract reasoning (BrckaLorenz *et al.*, 2011: 7-8).

Chesebro and McCroskey's (2001: 66) findings also show that ETE's clarity in teaching improved students' adaptability to new learning experiences; their anxieties and perceptions of incompetence in learning subject matter knowledge were alleviated by teaching clarity; students' motivation or enthusiasm towards their learning expectations were also enhanced by the clarity of teaching they were exposed to. Hativa (1998: 375) also found that teaching clarity promotes and maximises students' satisfaction and achievements in learning. To the contrary, lack of clarity in teaching results in PSTs struggling to understand the material they are learning form

the teacher educator and dissatisfaction with their achievements (Hativa, 1998: 375; BrckaLorenz *et al*., 2011:3).

Tyagi and Vashisth, (2012: 31) have documented the influences of the ETE's subject knowledge expertise which they present as "knowledgeability of the teacher". They explain "knowledgeability of the teacher" to mean an amalgam of cognitive and affective knowledge domains which include specific content and general knowledge; knowledge of students' diversity; knowledge of students' achievements and educational expectations; knowledge of effective teaching strategies or methods and communication; and knowledge of engaging and stimulating students' learning activities (Hativa, 1998; Berliner, 1988; Kreber, 2002).

According to Tyagi and Vashisth (2012: 31), this expertise of the ETE increases the students' proficiency in knowledge transfer to solve real-world problems; empower students to make meaningful connections between new concepts and already existing concepts; and unlearn erroneous knowledge and biases – to relearn deeper knowledge, empirically proven beliefs about their disciplines, especially beliefs about teaching and learning.

3.7.2. Enthusiasm, interpersonal relationship, and organisation and preparation in teaching

Tyagi and Vashisth, (2012: 31-32), highlight the impacts of ETEs' organisation and management of the instructional tasks in teaching and learning. According to them, this expertise enables ETEs to create a positive learning environment. They provide students with course materials, clearly defining course objectives and evaluation procedures that support students' effective learning to develop the desired knowledge, skills, and attitudes towards becoming experts in their disciplines. Chesebro and McCroskey (2001: 61) also found that educators' preparation, organisation, and assessment designs are among the practices which significantly improved student engagement and helped trainees to better understand the learning outcomes expected from them (BrckaLorenz *et al*., 2011: 10; Hativa, 1998: 354).

Similarly, enthusiasm in teaching has been found to empower the ETE to articulate his/her competence and confidence in teaching (Tyagi & Vashisth, 2012: 32). Tyagi and Vashisth explain further that this expertise enhances good relationships between the ETE and his students and motivates high achievement in students' learning outcomes.

Devlin and O'Shea (2012: 386), in their research about factors which helped some group of university students to improve their retention and progress through their course, document that those students appreciated their educator's interpersonal relations with them during their training. The students were motivated and inspired to learn from challenging experiences. According to them, the students were of the view that their educators' skill in unpacking and explaining academic requirements and expectations influenced their preparation extensively. Such teacher educators expertise could be consistent with the ETE's *articulation of subject knowledge expertise in teaching*; *clarity in lesson presentations/teaching*; *preparation for and organisation in teaching*; *positive relationships with students and approachability.*

Devlin and O'Shea (2012: 394) similarly identified the effect exerted on learning by the educators' communication skills, enthusiasm and dedication in teaching. The students' claimed that their educators "pay attention to their learning needs and speak to these needs in language students can understand, while maintaining academic challenge, are the most helpful to them and their learning". Devlin and O'Shea (2012: 386) conclude that such expertise also motivated and inspired the students to learn.

It can be seen that the expertise highlighted above confirms the attributes of teaching expertise guiding this study: *understanding of students' learning needs and creating a productive learning climate* reflects the experts' paying "attention to their learning needs" (Devlin & O'Shea, 2012: 394); Devlin and O'Shea's finding that the university educators "speak to these needs in language students can understand" could be seen as the combination of *enthusiasm in teaching, positive relationships with students and approachability*, *humour in teaching*; and ETEs' *articulation of subject knowledge expertise in teaching*; *clarity in lesson presentation/teaching*; *preparation for and organisation in teaching*; *motivating/stimulating students' interest and engagement with learning experiences* could match the educators' characteristics of "maintaining academic challenge" (Devlin & O'Shea, 2012).

Howitt (2007: 41) investigated the influence of "practicum, teacher educator, pedagogical content knowledge, learning environment, assessment and reflection" on PSTs' confidence in science and the teaching of science. The author identified these as the factors that influence PSTs' confidence about science and teaching of science. In the opinions of the PSTs, the most

valuable attributes of the teacher educator that significantly improved their learning experiences were the "enthusiasm, use of humour, passion for science, and an approachable and friendly nature" (Howitt, 2007: 49-50). Howitt's (2007) findings from comments from PSTs about the expertise of a teacher educator, that: "... She is a great teacher and her bubbly personality and passion for science really helped me to view science as a fun learning process rather than a boring subject. Her enthusiasm, energy and commitment to teaching science is so motivating" (Howitt, 2007: 50) also stress this.

Howitt (2007: 50) found that the educator's enthusiasm contributes greatly in changing the PSTs' feelings or beliefs about science. The author explains that teacher educators' enthusiasm and openly demonstrating a passion for science helps in developing PSTs' positive attitudes towards science. The author supports this claim with a comment from one of the PSTs: "She demonstrated what a student centred classroom should be, with hands on activities each week. I liked the way different strategies for teaching science were demonstrated throughout this course" (p. 50).

The evidence discussed above shows that meaningful ways in which PSTs experience the teaching expertise of the ETE can enhance their confidence in teaching. The evidence and views quoted above most likely confirm that PSTs develop their PD through exposure to the attributes of expert teaching of the ETE.

3.7.3. Humour in teaching

Friedman *et al.* (2002) conducted a study to find out about the "mechanisms by which humour serves to transform the statistics classroom into a more effective learning environment". Friedman *et al*. (2002) firmly acknowledge that humour is the key attribute in the teaching effectiveness of a successful teacher most appreciated by students (Powell & Andresen, 1985: 79; Torok *et al*., 2004: 14; Garner, 2006: 177). Modern pedagogical standards have recognised the importance of incorporating humour in colleges and universities, more so in mathematics and statistics (Torok *et al*., 2004: 14; Garner, 2006: 177). When the teacher educator incorporates humour in teaching or lecturing, learners find him or her more approachable, accommodating and friendly (Friedman *et al*., 2002). In addition, psychological benefits of humour have been

found to include reducing anxiety, decreasing stress, enhancing self-esteem, and increasing self-motivation (Garner, 2006: 177).

Friedman *et al*. (2002) identify four remarkable influences of humour in teaching in higher institutions on students' learning, namely promotion of effective communication between the university lecture and students; stimulating recall or retention of knowledge or ideas learnt (Powell & Andresen, 1985: 80); minimising or eliminating students' anxieties about the discipline; and enhancing students' interest in the course or module they are learning (Powell & Andresen, 1985: 83-84). According to Friedman *et al*. (2002), researchers have shown that using humour in the statistics class can "enhance communication; help to establish a warm, human relationship between the instructor and the class; make a potentially boring subject more interesting; reduce student stress and enhance recall" (Powell & Andresen, 1985: 80; Garner, 2006: 177). Their passionate approval of humour in teaching statistics motivated their convictions that teacher educators could start their courses with relevant humour to give the impression to students that the educator for that course is approachable and caring to eliminate all barriers and anxieties between them and the teaching professor, especially in mathematics and statistics (Powell & Andresen, 1985: 86; Flowers, 2001: 10; Torok *et al*., 2004: 14; Garner, 2006: 177).

Friedman *et al*. (2002) explain further that humour can develop learners' interest in the subject or course of study; it can relax and reduce tension, and "thereby create an atmosphere conducive to learning and communication". Learners tend to feel strongly connected with the lecturer and that ensures teaching and learning effectiveness (Garner, 2006: 178). The above claims that humour makes the lesson more interesting are supported by evidence that it enlivens the class and learners would not compromise on their attendance to the class (Garner, 2006: 178; Friedman *et al.*, 2002; Powell & Andresen, 1985: 84). Mathematics and statistics lectures are devoid of boredom when educators occasionally surface one or two humours. Because humour makes the lesson interesting and lively, it certainly enhances permanent retention of "novel information" in the long run (Friedman *et al.*, 2002; Powell & Andresen, 1985; Torok *et al.*, 2004; Garner, 2006). This is supported by researchers' claims that "humour serves to illustrate, reinforce and make more comprehensible the material being taught" (Powell & Andresen, 1985: 84).

Furthermore, some studies have shown that humour enhances learners' critical thinking or creative thinking and motivation to learn, facilitates understanding of subject matter content, encourages active participation in discussions, "increase learning speed, improve problem solving, increase perceptions of teacher credibility" (Torok *et al.*, 2004; Powell & Andresen, 1985; Flowers, 2001). Incorporating humour in teaching has been found to increase the learners' "mental sharpness" which, as Garner (2006: 177) remarks, adds to the desirable things in ensuring pedagogical effectiveness. It has been proven, for example, that the test achievements of university students who were taught through "content-relevant humour" were seen to be higher than those who were not exposed to this teaching expertise (Torok *et al*., 2004: 15; Garner, 2006: 177). Garner's (2006) own study, which sought to explore the impact of humour on the learning experiences of 4th-year undergraduate students in research methods and statistics, reveals that humour-oriented lectures can positively impact on students' learning enjoyment; on their ability to retain learnt ideas; increase students' ability to assimilate information or ideas properly; create a positive learning atmosphere, ability to gain incredibly great cognitive understanding of the material they are learning.

3.7.4. Some ways of sharing teaching expertise and their influence on learning

The eight attributes of teaching expertise in the new model cannot be assumed to have exhausted all teaching expertise. The researcher believes that each of the constructs of teaching expertise in the new model could be similar to other attributes of teaching expertise which have not been listed among the eight. Against this background, this section will present other attributes closely related to teaching the eight attributes of teaching of expertise.

According to Koster *et al*. (1998: 77) "creating conditions, giving instruction, modelling, providing feedback," are among the strategies used by teacher educators to share their expert knowledge with PSTs. Some of the strategies are found in Huinker and Madison's (1997: 112) observations that some teaching professors use "verbal persuasions, observations, modelling, discussions and reflections" as very effective teaching and learning strategies during interactions with their students. Shim and Roth (2008: 14) likewise note that ETEs share their expert knowledge with their students by integrating modelling and observation, reflecting on actions, metaphors, storytelling, and helping learners to reconstruct beliefs in the work of teaching. It is clear that most of the strategies listed above could be closely related or common to all three

research reports. This perhaps shows that most teaching expertise is universal and also emphasises the recognition of their effectiveness in promoting quality teaching and learning. The central goal of the current review was to discover the learning outcomes resulting from such ways of sharing expert knowledge. In addition, this review seeks to show that there are strong connections between the eight attributes of teaching expertise and the other ways through which ETEs share their expert knowledge with their students.

It could be argued, for example, that the teacher educator's modelling strategies are articulations of the educator's command of the subject knowledge of the discipline, clarity of presentations, and enthusiasm in teaching, among others (Lunenberg *et al*., 2007: 590). The researcher's argument has found confirmation in Huinker and Madison's (1997: 112) observations that the expertise of the teaching professors is evidenced in their incorporation of modelling teaching strategies during instruction. This could mean that the ETE's command of subject knowledge, clarity of presentations, and enthusiasm of teaching are well articulated through their modelling. Further justification of the researcher's argument above can be deduced from Howitt's (2007: 50) view that modelling has been considered an essential component of teaching expertise. This assertion could also mean that modelling could be a necessary aspect of the ETE's command of subject knowledge, clarity of presentation, and enthusiasm in teaching. The reason would be obvious; for example, if the educator is lacking subject knowledge expertise or teaching enthusiasm, she/he could find it difficult to incorporate modelling cognitive teaching tasks to connect with the mentee or the learner. In other words, those attributes of teaching expertise could motivate the educator's modelling of teacher and teaching effectiveness towards enhancing the PSTs' PD., Following this chain of thought, the influences of the educator's modelling strategies on the learning outcomes of the PSTs therefore could also be attributed to educator's *articulation of subject knowledge expertise in teaching*; *clarity in lesson presentation/teaching*; and *enthusiasm in teaching*. They enhance the effectiveness of the modelling strategies or any other strategy through which ETEs share their expertise with their students.

3.7.4.1. Educator's modelling strategies and students' learning

According to Howitt (2007: 50), modelling has been considered an important construct of expert teaching because it gives "students an opportunity to see and experience the strategies, to learn them and to use them". In eliciting PSTs' views about factors influencing their confidence regarding science and the teaching of science, Howitt (2007) recorded one of those impressions from the prospective teachers regarding their educator's teaching expertise who said: "She is a great teacher and her bubbly personality and passion for science really helped me to view science as a fun learning process rather than a boring subject. Her enthusiasm, energy and commitment to teaching science is so motivating" (Howitt, 2007: 50).

In interpreting the perceptions of the PSTs regarding this expertise of the educator, Howitt (2007: 50) asserts that the PSTs' comments indicate that the teacher educator was incorporating "modelling" in her teaching to enhance the PSTs' learning. With regard to the student's comment (above), some of the eight attributes pertaining to teaching expertise are mentioned – the educator's personality confirms p*ositive relationships with students and approachability*, and *humour in teaching* (Shim & Roth, 2008: 6); the educator's passion for science, enthusiasm, energy and commitment to teaching highlight *enthusiasm in teaching* (Shim & Roth, 2008: 6). The student teachers' view seems to show that their educator's enthusiasm, energy and commitment to teaching science, and personality and passion for science, have had both behavioural and conceptual impacts on their learning. It could be said that most of the student teachers are beginning to change their beliefs about and attitudes to the subject matter of science and the learning of it. It could also be deduced from the student teacher's comment that, if she/he is viewing science learning as fun, then most of the student teachers could be motivated to learn science in depth to enhance their CK and PCK. The above inferences are confirmed in Howitt's findings by comments from one of the PSTs: "My confidence has increased as I have a greater knowledge of what and how science can successfully be taught in early childhood. I will learn alongside with the children and I will make it fun and challenging" (p. 50).

The student teacher's perception shows that the teacher educator's modelling, personality, passion for science, enthusiasm, energy and commitment to teaching have increased their confidence, improved their CK, and developed their PCK. Specifically, the behavioural changes in the student teacher could include understanding learners' needs; being critical about learners'

characteristics; considering the interest of the learners; and developing positive instructional attitudes. The conceptual changes which could be deduced from the student teacher's comment above could include perceived ability to teach for conceptual understanding; effective communication with learners; focusing on the learner and the content.

In supporting the totality of findings, Howitt (2007: 50) claims that other studies have revealed that modelling strategies used by ETEs in methodology courses have contributed greatly to the development of PSTs' confidence. Howitt's findings have been confirmed in more recent research by Haydn (2014: 3) who claims that ETEs in information and communications technology (ICT) have been successful in making their teaching expertise accessible to PSTs in their professional development by regularly modelling how to apply ICT "in a persuasive and powerful manner". Haydn explains that the ETEs did so in a relaxed and confident way which became evident in the PSTs' account of the most influential factors that made them feel well prepared and confident about applying ICT in their teaching subjects. Both Howitt (2007) and Haydn (2014) have shown that modelling teaching expertise can increase students' confidence in the subject matter they are learning.

Murray's (2006: 386) study investigated the influences of teacher educators modelling "good pedagogical practices" and ideal teacher identity in preparing primary school mathematics teachers. Murray has observed that the teacher educators' teaching practices showed their values for "hands-on art activities" for developing the PSTs' personal creativity in teaching and learner-centeredness (p. 387). Murray (2006: 386) explains that the desired learning outcomes teacher educators hope to achieve from their teaching expertise are basically to empower PSTs to develop adequate subject matter knowledge (what to teach) and effective teaching methodology (how to teach the CK). These findings about the influences of teacher educators' modelling are consistent with Howitt's (2007) and Haydn's (2014) findings reported above. Murray (2006: 386) observes that the teacher educators are convinced that their teaching expertise has been highly influential in producing the desired learning outcomes. Being so passionate about their influence on their students, the teacher educators were hopeful that their teaching expertise would produce students in their own images, as they were using modelling to illustrate the image of a 'good' primary practitioner (Murray, 2006: 391).

3.7.4.2. Impact of reflections on learning

Koster *et al.* (1998: 77-78) explain reflection on action as learning from an experience of having been exposed to the learning problem. In this leaning process, the educator engages prospective teachers in evaluation of their own teaching behaviour, for example, towards becoming effective teachers. The authors believe that reflection on action is one of the most effective strategies incorporated by teacher educators in their teaching work for supervising the development of the PSTs towards becoming reflective practitioners in teaching. In the view of Chong, Low and Goh (2011: 59), reorienting PSTs' perceptions or beliefs about teaching would require deliberately involving PSTs in professional learning and reflection. They believe, for example, that engaging PSTs in discourse (Pernilla, 2008: 1297) that provokes deeper reflection can initiate the process of transformation towards developing well-structured beliefs based on a strong theory-practice relationship.

Koster *et al.* (1998: 77-78) outline the following benefits of engaging PSTs in reflection: PSTs are able to adopt strategies and techniques to analyse and evaluate their own teaching behaviour; PSTs are exposed to opportunities which make it possible for them "to step into a process of lifelong learning and professional development". Smith (2005: 178) also adds that reflection on action helps PSTs to "… learn from their own and others' practical experience". Even at school level, Stockall and Davis (2011: 196) and Da Ponte and Chapman (2008: 238) agree that reflection play a major role in teaching children for conceptual understanding. While identifying the advantages of engaging PSTs in reflection, Da Ponte and Chapman (2008: 238) note that, through reflection, the PST becomes aware of his/her personal theories and preconceptions; she/he makes an effort to confront those personal theories and preconceptions which might be counterproductive; and she/he tries to clarify misunderstandings and brings them to the surface for correction. To them, reflection thus promotes self-understanding.

Ambrose (2004: 116-117) believes that PSTs need to be engaged in "[reflection] on their beliefs so that hidden beliefs become overt". This can promote rethinking about their reasonableness and productivity, and give PSTs the opportunity to experience and reflect on teaching and learning situations or episodes. This could help them to appreciate possible connections between their pre-existing beliefs and emerging ones. To illustrate the benefits in practice, Ambrose (2004: 116-117) conducted research with the aim of changing PSTs' pre-existing beliefs about

mathematics and the teaching and learning of it by building on the PSTs' beliefs. The author incorporated intensive reflection in an initial teacher preparation mathematics course. She found that the PSTs began to believe in the "importance of multiple solution strategies" in teaching and learning mathematics, and they were also becoming "critical of their own actions" (Ambrose, 2004: 117). Ambrose's (2004) findings reported here confirm the benefits of reflection reported by the other researchers like Koster *et al.* (1998), Smith (2005), Stockall and Davis (2011) and Da Ponte and Chapman (2008). Other implicit implications, which could be deduced from the reports discussed above, could be that such experiences encourage PSTs to learn to develop in-depth mathematical CK and PCK (Pernilla, 2008: 1297) and consider changing or debunking their erroneous beliefs about and attitudes to mathematics and the teaching and learning of it.

Incorporating reflection in prospective teacher preparation could also pave the way for other new generative beliefs that can enhance their instructional decision making (Ambrose, 2004: 117). It may be expected that such progressive improvements can also enhance the PSTs' ability to take instructional decisions that can promote teaching for conceptual understanding. Ambrose is also optimistic that, as PSTs continue to explore experiences that engage them in constant reflection and as generative beliefs progressively emerge or develop, pre-existing beliefs may be marginalised and eventually become more resistible or even extinct in the PD of the PSTs.

In Pernilla's (2008) research, PSTs were deliberately engaged in unpacking classroom instructions and reflecting on their own teaching. Pernilla's aim was to intellectually challenge PSTs' own experiences about teaching practised on them through reflection to pave the way for initiating the development of effective knowledge about PCK. Pernilla states that the advantage of learning through unpacking real classroom lessons and reflection on own teaching practices is that PSTs are exposed to peer review and discussions which promote the development of effective PCK. The author explains that reflection has an indispensable role to play in promoting the unpacking of tasks which helped PSTs to develop the desired PCK, and this connection becomes most rigorous and germane when reflections initiate changes in beliefs (Pernilla, 2008: 1297). All the preceding reports about the deliberate strategies of teacher educators are justifiable, as evidenced in Thomas and Beauchamp's (2011:767) observations below,

> We have come to the realisation that the development of a professional identity does not automatically come with experience, and that some form of deliberate action is necessary to ensure that new teachers begin their careers with the appropriate tools to negotiate the rocky waters of the first few years.

Thus, teacher educators can explore alternative teaching and learning opportunities to help PSTs build the fundamental knowledge bases to their PD.

3.7.4.3. Reflections and the development of the teacher's professional identity

According to Chong *et al.* (2011: 51), professional identity development is a continuous process of "interpretation and reinterpretation" of the teaching and learning environment to gain useful knowledge for teaching. Teacher identity is one of the terms which directly connote teacher professionalism, and its significance is in the teacher's own perceptions about "what teaching is and what behaviours are expected of a teacher" (Mosoge & Taunyane, 2012: 189). Mosoge and Taunyane's (2012) views confirmed Chong *et al.'*s (2011: 51) views that a considerable part of a teacher's development and teaching effectiveness is greatly influenced by his perception of his professional identity as a teacher. The notions of idealistic teacher identity mentioned above are connected to this study's aims to investigate PSTs' developing beliefs about what makes teaching Foundation Phase mathematics effective. Interestingly, Da Ponte and Chapman (2008) are of the view that reflection plays a very important role in the development of PSTs' professional identity (p. 2465).

According to Da Ponte and Chapman (2008: 243), there are three perspectives on the teacher's professional identity development. First, the cognitive perspective, whereby teachers perceive themselves "as active decision makers who have to deal with difficult problems and define their priorities rather than just implement standard routines following external directions". Teachers also are advanced in this perspective or aspect when they are practising "as problem solvers with several dimensions of competence". Second, the humanistic perspective, whereby teachers perceive themselves as "engaging in a special kind of artistic activity, in which different forms of reflection – such as reflection on self and reflection on practice, about practice, and about reflection on practice" which contribute to their professional growth. Third, the socio-cultural perspective: a teacher's professional identity develops through his/her interaction with other teachers and educational actors, especially students, school administrators and teacher educators (Da Ponte & Chapman, 2008: 243). Unlike Da Ponte and Chapman (2008), Mosoge and Taunyane (2012: 189) link the development of teacher's identity to the perspective of symbolic

interactionism, saying that the beginning teacher, for example, develops his/her identity as a teacher through interaction with school administrators, students and role models, and learns to adopt the image or symbol of teacher and a teacher's responsibilities as portrayed in that environment. Both the socio-cultural and symbolic interactionism perspectives above seem to show that PSTs could also learn from the teaching expertise modelled by the ETE facilitating the modules (Huinker & Madison, 1997; Howitt, 2007; Koster *et al*., 1998). Therefore, both perspectives on the teacher's professional identity development are linked to the current research interest in PSTs' perceptions of the influences of the ETE's teaching expertise on their PD.

Da Ponte and Chapman (2008: 247) have noted that the humanistic perspective of professional identity is developed well and enhanced when PSTs reflect on their learning experiences and on their beliefs about mathematics and the teaching and learning of it. This means the PSTs' are engaged in reflecting to ascertain self-understanding, which fosters the development of teacher identity (Da Ponte & Chapman, 2008: 247). They explain that, in this case, PSTs attend to their own on-going PD as mathematics teachers; it gives them the opportunity to explore the relationship between their self, personal experiences and pedagogy; they are able to evaluate their on-going learning and development without being dependent on formal external feedback mechanisms; and construct and critique their own mathematical understanding and educational identities. In supporting these claims, Da Ponte and Chapman (2008) have argued that PSTs need to be aware of their preconceptions, including the superficial nature of mathematics that they have developed, and the limitations that come with this. The authors are emphatic that this awareness can be optimised through reflection on their own actions and self-experiences. This is the effective way by which they can develop the desired identities of effective teachers. Such deliberate engagements could ensure that the PSTs' PD becomes explicit, progressive and practical, because they are more or less experiencing the activities and are assuming roles closer to those of practising teachers (Da Ponte & Chapman, 2008: 247).

Drawing from the foregoing discussions, the role of the ETE in preparing reflective practitioners for our schools cannot not be overlooked. Stockall and Davis (2011: 195) have documented, for example, that PSTs whose entry beliefs were shaped by a "reflective type of learning" were inspired by teacher educators who themselves were "reflective or internally directed learners". According to Stockall and Davis (2011: 195) researchers have been positive that teachers' beliefs

and assumptions can be transformed when actually engaged in teaching and through interaction with expert teachers. All the evidence indicate that PSTs' beliefs could be transformed significantly through their interaction with the expert teacher educator.

3.7.4.4. Scaffolding strategies and students' learning

Hume and Berry (2011) investigated a chemistry teacher educator's use of scaffolding strategies to assist PSTs to build the foundation upon which they could develop their PCK in future, even though they have not experienced actual classroom teaching. The teacher educator describes the scaffolding strategies as her use of "prompts and suggestions and engaging students in critical analysis and reflection" (Hume & Berry, 2011: 349). The researcher is convinced that the attributes of teaching expertise congruent with the educator's scaffolding strategies could be *stimulating the interest of motivating/stimulating students' interest and engagement with learning experiences*; and *understanding of students' learning needs and creating productive learning climate.*

According to Hume and Berry, the teacher educator was a constructivist, who, despite the claims that PCK is developed in actual classroom teaching, was determined to use the "Content Representation (CoRe)" design by integrating scaffolding in her teaching in introducing modelling, examining, and developing awareness of PCK for her student teachers. Di Eugenio *et al*. (2006: 506) support the educator here in focus, saying that, unlike non-expert teachers, expert teachers encourage students to learn to construct their own knowledge by using prompts and scaffolding. The educator's constructivist orientation, as noted by Huinker and Madison (1997: 112) has the advantage that teaching and learning in the constructivist environment could provide PSTs with experiences in evoking intellectual discussion and reflection on learning situations.

Hume and Berry's (2011) findings show that the PSTs were able to work/learn confidently and independently after the introduction of scaffolding strategies. One very significant achievement noted by the educator was that the PSTs were competent in developing transferable knowledge as compared to past PSTs taught the same course at the same level without employing scaffolding strategies (Hume & Berry, 2011: 349).

In addition, they found evidence in the educator's reflection journal that showed that the exposure to the expert's scaffolding strategies developed student teachers' enthusiasm for understanding very relevant information in the CoRe design (p. 349). The authors quoted the educator saying: "My observations were that students this year still found the initial Redox CoRe difficult to do, but valuable to do. They needed less direct help from me to complete the task."

Hume and Berry (2011) also found corresponding evidence from the PSTs which showed that they perceived the initiative as empowering them with adequate skills to be able to acquire very useful information sources for their professional growth (p. 349). The authors supported this with a quote from a prospective teacher: "So she's been really helpful in giving us lots of different things to go to look for information, just almost building up a conscious list of where you can source what you need to know."

Interestingly, the authors also found that the student teachers' learning outcomes appreciated to the levels of experienced teachers. The reason they gave was that the components of the PSTs' PCK was likely to be part of the PCK of experienced chemistry teachers (Hume & Berry, 2011: 349). This clearly shows that the impact of the educator's scaffolding strategies had succeeded in building the foundation for PSTs to advance the development of their PCK. In the view of the authors, the initiative had achieved its aims of improving PSTs' "thinking and experience required to develop that very special kind of professional teaching knowledge known as PCK" (Hume & Berry, 2011: 354). Hume and Berry (2011) did not hesitate to emphasised that this remarkable achievement could not have been possible without the introduction of the expert teacher educator's scaffolding strategies such as prompts and suggestions (Hume & Berry, 2011:354). They held the strongest conviction that PSTs would be able to access and accumulate some of the knowledge from the expert teacher educator's experiences to build their confidence and competencies towards developing PCK if scaffolding of the learning experiences were carefully introduced in teaching, (Hume & Berry, 2011:354). They support their views by saying that the facilitator was confident that her exemplary teaching strategies in the initiative succeeded in building the solid fundamental knowledge that would enhance the development of PSTs' PCK (Hume & Berry, 2011: 354).

3.7.4.5. Other integrated strategies and their influence on learning

Huinker and Madison (1997: 123) reported on the integration use of "verbal persuasion, observation, modelling, discussion and reflection" by the teaching professors in their interactions with the PSTs. According to the authors, the teacher educators used verbal persuasion in order to convince the student teachers that they can also be very effective teachers of science and mathematics. In support of their claim, Huinker and Madison (1997: 123) provided evidence from the comments of the mathematics teaching professor saying: "I would like them to leave the course much more confident in their own ability".

According the researchers, such situations emerge when there is an on-going discussion of the PSTs' concerns relating to actual classroom teaching (Huinker & Madison, 1997: 123). Furthermore, the integration of discussion and reflection in the educators' teaching practice is evidenced from the teaching professor saying that:

> I think they have to struggle. I give them some, I think, fairly demanding exercises… something that will force them to just have to think about it and not just follow slavishly a set of directions. I like getting them in perplexing situations where they have to work at it and think in order to understand-so they are in the role of the learner… they are struggling to make sense for themselves. (Huinker & Madison, 1997: 112)

The integration of verbal persuasion, modelling, and observation strategies of the educators also became evident from Huinker and Madison's report that the educators were demonstrating to their PSTs how science can be taught and also convincing them that learning and teaching science is an interesting and a worthwhile experience.

The impact of those strategies on the PSTs were observed in their ability to talk about "how science can be organised" and how to develop science units (Huinker & Madison, 1997: 112). In the case of the PSTs prepared by the mathematics teacher educator, Huinker and Madison (1997: 112) report that, with expertise similar to the science teacher educator, the PSTs experienced learning mathematics as a "sense-making experience" and developed their competencies or expertise in teaching children to understand mathematics conceptually. According to Huinker and Madison, these findings are consistent with the mathematics educator's claims that the goals of their strategies in the preparation of the PSTs are to assist the PSTs to develop more

confidence in their own abilities; understand mathematics conceptually; view mathematics from a much broader angle; feel more comfortable exploring mathematical ideas; and readiness to utilise manipulatives and calculators (Huinker & Madison, 1997:112).

In their findings, Huinker and Madison (1997: 113) note overall appreciation in PSTs' personal teaching efficacies with much interest in the "most dramatic change" in the teaching self-efficacy of one relatively low-performing PST. The authors note that this PST entered the course feeling relatively weak regarding her own abilities to become an effective teacher in mathematics and science. They support this claim with the student's own comment, which was: "I was coming in hoping that I would be able to definitely change myself and my attitudes so that I can be a better teacher" (Huinker & Madison, 1997: 113). The authors note that the facilitation of the method course by the ETEs did increase the PSTs' beliefs in their abilities to teach mathematics effectively (Huinker & Madison, 1997: 122). This is evidenced in the descriptions of the methodologies used by the teaching professors in that module, with the professor saying: "I made up my mind early on, that one of the things I wanted to do was to make the class so palatable that they would leave with a very positive, or as much as possible, positive attitude about the value of science and the need to for children to experience science" (Huinker & Madison, 1997: 122).

According to the authors, the students of these teaching professors actually demonstrated positive experiences as learners of mathematics and science. In conclusion, Huinker and Madison remark that, after such exposure to the expert teaching strategies, the PSTs' psychological problems in connection with teaching and learning mathematics and science were solved and that they realised that "learning science and mathematics does not have to be stressful or anxiety provoking" and could be very enjoyable.

3.8. CONCLUSION

It has been made clear that both the teaching expertise and fundamentals of PSTs' PD are part of teacher education ecology. This ecology describes the factors which interact in shaping the PSTs' PD. It has been shown that teaching expertise of the teacher educator plays a significant role in the preparation of PSTs in this ecology. This makes the teacher educator a special factor

with unique contributions to the PD of the PST in this ecology. This exploration helped the researcher in his attempt to describe a conceptual framework showing what and how he planned to explain or interpret from the interaction of these factors in the ecology and how to go about explaining or interpreting.

In an attempt to justify the relevance of focusing strictly on the three components of PSTs' PD, the researcher explored the literature to relate those three attributes of PSTs' PD to PD in the landscape of in-service teacher education; and teachers' knowledge and teaching effectiveness in South Africa. Furthermore, this review sought to explore literature to prove PD in initial teacher education, to make clear what constitute PSTs' PD, and to show how researchers assess changes in PSTs' PD. This is one of the cornerstones of this review. It was to be the yardstick for assessing the perceptions of the PSTs involved in this study, about changes in their PD.

At the heart of the entire review, as well as of the study as a whole, the researcher sought to provide evidence about the influences of the attributes of teaching expertise on learning outcomes in the domain of PSTs' PD. This review has documented empirically proven evidence about the influences of ETEs' teaching expertise or the strategies of sharing teaching expertise in learning. Having said this, it would be much clearer to present the teaching expertise together with associated learning outcomes as shown below.

ETEs generally make their teaching knowledge accessible to PSTs through verbal persuasion, observation, modelling, scaffolding, discussion and reflection, which help PSTs to improve their CK and PCK as they unlearn their misconceptions and relearn mathematics for conceptual understanding (Huinker & Madison, 1997; Howitt, 2007). It appears that PSTs also learn effectively through those processes of knowledge transfer. When PSTs are exposed to worthwhile learning experiences their confidence in teaching is enhanced and they develop their personal self-efficacies to an appreciable extent (Huinker & Madison, 1997).

When ETEs stimulate the interest of PSTs students for engagement in learning it results in productive conceptual change. Reflection in learning and practice also result in transformation of prior learning; confronting misconceptions and reconstruction of a new knowledge base (Kagan, 1992). ETE's stimulation of the interest of PSTs for engagement in learning; enthusiasm in teaching; and understanding of students and creating a positive environment facilitate reflection

which results in PSTs becoming enabled to adopt strategies and techniques to analyse and evaluate their own teaching behaviour; PSTs get exposed to opportunities which make it possible for them "to step into a process of lifelong learning and professional development" and it helps PSTs to "… learn from their own and others' practical experience" (Koster *et al*., 1998). Hume and Berry (2011) highlighted the following influences of expertise on PSTs in their research:

- PSTs worked confidently and independently
- PSTs also become competent in developing transferable knowledge
- PSTs developed adequate skills for acquiring very useful information sources for future improvement
- PSTs perceived that they have been adequately prepared for classroom teaching
- PSTs' learning outcomes appreciated to the extent that components of their developing PCK are likely to be part of the PCK of experienced teachers
- PSTs' thinking and experience required to develop their PCK (special kind of professional teaching knowledge) were enhanced.
- The development of PSTs' PCK on solid fundamental knowledge were enhanced.

According to Howitt (2007), well-developed PCK equips PSTs with the desired knowledge and skills or profound understanding of the subject content, and increases their teaching confidence, and willingness to share the fun and challenges of learning the subject matter content with learners, which result from PSTs' exposure to the ETE's teaching expertise.

The ETE's clarity of presentation; preparation and organisation and command of subject knowledge assist PSTs to form meaningful, coherent representations of knowledge. PSTs are able to develop independent and self-regulated learning strategies from the ETE's enthusiasm in teaching; interpersonal relationships; humour and approachability; understanding of students and creating a positive environment. These aspects of the teaching expertise of the ETE are able to change PSTs' states, beliefs, interests, goals and habits of thinking (Hativa, 2000).

Howitt (2007) concluded that ETE's enthusiasm in teaching; interpersonal relationships; and humour and approachability enhanced PSTs' learning effectiveness and confidence in developing the necessary knowledge for teaching; changed the PSTs' feelings or beliefs about science; and developed positive attitudes towards science in PSTs.

An ETE's teaching clarity is able to overcome PST anxieties about the subject matter and misconceptions about themselves and the subject matter of the discipline; they are well motivated; they are challenged to understand the subject matter thoroughly; it enables learners to

make meaningful connections between seemingly different concepts, facts and procedures. The review has also shown that ETE's command of subject knowledge improves students' proficiency in what they are learning; empowers students to articulate meaningful connections between new concepts and already existing concepts; enables students to unlearn erroneous knowledge to relearn deeper knowledge; reflect on their beliefs and bias towards their disciplines, especially beliefs about teaching and learning.

In addition, the ETE's preparation and organisation creates an environment conducive to learning, which supports effective learning for students to develop the desired knowledge, skills, and attitudes in their disciplines. The ETE's enthusiasm in teaching enhances good inter-personal relationships between the ETE and students and motivates high achievement in the students' learning outcomes. Similar effects have also been reported with regard to the ETE's humour in teaching; interpersonal relationships with students for stimulating students' learning; and creating a positive learning environment, among others. Surprising and interesting findings about the influence of humour on students' learning and development indicate that humour in the work of teaching "decreases students' anxiety, improves the ability to learn, and boosts self-esteem, thus encouraging a more receptive learning atmosphere" (Friedman *et al*., 2002).

Researchers have also reported that when teacher educators were able to combine aspects of their teaching expertise, for example humour and enthusiasm in teaching, a uniquely positive learning atmosphere is created to enhance learning effectiveness (Garner, 2006: 178). To sum up: expert teaching has been shown to promote the development of deep knowledge of the discipline, improve the problem-solving skills of students, motivate students to engage with the learning tasks, and increase students' appreciation of their own competencies and professional strengths (Mitchell *et al*., 2004: 281).

4. CHAPTER 4
RESEARCH DESIGN AND METHODOLOGY

4.1. OVERVIEW

This study sought to elicit PSTs' perceptions about their PD with the use of a mixed methods research design (Krauss, 2005: 761). The PSTs were learning from the ETE to develop expert teaching knowledge to improve their PD. There was a need for wider and in-depth coverage of their viewpoints (Krauss, 2005: 758) to ascertain detailed understanding for interpretation of their own perceptions regarding the changes or improvement in their PD during their interaction with the ETE's teaching expertise. In order to accomplish this goal, studies of this nature can effectively combine both quantitative and qualitative methods, given that the use of either quantitative or qualitative methods alone cannot adequately achieve the aim of the study (Onwuegbuzie & Collins, 2007: 283; Krauss, 2005: 758). The quantitative method would accurately gather large-scale data on the student teachers' perceptions (Rowley, 2014: 310), while the qualitative method would provide the required data on the subjects' viewpoints in detail for detailed explanation of the quantitative results (Wilkins & Woodgate, 2008: 24; Macnab & Payne, 2003: 59; Hanson, Creswell, Clark, Petska & Creswell, 2005: 225; Onwuegbuzie & Collins, 2007: 283; Frykholm, 1999: 85; Levin, 2014: 60). To understand PSTs' developing beliefs, Levin (2014), for example, supports the combination of a survey and interviews, arguing that surveys do not always capture real meanings of views or detail reasons and, for that matter, would not provide us with detailed understanding of the PSTs' developing beliefs, unless the researcher employs interviews with the PSTs to get complete understanding of the phenomenon under investigation (Krauss, 2005: 761).

Using mixed methods in this study allowed the researcher to take advantage of the potential strengths of both qualitative and quantitative methods at the same time (Östlund, Kidd, Wengström & Rowa-Dewar, 2011: 369; Krauss, 2005: 761). Onwuegbuzie and Leech (2005: 383) support this idea by saying that "… the inclusion of quantitative data can help compensate for the fact that qualitative data typically cannot be generalized" and, in much the same way "… the inclusion of qualitative data can help explain relationships discovered by quantitative data" (Pearce, Christian, Smith & Vance, 2014: 27). Small (2011: 64) also offers the same argument,

saying that "... the greatest value in combining types of data lies in the ability of one type to compensate for the weaknesses of the other" (Pearce *et al*., 2014: 27).

In terms of suitable research fields where mixed method designs are applicable, Guest (2013: 142) claims that "... social scientists were using qualitative methods to inform structured surveys decades before the emergence of mixed methods as a scholarly field". Additionally, Small (2011: 58) also says that mixed-method designs are gaining the attention of social scientists and educationists, among others in the field of sociology.

If mixed methods have been found to be viable research methodologies and methods (Hanson *et al*., 2005: 226; Hesse-Biber, 2010: 456) in the above disciplinary domains, then this study, which is within such domains, would not be an exception. At this juncture, the researcher was fully convinced that using mixed method design was the best alternative towards getting adequate information or insight (Bryman, 2007: 9) to sufficiently answer the research questions and achieve the research aim and objectives (Creswell, 2013: 4; Woolley, 2008: 2; Wilkins & Woodgate, 2008: 26; Jang, McDougall, Pollon, Herbert & Russell, 2008: 222), instead of using a single method design – either qualitative or quantitative (Östlund *et al*., 2011: 370; Srnka & Koeszegi, 2007: 30; Onwuegbuzie & Leech: 2005: 268).

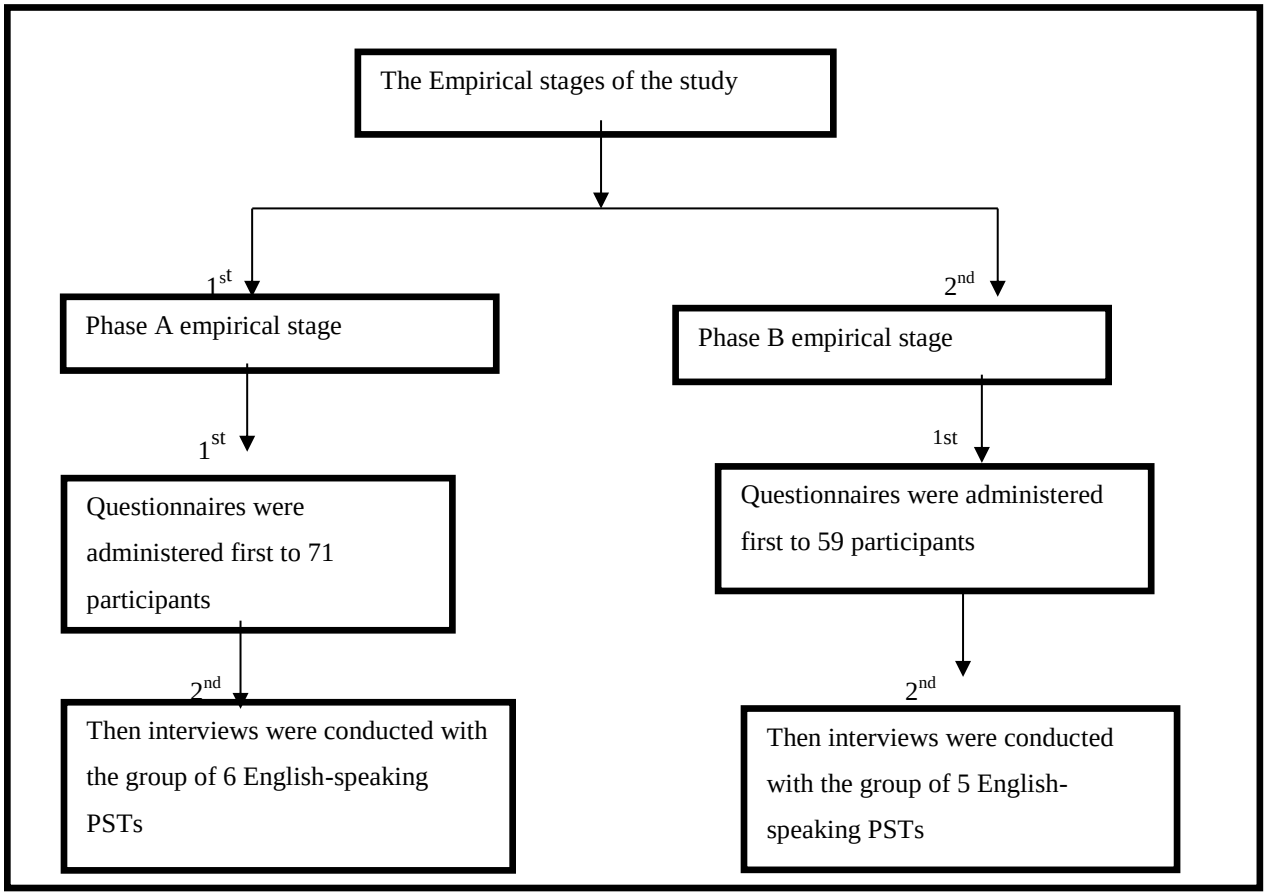
Furthermore, this phenomenon under investigation could be characterised as two-dimensional, because, on one hand the perceptions of the PSTs' regarding improvement in their PD may appear to be similar to some extent. On the other hand, it is equally likely that perceptions may differ to some extent. The researcher was of the view that a multifaceted phenomenon of this kind could be well understood and explained or interpreted by employing both quantitative and qualitative methods (Hativa, 1998: 357; Hanson *et al.*, 2005: 224). Östlund *et al*. (2011: 370) support this, saying that "Mixed methods can also help to highlight the similarities and differences between particular aspects of a phenomenon".

Employing mixed method designs in mathematics education research is being strongly advocated at present (Da Ponte & Chapman, 2008: 254; Levin, 2014: 60/62), to the extent that recent projects which do not provide qualitative perspectives in addition to the dominant quantitative findings are severely criticised. Brown *et al*. (1999: 301) strongly argue that research in mathematics could be strengthened by employing mixed methods in this field, because

"cognitively oriented" researchers in mathematics education have been penalised more recently for ignoring the "social dimension" of their subjects.

The above were the reasons for employing a mixed methods design in this research. Several longitudinal studies which elicited teachers' and PSTs' perceptions on, for example, issues relating to teaching and learning and learning to teach have been successful by combining quantitative and qualitative methods (for example Sheridan (2009), Sheridan (2013), Bantwini (2012), Yeşilyurt (2013), and Jegede *et al*. (2000). The quantitative and qualitative stages are shown in Figure 4.1:

Figure 4.1: The empirical stages of the study



4.2. THE RESEARCH DESIGN EXPLAINED

An investigation in which the researcher mixes different research methods, for example, quantitative and qualitative methods, is referred to as mixed-methods research (Onwuegbuzie & Collins, 2007: 281). Mixed methods may be understood as a "method" that equips the investigator with the "research tool" and also as a "methodology" that determines how the research tools should be utilised to achieve the aims and objectives of the investigations (Hanson *et al*., 2005: 226; Hesse-Biber, 2010: 456). Most mixed methods practitioners combine numbers and words (Creswell, 2013: 3-4) to help them to understand a real-world phenomenon in detail and from different perspectives. For example, Östlund *et al*., (2011: 370) remind us that mixed methods research was first introduced into the landscape of research by T. D. Jick in 1979, in his quest to converge quantitative and qualitative results in social science research. Hanson *et al*. (2005: 225) claim that it was "Campbell and Fiske's (1959) study of the validation of psychological traits that brought multiple data collection methods into the spotlight". The examples above show that mixed method practices have historical background and purposes.

This research design started gaining popularity among researchers from 1985 (Pearce *et al*., 2014: 27) in different disciplines including social, behavioural, and health sciences with the view of understanding research problems by integrating the processes of data collection, analysis and interpretation in quantitative and qualitative methods (Creswell, 2013: 4; Hanson *et al*., 2005: 225). Creswell (2013) was emphatic that a mixed method study is distinguished in its intentions and focus to integrate quantitative data (generated, e.g., by using closed-ended questionnaire items) and qualitative data (generated, e.g., by using semi-structured interviews) in a defined procedure – one of convergent parallel design; explanatory design; or exploratory design.

In using a mixed methods design here, a quantitative method (i.e. survey) was used to gather large-scale data on the prospective teachers' perceptions about their PD, while a qualitative method (i.e. a semi-structured interview) was used to generate data about the subjects' viewpoints about their PD in detail (Levin, 2014: 60). The researcher used a convergent parallel design in collecting, analysing and interpreting the data which were generated in the study. In

this design framework (i.e. convergent parallel design), qualitative and quantitative data were collected and analysed separately, then the results were merged for interpretation and discussion of congruent, complementary, contrasting, clarifying or divergent findings in the light of the guiding research questions (Östlund *et al*., 2011: 370; Bryman, 2007: 9). Creswell, Plano Clark, Gutmann & Hanson (2003) confirm the appropriateness of the above method, saying that, "… in concurrent parallel design the researcher seeks to compare the findings to search for congruent findings – that is, how the themes identified from the qualitative results compare with the statistical results in the quantitative analysis" (p. 217-218). Small (2011) also supports the suitability of this strategy, saying that

> Researchers have used complementary designs when they are reluctant to limit the kind of knowledge gained to that which a type of data can produce. The core assumption is that any given type of data can produce only a given kind of knowledge. (p. 64)

Complementary findings from studies then become very necessary for better understanding of the research problem.

4.2.1. Why Convergent parallel design

The research questions guiding this study aimed at gaining both detailed understanding of the problem and comparing those understandings (Pearce *et al.,* 2014: 22). Hence, a convergent parallel design was employed as the main methodological framework or design for this study (Jang *et al*., 2008). Support for the fundamental rationale for this choice was found in Jang *et al*. (2008: 222), Wilkins and Woodgate (2008: 26) and Bryman (2007: 20), and it was also consistent with Hanson and colleagues' descriptions of emerging trends among mixed methods practitioners that most researchers in this field try to "better understand a research problem by converging numeric trends from quantitative data and specific details from qualitative data" (Hanson *et al.,* 2005, p. 226). Wilkins and Woodgate (2008) refer to this as triangulation, whereby researchers attempt to ascertain the extent to which both qualitative and quantitative findings in the same study are "mutually reinforcing …" (p. 26).

Furthermore, Creswell (2013) defines the framework for doing a mixed method design within which the convergent parallel design used in this study became apparent or was rightly positioned:

i. Need for different, multiple perspectives, or more complete understandings
ii. Need to confirm our quantitative measures with qualitative experiences
iii. Need to explain quantitative results (p. 30).

This convergent parallel design permitted structural or systematic following of all the necessary procedures towards obtaining reliable and valid findings in each method before combining them. To reiterate the earlier claim, the fundamental purpose of using convergent parallel design was to ascertain the detailed and more comprehensive understanding and interpretations of the PSTs' own perceptions about their PD during their interactions with the ETE's teaching expertise. This was consistent with Creswell's point (**i**) above. Furthermore, the purpose of choosing a convergent parallel design over "explanatory and exploratory designs" was to afford the researcher a pool of advantages, which were consistent with Creswell's (**ii**) and (**iii**), to accomplish the research goal. That is to say, the convergent parallel design permitted the researcher to triangulate the findings – an advantage over sequential mixed method design – in addition to using it for the purpose of getting complementary findings, for which both designs were used (Onwuegbuzie & Collins, 2007: 291-292). Indeed, the convergent parallel design helped in comparing the qualitative with the quantitative findings to find out where results confirmed or contradicted each other.

4.2.2. Some challenges in using convergent parallel designs

In general, employing mixed methods designs in research is not as easy as using a single method. One of the daunting challenges of the convergent parallel mixed methods design is reported to be that when pronounced inconsistencies in the component findings are created, there is another burden on the researcher to revise the survey instrument or develop a new instrument that accurately captures those themes which may arise in qualitative findings (Jang *et al.*, 2008: 241) within the limited time allocated to the research. However, time constraints have been a scarce resource for researchers before (Jang *et al*., 2008: 243).

Secondly, the analytic strategies involved in this research design require a great deal of knowledge about the data, and it also requires skills in both quantitative and qualitative methods (Jang *et al*., 2008: 243). This makes it one of the most challenging mixed method designs to the extent that researchers prefer to team up to implement this form of research design (Doyle, Brady & Byrne, 2009: 181; Wilkins & Woodgate, 2008: 26).

Even working in a team does not seem to be easy for implementing convergent parallel mixed methods designs, because "when research teams are composed of quantitative and qualitative specialists, this may militate against the degree to which findings are integrated" (Bryman, 2007: 15). It clearly may be extremely challenging for an individual researcher to implement a convergent parallel mixed methods design, but, all things being equal, the individual in this case could work more effectively than the team at the analytic phase merging the study's quantitative and qualitative findings, because the conflict of expert dominance may be absent.

Thirdly, the convergent parallel mixed method is more challenging compared to the other designs because there are very few effective or established examples, models, or templates of it in the field to guide novices whose research problems could be addressed appropriately by this design (Bryman, 2007: 21; Woolley, 2008: 2; Östlund *et al*., 2011: 370- 371; Srnka & Koeszegi, 2007: 31; Kerrigan, 2014:10).

Despite all the above real or practical challenges reported from research accounts and experiences, the researcher found motivation in the fact that, as far as this research problem was concerned, the convergent parallel mixed method design employed here was capable of helping to answer the research questions adequately. Moreover, the challenges above are not only associated with the convergent parallel mixed method design, because Doyle *et al*. (2009: 183), Wilkins and Woodgate (2008: 26) and Bryman (2007: 15) unanimously agree that sequential mixed method designs also have similar challenges, as reported by the advocates and practitioners of convergent parallel mixed method design. In especial, considerable time and resource commitment is needed to undertake distinct phases of sequential mixed method designs, in addition to the knowledge and skills required of the researcher in both quantitative and qualitative research to be successful in his study.

The above shows that all mixed method research designs have been acknowledged to be highly technical, but, in the face of those technical challenges, many researchers have been able to create effective combinations of qualitative and quantitative research (Wilkins & Woodgate, 2008: 25). To achieve the effective combinations of the two methods, the researcher gave more attention to the integration of findings and to the representation of those findings in this current study. Jang *et al.* (2008: 222) support this with their claim that the final conclusions (i.e.

explanations, interpretations, knowledge and understanding) drawn from a mixed method study must represent the collective findings from both methods. Bryman (2007) also suggests that "one way of addressing this issue in the future would be to give greater attention to writing issues in mixed methods research ..." (p. 21).

4.3. THE DEVELOPMENT OF RESEARCH INSTRUMENTS

Basically, the development of the instruments for this study were tailored towards enabling the researcher to collect rich and in-depth information to find reasonable answers to the research questions guiding the study (Rowley, 2014: 312). This section describes the development of the data collection instruments: the questionnaire and the interview protocol. It provides detailed descriptions of the contents of the instruments and how they were oriented to elicit the desired responses from the subjects towards understanding the problem under study. It is also important to point out that the development of the instruments became necessary because there was no existing survey instrument that could be adopted for this study.

It should also be re-emphasised that both the questionnaire and interview questions were developed with the aim of eliciting the perceptions of the PSTs regarding the changes or improvements in their PD in Foundation Phase mathematics (Macnab & Payne, 2003: 56; Busi & Jacobbe, 2014: 24) before and after their interactions with the ETE's mathematics teaching expertise (Hudson & Ginns, 2007: 7; Thomas & Beauchamp, 2011: 764). This is the overarching orientation and framework of both instruments and it is consistent with the main aim of the study (Rowley, 2014: 312) (see section **1.3**).

Furthermore, the initial considerations towards the development of the instruments were guided by the research problem and questions; an existing relevant and validated survey framework designed by Hudson (2009) and Hudson and Ginns (2007). Other relevant literature sources (Rowley, 2014: 312; Hativa, 1998: 359; San, 1999: 20) such as the recommendations in Carney, Brendefur, Thiede, Hughes & Sutton's (2014: 25) study, Mosoge and Taunyane's (2012) documentation on the instructional reforms in South Africa and the framework of the questionnaires they developed for their study. Rowley (2014: 312) suggests that "it may be possible and even advisable to use part or all of a previous questionnaires from a published

article on a similar topic". Rowley (2014: 312) suggests further that the development of new research instruments can be informed by relevant literature sources, "…practice or experience, or by theory or previous research, or, as is common with research in practitioner disciplines, a mix of both".

Firstly, Mosoge and Taunyane's (2012) own questionnaire structure guided and shaped the conceptualisation of the framework of the instruments for this study. Mosoge and Taunyane, (2012: 190) developed their questionnaire to elicit teachers' perceptions about the extent to which they were articulating professionalism in teaching. The conceptual framework of their questionnaire considered the need for understanding and describing the teacher's professional traits which include very significant attributes like teachers' specialised knowledge and skills, beliefs and attitudes, and teachers' actions, among others. What is more important to note is the relevance and connections of those attributes of teacher professionalism to the attributes of PSTs' PD considered in developing the current study's questionnaire and interview questions.

In other words, the development of this study's questionnaire, as well as the interview questions, focused on PSTs' developing or changing beliefs (similar to beliefs and attitudes); CK and PCK (similar to specialised knowledge); and their perceptions of what they think those perceived changes or development could afford them to do (similar to teachers' actions) (Busi & Jacobbe, 2014: 25; Da Ponte & Chapman, 2008: 247).

Secondly, Hudson's (2009) and Hudson and Ginns's (2007) instruments guided the questioning techniques employed in the design of the current instruments: the questions began by eliciting the PSTs' responses about perceived changes in their PD, followed by corresponding questions which elicited their responses about perceived affordances of the changes in their PD. The two sets of questionnaires that were developed (for before and after learning to teach from the ETE's teaching expertise) were both oriented as described above, except that the questionnaire eliciting the PSTs' responses after their learning experiences with the ETE focused specifically on the influences of the ETE's attributes of teaching expertise on their PD. These orientations of the instruments (perceived changes and perceived affordances of the changes) were also guided by the current study's objectives and questions.

Thirdly, recommendations by some researchers guided the selection of items or contents of the current survey. For instance, at the end of their study on teachers' PD in which teachers were given the opportunity to evaluate their own "beliefs regarding the nature of mathematics and student learning" and their self-efficacy, Carney *et al.* (2014: 25) made certain recommendations which helped in conceptualising the content of the instruments developed in this research. They recommended that teachers' PD should empower them to consider student's ideas constructively; promote student's conceptual understanding of mathematics subject matter; encourage multiple strategies and models, especially in problem solving; address learners' misconceptions about mathematics and learning mathematics; and be focused on the structure of the mathematics, as set of interrelated concepts and procedures. Similarly, Mosoge and Taunyane (2012: 182) have documented that the South African educational landscape has shifted emphasis to learner engagement for meaningful learning in order to eliminate the teacher-centred instructional approach, thus promoting a learner-centred approach; prioritising problem-based learning over rote learning; and changing the teacher's professional practice from knowledge transmission to knowledge transfer in which teachers assume the primary role of facilitators of the desired learning outcomes. Those recommendations and visions about teaching and learning effectiveness guided the selection and sequencing of practical and relevant items that are essential determinants of mathematics teaching and learning effectiveness to be included in the response eliciting items in the design of the instruments.

4.3.1. The Bifocal Lenses of the Proposed Framework of the Instruments

When exploring Carney *et al.*'s (2014) recommendations, they seemed to be silent about exploring the attributes of change which could provoke the teacher's empowerment. The researcher is convinced that teacher empowerment could be understood from the perspective of changes [in the teacher's beliefs, CK, and PCK] and what those changes could achieve in the teacher's instructional practice. These two perspectives are the emphasis of the current instrument development in eliciting PSTs' perceptions about their PD – linking their professional abilities to changes that are necessary to bring about those efficacies in the work of teaching mathematics. Carney *et al.*'s (2014) recommendations seem to focus on only one perspective of the teacher's PD (i.e. what the teacher should be able to do) without exploring the source of those empowerments. The researcher argued that, if mathematics teacher educators are

considering the above recommendations from just one perspective while neglecting the other, which is the cause, then it is likely that we may not optimise the teacher's PD as desired in Carney *et al.*'s (2014) recommendations (Ma & Singer-Gabella, 2011: 8; Ball, Hill & Bass, 2005: 14; Bantwini, 2012: 520; Da Ponte & Chapman, 2008: 226/254; Borko *et al.*, 1992: 196; Brown *et al.*, 1999: 301; Da Ponte & Chapman, 2008: 223). Hence, the instruments developed for this study elicited the PSTs' views about the changes which could result in the enviable PD empowerment recommended by Carney *et al.* (2014).

Furthermore, it seemed that the shift in the South African instructional emphasis documented by Mosoge and Taunyane (2012) was echoing the two perspectives of teachers' PD as introduced in the development of this study's instruments. The researcher was convinced that such shifts in instructional practices could be optimally realised when teachers' PD prioritises changes in teachers' beliefs and attitudes, and improve teachers' CK and PCK, which are fundamental in teachers' professional empowerment (Yang & Leung, 2011: 1007; Busi & Jacobbe, 2014: 23; Ambrose, 2004: 92; Frykholm, 1999: 81; Ball, 1988: 6/11; Brown *et al.*, 1999: 301; Da Ponte & Chapman, 2008: 223).

4.3.2. The structure of the questionnaire

Rowley (2014: 315) is convinced that well-structured questionnaires are those that are developed under well-defined themes or sections, as the structure of this study's questionnaire. Basically, two types of questions were asked and arranged in the five sections: questions in sections **A** to **D** required PSTs to indicate the degree to which they agreed or disagreed with a given statement or phrase, but section **E** required PSTs to associate one or more attributes of the teaching expertise of the ETE to a changes they perceived in their beliefs, CK, or PCK (Macnab & Payne, 2003: 57). The framework of the questionnaire described above was consistent with Rowley's (2014: 315) view that well-structured questionnaires have clear headings or titles in each section in addition to brief instructions or introductory sections for the orientation of the study's respondents.

In all, the survey consisted of 41 items on four-point Likert-type scales, which were fewer than Jang *et al.*'s (2008: 228) 75 survey items on a six-point Likert-type scale and Hudson and Ginns' (2007) and Hudson's (2009) five-point Likert-type scale. The responses on these four-point

Likert-type scales were assigned numbers as shown here: Strongly Disagree = 1, Disagree = 2, Agree = 3, and Strongly Agree = 4. Similar to this study, Mosoge and Taunyane, (2012: 191) also used a four-point Likert-type scale in their questionnaire design. The reason for using a four-point Likert-type scale was to minimise the respondents' likelihood of always choosing the middle options when they wanted to avoid taking trouble to reflect before responding appropriately. More importantly, when it comes to the choice of a particular Likert-type scale in surveys, what is necessary is to address the issue of measurement sensitivity – the ability of the chosen Likert scale to enable respondents to discriminate between their levels of experience along the given scale points.

It should also be added that the researcher used-closed ended questions in developing the measurement scales. The reason was that respondents feel less burdened and bored to respond and their responses are quicker, thus encouraging a high rate of participation and return, which could be less if the researcher had used open-ended questions (Rowley, 2014: 314). The researcher was further motivated to use closed-ended questions, because of the fact that the responses are much easier to code and analyse, compared to open-ended questions (Rowley, 2014: 314). Despite the advantages of using the closed-ended questions, it was challenging to develop suitable questions that were devoid of ambiguities and researcher bias; questions that respondents would not find relevant; breach of subjects' confidentiality; too general questions; and making the questions easily understandable; and free from sensitivity to any form of personality (Rowley, 2014: 314-315). The researcher was able to overcome those challenges through expert advice from his promoter and the ETE of the module and piloting the questionnaire. The researcher would like to point out that data about the respondents' basic profiles have not been considered necessary due to their irrelevance to the research aim and questions (Rowley, 2014: 318).

4.3.2.2 The Response-Eliciting items in the light of literature

Table 4.1: The response eliciting items in light of the literature

Section A: Survey items eliciting PSTs' perceived changes/improvement in the PD	**Section B:** Survey items eliciting PSTs' perceived affordances of the changes/improvement in the PD	Recommendations Supporting Survey Items
Q. 1: Reflect on and correct my ***misconceptions*** about teaching young children mathematics. Q. 2: Reflect on and correct my ***misconceptions*** about how young children learn mathematics Q. 3: Reflect and correct my misconceptions about the subject matter of the mathematics I am going to teach Q. 4: Overcome my feelings of incompetency in engaging young children in solving mathematical problems. Q. 5: Be critical about the needs and characteristics of children when thinking about my teaching strategies Q. 6: Think carefully through my decisions about suitable ways to cater for children's needs and characteristics in teaching mathematics. Q. 7: Focus on content of the mathematics I will be teaching in my teaching strategies.	Q. 1: Engage children in learning mathematics for meaningful understanding as I reflect on and correct my misconceptions. Q. 2: Implement a learner-centred approach in my mathematics lesson to help children learn mathematics effectively. Q. 3: Assist children to overcome their anxieties by engaging them in problem solving. Q. 4: Assist children to overcome their anxieties by engaging them in using manipulatives. Q. 5: Assist children to overcome their incompetency by engaging them in problem solving. Q. 6: Focus my instructional decisions on the interest of my students Q. 7: Create opportunities for effective communication and sharing (active participation and discussion) of ideas among children in my teaching	Carney *et al.* (2014) recommend that teachers' PD should empower them to consider student's ideas constructively. Carney *et al.* (2014) recommend that the teacher's PD should empower him/her to address learners' misconceptions about mathematics and learning mathematics and to focus on the structure of the mathematics as sets of interrelated concepts and procedures. Problem-based learning is being advocated and is receiving more attention compared to rote learning in the new instructional practices in South Africa (Mosoge & Taunyane, 2012). There is a growing emphasis on promoting a learner-centred teaching and learning approach over teacher-centred strategies in the new instructional reforms in South Africa (Mosoge & Taunyane, 2012). There is a strong recommendation to shift emphasis in professional instructional practices from knowledge transmission to knowledge transfer (Mosoge & Taunyane, 2012). Carney *et al.* (2014) and Mosoge and Taunyane (2012) recommend that a teacher's PD should empower him/her to promote the student's conceptual understanding of mathematics subject matter and shift emphasis to learner engagement for meaningful learning in order to eliminate the teacher-centred instructional approach .

Table 4.2: The response-eliciting items in the light of literature

Section C: Survey items eliciting PSTs' perceived changes/improvement in PD	**Section D:** Survey items eliciting PSTs' perceived affordances of the changes/improvements in PD	Recommendations Supporting Survey Items
Q.1: The mathematical concepts and procedures I will be teaching young children. Q.2: How young children learn about number operations and relationships. Q.3 How to assist young children to find answers to problems by/when using different strategies. Q.4: How to explain to young children why mathematical procedures work. Q.5: How to explain solution methods in problem solving to young children. Q.6: How to explain the similarities and differences among young children's representations, solutions, or methods in a problem. Q.7: How to assist young children to solve problems requiring multiple ideas and strategies. Q.8: How to access young children's thinking around mathematical ideas in learning. Q.9: How to help young children connect their mathematical ideas in problem solving. Q.10: How to assess young children's understanding of mathematical ideas and procedures.	Q.1: Explain to young children why mathematical procedures work. Q.2: Provide a problem-solving learning environment for enhancing young children's interest in problem-solving. Q.3: Assist young children to find answers to problems by/when using different strategies. Q.4: Explain solution methods or strategies in problem-solving to young children. Q.5: Explain my understanding of the similarities and differences among children's representations, solutions, or methods on a problem. Q.6: Assist young children to solve problems requiring ideas and strategies known or unknown to them. Q.7: Assist young children to solve problems requiring multiple ideas and strategies. Q.8: Help young children connect their mathematical ideas in problem-solving tasks. Q.9: Select appropriate activities and resources for helping young children's thinking in problem-solving. Q.10: Use effective questioning skills to access young children's thinking in solving a problem. Q.11: Plan and implement mathematics lessons that cater for young children with different learning abilities. Q.12: Critically reflect on the effectiveness of my teaching methodologies in dealing with young children. Q.13: Use concrete materials to assist young children to understand mathematical ideas and procedures. Q.14: Assess young children's understanding of mathematical concept and procedures.	Carney *et al.* (2014) and Mosoge and Taunyane (2012) recommend that a teacher's PD should empower him/her to promote student's conceptual understanding of mathematics subject matter and shift emphasis to learner engagement for meaningful learning in order to eliminate the teacher-centred instructional approach. Carney *et al.* (2014) also recommend that a teacher's PD should empower him/her to encourage multiple strategies and models in teaching and learning mathematics, especially in problem solving. Carney *et al.* (2014) recommend that teacher's PD should empower him/her to address learners' misconceptions about mathematics and learning mathematics and to focus on the structure of the mathematics, as set of interrelated concepts and procedures. There is a strong recommendation to shift emphasis in professional instructional practices from knowledge transmission to knowledge transfer (Mosoge & Taunyane, 2012).

4.3.2.1. The response-eliciting items with reference to the ETE's teaching expertise

ETEs' teaching expertise has been noted as a phenomenal source of PSTs' PD (Levin, 2014: 51), thus supporting the purpose of this study. ETEs have been observed to be capable of motivating their students; conveying concepts to their students; and helping PSTs to overcome their learning difficulties (Kreber, 2002: 9). Furthermore, the suggestion that the ETE should have knowledge about PSTs' pre-conceptions about mathematics and the teaching and learning of it, for example, by Levin (2014: 50) is an indication of the fact that ETEs consider the PD of PSTs in mathematics education to be very important (Ambrose, 2004: 116). The above issues regarding the ETE's teaching expertise motivated the following response-eliciting questions.

Question **1** in section **E** elicited responses on question about the influence of the ETE's teaching expertise on changing PSTs' beliefs about the mathematics they were going to teach and the teaching and learning of it. Support for this question came from Yang and Leung (2011: 1010) and Levin's (2014: 51) argument that expert teaching in mathematics becomes more influential on learning outcomes in a socio-cultural context which gives PSTs the golden opportunity to learn to develop their teaching knowledge. Most importantly, extensive research is showing that teachers' developing professional identities are being influenced by the socio-cultural context, among others, that they are exposed to (Levin, 2014: 49), from which the ETE's teaching expertise could not be left out. The author explains further that research has shown that PSTs' pedagogical beliefs (for example beliefs about what makes mathematics teaching effective) are influenced by being exposed to the ideas of teacher educators (p. 51).

Question **2** elicited responses about the influence of the ETE's teaching expertise on developing PSTs' CK. Yang and Leung (2011: 1009) have shown that the ETE's command of mathematics subject matter knowledge is very a crucial component of the ETE's teaching expertise, for which supported was found in Shim and Roth (2008). Since mathematics expert teaching has been noted to be well articulated in a social–cultural context, it could be expected that the PSTs could improve the quality of their CK as they access the ETE's mathematics teaching expertise. Yang and Leung (2011) also added that PSTs could be said to be developing their CK if this exposure to the ETE's teaching expertise is helping them to improve their understanding of mathematics subject matter knowledge and also to plan mathematics instructions skilfully.

Question **3** sought responses on the influence of the ETE's teaching expertise on developing the pedagogical content knowledge (PCK) of PSTs. PCK is noted to be a necessary requirement for a teacher educator to be referred to as an expert teacher (Yang & Leung, 2011: 1009). It should be noted that the central mission of initial teacher education in mathematics is to empower future teachers with the desired professional mathematical knowledge and skills (König *et al.*, 2014: 79). This question was based on the arguments that mathematics teaching expertise is best articulated and shared both in social-cultural contexts and in context-driven opportunities (Yang & Leung, 2011; Levin, 2014). Therefore it could be possible to inquire from the PSTs about the influence on developing their PCK of the mathematics teaching expertise they experienced.

Li and Even (2011: 760) also argue that developing professionalism require PSTs to develop expert teaching knowledge (PCK) from the ETE's mathematics teaching expertise.

The set of questionnaires used in this study is included in the appendices.

4.3.3. The structure of the questions in the interviews

The interview questions required PSTs to recall and reflect (König, 2013: 1003) on very significant situations or scenarios when their learning experiences were influenced by the ETE's teaching expertise. In doing so, the questions were challenging them to examine the phenomenal influences of the attributes of teaching expertise on their beliefs, CK, and PCK. More specifically, the interview questions challenged the PSTs to reflect and then describe or explain their experience of the phenomenal influence of the ETE's teaching expertise on their professional growth or changes. The above questioning orientations could be considered suitable alternatives to König's (2013: 1000) strong conviction that empirical testing in research is the best way to provide information about PSTs' acquisition of professional teaching knowledge, which aims to promote the improvement of teacher education.

The interview questions followed the same layout as the questions in the questionnaire, for the purpose of triangulation of data – qualitative views regarding perceived changes in their PD and perceived affordances of the changes, to be compared with the pattern in survey responses (DiCicco-Bloom & Crabtree, 2006: 316; Small, 2011: 64)., The interview questions therefore also had five sections (A, B, C, D, and E) developed by the researcher. Section **A** inquired from about PSTs' perceived improvement regarding their beliefs, misconceptions, and attitudes

towards the mathematics they were learning to go and teach and the affordances of those improvements. This was consistent with the following research questions:

i. What transformation does the PSTs' perceive in their beliefs about mathematics and teaching and learning of mathematics?
ii. What affordances do the PSTs perceive from the improvements they perceive in their beliefs about mathematics and teaching and learning of mathematics?

Section **B** inquired about PSTs' perceived improvements in their understanding of the mathematics CK and the affordances those improvements. Likewise, the researcher, in section **C**, inquired about PSTs' perceived improvement in their developing PCK for Foundation Phase mathematics and the affordances of such developing PCK. Both sections **B** and **C** helped the researcher to answer the research questions presented below:

i. What improvements do the PSTs' perceive in their understanding of the mathematics CK and development of their PCK for Foundation Phase mathematics?
ii. What affordances do the PSTs perceive from the perceived improvement in their understanding of the mathematics CK and development of their PCK for Foundation Phase mathematics?

These were followed by section **D** which elicited their viewpoints about which component(s) of the PD was or were most improved. This was linked to the research question: "Which of the three dimensions of their professional development (i.e. beliefs, content knowledge and pedagogical content knowledge) is most/least influenced by the dimensions of the teaching expertise of the expert teacher educator?"

Finally, the questions in section **E** required them to identify one (1) or more aspects of the ETE's teaching expertise which was or were strongly connected with the changes in their beliefs, CK, and PCK which they claimed. This was connected to:

i. Which of the three dimensions of their professional development (i.e. beliefs, content knowledge and pedagogical content knowledge) was most/least

influenced by the dimensions of the teaching expertise of the expert teacher educator? and

ii. Which of the dimensions of the ETE's teaching expertise influenced the PSTs' PD most/least?

The set of interview protocols used in this study may be found in the appendices.

4.4. RESEARCH METHODOLOGIES: QUANTITATIVE AND QUALITATIVE METHODS

The quantitative method involved a survey in which the investigator used the developed questionnaire for data collection (Rowley, 2014: 308). The quantitative data which were generated were analysed to obtain measures of the improvements perceived by the PSTs about their PD over the period in which they were exposed to the ETE's teaching expertise in the 3rd-year Foundation Phase mathematics module. This method significantly helped to reduce errors and increase objectivity in the data generation and analysis phases of this study (Creswell, 2003: 7-8). The quantitative method (survey or administration of the questionnaire) also made it possible for the researcher to obtain a large number of responses within a shorter time frame, compared to what would have been possible with the qualitative method (face-to-face interviews) (Rowley, 2014: 309). Collecting qualitative data using face-to-face interviews, for example, would require more time and the researcher as such would only get the required information from very few respondents, making it extremely difficult to generalise the research findings from the qualitative results. In addition to gaining a wider coverage of the respondents' perceptions about their PD, using the questionnaires made it possible for the researcher to generate objective findings that are generalisable (Rowley, 2014: 310). Like qualitative researchers, quantitative researchers in the social sciences undertake investigations to elicit people's perceptions in connection with their experiences with different social phenomena, e.g. the benefits they derive from, say, their membership of a particular social network site (Rowley, 2014: 310). This shows that using questionnaires in the current research to elicit PSTs' perceptions about PD during their interactions with the ETE's teaching expertise was appropriate.

On the other hand, the researcher designed interview questions for interviews in the qualitative method. Despite this method's weakness in generalising findings over a large population, its potential in generating a range of insights and understandings of the problem under investigation cannot be under estimated (Rowley, 2014: 310). Interestingly, both quantitative and qualitative researchers unanimously agree that the qualitative method is most suitable for gaining complex understanding of a problem when the subjects who hold the key to understanding the problem are clearly identified by the researcher (Rowley, 2014: 310). This also supports the use of face-to-face semi-structured interviews to ascertain the PSTs' perceived improvements and perceived affordances of improvement in the PD resulting from their learning experiences with the ETE's teaching expertise in the 3rd-year Foundation Phase mathematics module. In-depth interviews, for example semi-structured interviews, are regarded as empirical studies for generating "rich" qualitative data in understanding the development of educators' professionalism (Murray, 2006: 385). The use of semi-structured interview questions, in this method, helped to obtain in-depth information from the PSTs on their perceptions about their PD. This was consistent with Krauss's (2005: 764) claim that: "The goal of a qualitative investigation is to understand the complex world of human experience and behaviour from the point of view of those involved in the situation of interest", thus getting in-depth information (details of personal opinions) which might not be covered in the quantitative data (Guest, 2013: 142).

It has been shown that the use of questionnaires was extremely valuable to enable possibly adequate data generation; minimising errors and ensuring validity and reliability in data collection and analysis; and potential generalisation of the findings from this study. To get deeper insight into the subjects' perceptions (own viewpoints and ensure their validity) (Krauss, 2005: 764) about their PD (improvement their beliefs/perceptions, CK, and PCK) during their interaction with the teaching expertise of the ETE, the interviews that were conducted were very instrumental. In all, the research methodologies with their embedded methods and instruments assisted in deeply understanding the research problem and answering the research questions backed by deeper knowledge.

4.4.1. The value of study participants' perceptions in qualitative research

Investigating people's viewpoints and their interpretations of a given phenomenon experienced or being experienced is at the heart of all social science research (Krauss, 2005: 765). Researchers in this field, generally qualitative researchers, are of the opinion that they are able to grasp the participants' own viewpoints in their investigations, hence, eliciting the perceptions of study subjects is regarded "…as a crucial criterion of adequate social science" (Krauss, 2005: 764). More to the point, eliciting people's perceptions in qualitative research has been highly recognised by qualitative researchers because they believe that failure to elicit their perceptions of their experiences could be de-motivating to their development and progress (Krauss, 2005: 765). The arguments presented above support the focus and value of the current investigation. Thus, involving the PSTs directly in this investigation about their own PD could prove to be highly motivational to them because their voices were considered important in evaluating their training and achievements.

4.4.2. Piloting of the instruments

The researcher ensured that the development of both the questionnaire and interview protocol for study took into account the research interest as well as the respondents' understanding, sensitivity, and interpretation of issues directly related to their learning (Rowley, 2014: 310). Arber (2001: 60) has pointed out that potential non-sampling errors usually occur in the processes and stages of instrumentation, data collection and data analysis, for example, "poor questionnaire design", interviewer/observer bias, and "coding errors". Addressing the reliability and validity of all the research data was considered very significant in giving credibility to final interpretations and conclusions from the study. The researcher also understands that the reliability and validity of the quantitative and qualitative data largely depended on the reliability and validity of the contents of the questionnaires and interviews. Therefore, the researcher took effective measures to minimise or eliminate potential errors which were associated with the instruments developed by pilot testing the instruments (Wilkins & Woodgate, 2008: 27) and consulting relevant available expertise.

In developing the research instruments, validity was first and foremost achieved to a greater extent by consulting experts in the field (Kerrigan, 2014: 8), including the promoter of the project, the statistician, and the cooperating ETE. Over all, the measures taken by the researcher during the data collection process included excluding the participants in the pilot exercise from the actual data collection processes (Brown *et al.*, 1999: 303). This was an advance measure taken by the researcher to ensure the validity of the data obtained from both quantitative and qualitative methods. Using the standardised instruments on the actual sample that did not have any idea of how questions looked and sounded thus ensured the reliability and validity of the outcomes.

4.4.2.1. Piloting the questionnaire

The purpose of the pilot study was to test the instrument's reliability and validity in providing reliable and valid scores, which led to standardisation of it for the actual survey (Rowley, 2014: 315; Buchholtz *et al.*, 2013: 110). Onwuegbuzie and Leech (2005: 378) argue that sound research must provide a measure of reliability scores to authenticate its final findings and interpretations. For example, in order to ensure the reliability and validity of their questionnaire, Mosoge and Taunyane (2012: 191) sought expert statisticians' verification in addition to pre-testing the questionnaires. In the current study the reliability and validity of the developed questionnaires was established by seeking the advice of the researcher's promoter, the ETE, and the statistician and then piloting the questionnaires before actual data collection started (Pearce *et al*., 2014: 25). The researcher also ensured that the questions were understandable or self-explanatory from the perspective of the respondents (Rowley, 2014: 312).

The researcher found a sample of PSTs who were enrolled in mathematics teacher preparation courses similar to those in the main study (Rowley, 2014: 315) for the purpose of piloting. In this pilot study the researcher administered the questionnaires and received responses from **42** PSTs enrolled in similar initial teacher education programmes from different teacher education institutions: **10** responses were from institution **A** and **32** responses from institution **B**. The researcher widened the search for volunteers from other institutions where the PSTs were willing to participate because it was difficult to get all respondents from one institution.

After receiving the questionnaires from the respondents, the researcher sought an expert's help in analysing the data. The researcher needed Chronbach's alpha outputs for the various themes (except single-item themes) to demonstrate the reliability of the instrument (questionnaire) that had been developed for collecting the data that showed that the items/scales could produce a consistent and reliable measure of the responses being elicited, for worthy and trusted conclusions/inferences. The researcher identified four major analytic themes and their sub-themes. The Chronbach's alpha outputs for the four major analytic themes and their sub-themes are shown in Table **4.3**:

Table 4.3: The Chronbach alpha outputs for the themes

Scale	Alpha	Number of items	N (sample size)
Respondents' (PSTs') perceived transformation/changes in their beliefs about the subject matter of mathematics and the teaching and learning of it	*α=0.882647*	7	42
Enhance reflection on learning and actions	*α*=0.915377	3	42
Enhance mathematical competence	-	1	42
Critical about learner needs	*α=0.526838*	2	42
Improve content-focused	-	1	42
Respondents' (PSTs') perceived affordances of the changes in PSTs' beliefs about subject matter of mathematics and the teaching and learning of mathematics	*α=0.913263*	7	42
Promote learning mathematics for meaningful understanding	-	1	42
Capable of adapting learner-centred approach	-	1	42
Overcome anxieties and incompetence in learning	*α=0.832099*	4	42
Focus instructional decisions on learners' interests	-	1	42
Create ample opportunities for active learners' participation	-	1	42
Evaluation of PSTs' perceived improvement in their understanding of mathematics CK and development of PCK	*α=0.924455*	10	42
Improvement in understanding of content knowledge	*α=0.801343*	4	42
Improvement in pedagogical content knowledge	*α=0.886392*	6	42
PSTs' perceived affordances of the improvements in their mathematics understanding of CK and development of their PCK	*α=0.972247*	14	42
Ability to work/articulate with understanding of content knowledge	*α=0.956204*	7	42
Ability to work/articulate with pedagogical content knowledge	*α=0.938650*	7	42

The calculated Cronbach's coefficient or "alpha" statistics seemed to indicate an acceptable level of reliability and validity (i.e. $\alpha \geq 0.7$) for all the major analytic themes and their sub-themes, except for "Critical about learner needs" with $\alpha < 0.7$. Overall, the instrument thus could be seen as reliable in producing trustworthy results. The researcher used the pilot study to improve the clarity, design, and style of the instrument (i.e. questions constituting the instruments) to enhance its efficiency in the main study (David, 2011: 88; Rowley, 2014: 312/315).

4.4.2.2. Proof of interview protocol's reliability and validity

To ensure the clarity, simplicity, appropriateness of the interview questions, the researcher made an effort to arrange face-to-face or telephone interviews with either the respondents of the piloted questionnaires or any other PSTs in the same category. However, none of the options mentioned here was possible within the period of piloting the research instruments. Nonetheless, the clarity, simplicity, and appropriateness of the interview protocol could be assumed to have been achieved based on the fact that the questions prepared for the interviews were similar to the questions piloted in the questionnaire. So, if reliability and validity of content were achieved by piloting the questionnaires, it could be assumed that the interview protocol would achieve the same status to a fair extent. The researcher additionally was in constant consultation with the ETE and the promoter of this project for their expert advice (Kerrigan, 2014: 8; San, 1999: 20) throughout the development and revision of both the questionnaire and interview protocols up to the piloting stage. The developmental stages of the interview protocol were very important in ensuring the content validity of the interview questions, even though piloting it would have increased the content validity.

The consultations with and inputs of the experts mentioned above were very necessary to ensure that the researcher had acquired the desired interview skills for the main study and to improve the potential of the questions for achieving the desired results in the main study. These achievements were optimised when the researcher and the experts evaluated the interview questions to ascertain the clarity, simplicity, understandability, appropriateness, and duration of the interviews (Rowley, 2014: 312; Onwuegbuzie & Leech, 2005: 380). The experts were satisfied with the questions in general regarding clarity and duration. Their contributions in reshaping and improving the questions were considered. Overall, expert advice/guidance was

very instrumental in ensuring the quality of the research instruments developed by the researcher (Rowley, 2014: 315)

4.4.2.3. The approval of research instruments

All the instruments that were used to collect data for the study were approved by the Institutional Research and Planning, Department Ethics Screening Committee and the University's Research Ethics Committee before the researcher used them in the main study. This has been the traditional processes that all researchers in the University have to pass before they are able to start their field studies.

4.5. THE SAMPLING SCHEME AND SAMPLE SIZE

4.5.1. Sampling scheme (convenience/purposive sampling)

Samples are subsets of a population which are used in research for the purpose of obtaining accurate findings that can be generalised over the actual population (Arber, 2001: 59; Onwuegbuzie & Collins, 2007: 281). From among the 24 available sampling schemes, the researcher chose to use convenience sampling because it was seen as the most suitable for the study (Wilkins & Woodgate, 2008: 27; Bryman, 2007: 9). This was a longitudinal study that focused on the 3rd–year PSTs in Foundation Phase mathematics, therefore the choice of the participants was consistent with the purposive sampling scheme (Buchholtz *et al*., 2013: 110: Levin, 2014: 62) whereby "groups and individuals that are conveniently available and willing to participate in the study" were used (Rowley, 2014: 319; Onwuegbuzie & Collins, 2007: 286). It has been observed that purposive sampling is very popular among both qualitative and quantitative researchers, more so among researchers in the social sciences (Pearce *et al*., 2014: 23; Onwuegbuzie & Collins, 2007: 284; Rowley, 2014: 318). Using purposive sampling here in this mixed methods research project thus amounted to harnessing the compatibility of both quantitative and qualitative methods, which are seen by others as incompatible or un-integrable (Onwuegbuzie & Leech, 2005: 377; Small, 2011: 61; and Doyle *et al.*, 2009: 177 and 183). Pearce *et al*. (2014: 23) made a slight distinction claiming that purposive sampling is very effective in qualitative methods, while convenient sampling is suitable for quantitative methods, but what is important is that the uniqueness of both are embedded within one mixed methods

design. Thus, either sampling scheme (purposive or convenience sampling) again provided an opportunity to utilise the potential advantages of both research methods in understanding research problems (Östlund *et al.,* 2011: 370; Small, 2011: 64; Onwuegbuzie & Leech, 2005: 383). Additionally, the suitability of purposive sampling could allow for both statistical and analytical generalisations to be made in this study (Onwuegbuzie & Collins, 2007: 283; Hanson *et al.,* 2005: 224).

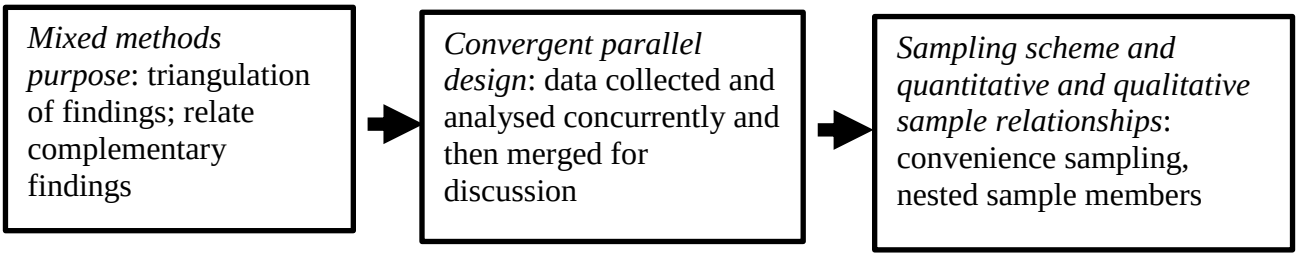
Furthermore, the decision to use the purposive sampling scheme (i.e. convenience sampling**)** was motivated or informed by the research goal, objectives, purpose, questions, researcher's time and resources, and the possibility of generalising the findings (Onwuegbuzie & Collins, 2007: 285). Thus, the samples (i.e. sample for the quantitative & sample for the qualitative) were chosen to suit the interest of the research (Kaiser & Vollstedt, 2007: 5). The project's goal was to add to our understanding of the PSTs' perceived PD in learning to teach from the ETE's teaching expertise, by surveying (to gain deeper insights from both quantitative and qualitative results) the PSTs' perceptions about their PD. The project's objective was to elicit the PSTs' own explanations and interpretations of the perceived improvements in their PD from their learning experiences with the ETE's teaching expertise. The project's purpose was to merge both the quantitative and qualitative findings in order to triangulate the findings: find the convergence or divergence of the PSTs' perceptions; and find evidence of complementary or contradictory findings in the subjects' perceptions regarding the improvements in their PD (Doyle *et al.,* 2009: 178).

It will be helpful to point out that in both quantitative and qualitative methods, the researcher used the same sampling technique (purposive/convenience sampling) which helped in minimising the risk and complications of using different sampling techniques (Onwuegbuzie & Collins, 2007: 281-282 & 290), even though the sample sizes differed – a large sample size was used for quantitative method and a small sample size for the qualitative method. This choice by the researcher was motivated by Onwuegbuzie and Collins' (2007: 284) argument that very successful mixed method projects have used purposive sampling in both quantitative and qualitative approaches in their efforts to achieve their research goals, objectives, and purposes.

It is equally important to note that the convenience sampling used for both the quantitative and qualitative phases of the investigation was consistent with what Onwuegbuzie and Collins (2007: 292 & 295) have described as "concurrent design using nested samples". This describes the relationship between the quantitative and qualitative samples, whereby one sample (a smaller sample) is obtained from the other sample (a bigger sample). In this project, the qualitative sample was obtained from the quantitative sample. The relationship between this study's purpose, design, and sampling design described above is summarised below in Figure **4.2**:

Figure 4.2: Relationship between mixed methods purpose, design, and sample

Source: Onwuegbuzie and Collins (2007: 292-295).



4.5.2. Sample size/members

Ideally all PSTs attending mathematics education modules in the university would have been involved in this study (Arber, 2001: 59). These were student teachers between the ages of 21 and 25 years. However, due to time and financial constraints (Arber, 2001: 59), this investigation had to be limited to the PSTs who were attending the 3rd-year Foundation Phase Mathematics Module in the 2015 academic year. More importantly, this group of PSTs was recommended by several lecturers because 3rd-year students comprised the group that would be most likely to show changes in their PD.

All the third-year Pre-service Foundation Phase Mathematics teachers (about eighty-seven (87) in number) were invited to voluntarily participate in the survey (Devlin & O'Shea, 2012: 395). This was the sample for the collection of survey data. The sampling procedure was purposive (i.e. convenience sampling) because the researcher did not intend to leave out any student who was willing to participate (Onwuegbuzie & Collins, 2007: 286) from this group attending the 2015 academic year's Foundation Phase Mathematics Module. However, seventy-one (71) of

these students voluntarily participated in the first survey phase and fifty-nine (59) participated in the second survey phase of this study.

During phase of collecting data through interviews, the participants who volunteered (Frykholm, 1999: 85) were from one of the existing English-speaking groups in the large sample of about eighty-seven (87) PSTs. This small group was used for the purpose of interviews. Dealing with a relatively small group, as in this case, was because of time constraints, and also because the researcher was able to work intensively with this small group (Arber, 2001: 59) during and after the interviews, for transcriptions, member checks, and analysis. Usually the membership of such groups does not exceed 8 PSTs working together to present lessons in micro-teaching projects. The selection of this group was also purposive, because the researcher relied on the group that volunteered to participate in the interviews (Thomas & Beauchamp, 2011: 764). Only six (6) from this group of eight PSTs, participated voluntarily in the first interview phase and five (5) in the second interview phase.

The sample sizes for both methods, 87 for quantitative and 8 for qualitative, were reasonable because they were within the range of sample sizes recommended by both quantitative and qualitative researchers (Onwuegbuzie & Collins, 2007: 287-289). Sheridan (2013: 59), for example, also conducted interviews with six to eight PSTs – similar in number to the six to five PSTs involved in this current study. The possibility of reaching data saturation point with the sample size of six to five PSTs is worth emphasising at this point (Onwuegbuzie & Collins, 2007: 289) – it is neither too small nor too large for generating interview data. Though the sizes vary, it could help in achieving "meaningful data convergence and comparison" (Wilkins & Woodgate 2008: 27; Jang *et al*., 2008: 222) to a fair extent, thus contributing to meaningful interpretation and answering the research questions and achieving research aims and objectives.

Variations in sample sizes are very common in mixed methods designs similar to the current study, which have not posed any potential threat to reliability and validity of the research findings (Wilkins & Woodgate, 2008: 27). To enhance the effectiveness of the convergence and comparisons, the research subscribed to Wilkins and Woodgate's proposition that situations of this kind (unequal sample sizes) could be handled by "… stating that comparison of the data is limited by the discrepancy in sample size" (p. 27).

Getting such a massive amount of data could represent the views of the population of the PSTs in the university fairly well. According to Rowley (2014: 310), most survey studies using questionnaires involve a relatively large number of respondents – in the neighbourhood of 100 to 1000, which this study's sample size satisfied. In Rowley's (2014: 317) view, a research study could be regarded as more robust and as offering exciting opportunities for generating a wider range of insights if the researcher obtained 100 or more responses from the participants in the study. For example, this study's sample of 71 PSTs could be close to Sheridan's (2011: 3) sample of 161 cohort of PSTs; Sheridan's (2009: 60) sample of 183 and a cohort of 129 PSTs in the same study; and much higher than Hudson and Ginn's (2007: 7) sample of a cohort of 59 PSTS; but much closer to Hudson's (2009: 67) sample of a cohort of 106 PSTs. It is worth noting that all these studies also used purposive sampling techniques.

4.5.3. Addressing sampling error

The researcher's aim was to be able to possibly generalise the findings obtained from the sample of PSTs used in this study over the population of PSTs in the same category, i.e. student teachers in the Foundation Phase mathematics programme (Arber, 2001: 58-59).

However, it is worth acknowledging that samples and sampling processes could have potential errors such as an incomplete sampling frame; non-response errors; and selection errors (Arber, 2001: 60); these were fairly minimised by using the convenience sampling scheme. The use of purposive sampling addressed the above potential errors that are mostly associated with a random sampling method, for example. Non-response errors were minimised in this study when the researcher administered the questionnaires to all the 3rd-year PSTs at a time when the majority of them were attending the same lecture at the same time, and ensured high a return rate (Macnab & Payne, 2003: 56-57): all of the 71 questionnaires were responded to, all sections/items were completed, and all were returned. The researcher achieved an appreciable response rate (of above 70%) from the sample, which is within the desired range of response for both the survey and interviews (Arber, 2001: 60-61).

4.5.4. The viability of the sample members (3rd-year PSTs)

To enhance the sample's representativeness, the 3rd-year PSTs were considered a suitable sample because they were at the stage in initial teacher education at which they had had much more

exposure to the essence of professional learning and training than 1st- and 2nd-year PSTs, but slightly less than 4th-year PSTs along the continuum of the package of professional learning and training experiences. For this reason, the researcher considered investigating the PD of the PSTs at this stage as very viable. This consideration is much closer and similar to Borko *et al.*'s (1992: 196) claim that they focused on final year PSTs as the their study sample in one of their research projects. Comparatively similar investigations about the PD of PSTs who might not have had adequate exposure to professional learning and training- compared to 3rd year PSTs in this study have been conducted by Jegede *et al*. (2000: 292), Hudson and Ginn (2007: 7) and Hudson (2009: 67) which involved 2nd year PSTs. Jegede *et al*.'s study involved very few 3rd-year PSTs. The researcher has been informed that students graduate at the end of their 3rd year in some university programmes and start practising their professions, for example teaching, so the 3rd-year PSTs were seen as representative of the population of the PSTs, and therefore it was worth focusing on them as the sample.

4.6. DATA COLLECTION PROCEDURE

The researcher collected data through surveys and interviews to accomplish the goal and objectives of the study, Data collection procedures generally took place concurrently – the survey and interview sessions were undertaken separately within the same period (Hanson *et al.*, 2005: 227; Wilkins & Woodgate, 2008: 27; Kerrigan, 2014: 5). The researcher elaborates each method, detailing what was done and how it was done towards achieving the research aims and objectives in the sections that follow.

4.6.1. Ethics and considerations

The survey processes strictly complied with the university's research ethics. The researcher sought ethical clearance and permission from Institutional Research and Planning, Department Ethics Screening Committee and the University's Research Ethics Committee (Nicholas, Ng & Williams, 2010: 280: Patrick & McPhee, 2014: 6). The researcher then administered the first set of questionnaires to all the PSTs to be completed anonymously and on a voluntary basis (Patrick & McPhee, 2014: 6). The participants were informed well in advance of the researcher's visit and the purpose of the visit, by the lecturer (Rowley, 2014: 319). The researcher encouraged

mass voluntary participation (Nicholas *et al.*, 2010: 280) as well as ensuring compliance with the institution's research ethics (Rowley, 2014: 317). This activity was completed within an hour.

The researcher strictly followed the rules of ethics that guide conducting the interviews in the study's context, more especially by acquiring the informed consent of the interviewees, obtaining approval from Institutional Research and Planning, Department Ethics Screening Committee and the University's Research Ethics Committee, and the lecturer who facilitated the module (Thomas & Beauchamp, 2011: 764). The researcher explained the purpose of the interviews and the proposed distribution of the research findings in detail to the interviewees, (Whiting**,** 2008; 39). In compliance with interviewing ethics, the interviews furthermore were conducted at the convenience of the interviewees regarding times, venues, the duration of interviews, and the voluntary nature of participation (Devlin & O'Shea, 2012: 388; Frykholm, 1999: 85). In addition, the interviewees were assigned anonymous identities throughout the study to ensure privacy and confidentiality (Rowley, 2014: 317).

According to DiCicco-Bloom and Crabtree (2006), ethical issues relating to interviews include "reducing the risk of unanticipated harm; protecting the interviewee's information; effectively informing interviewees about the nature of the study; and reducing the risk of exploitation". These aspects guided the researcher in dealing with interviewees and the information obtained (p. 319). In anticipation of unforeseen stress or psychological implications due to the process, the researcher was ready to provide psychological assistance to interviewees to relieve participants of such (DiCicco-Bloom & Crabtree, 2006: 319). The researcher protected the interviewee's information by means of the safety net of anonymity to protect the subjects' information and identity from reaching the public domain (DiCicco-Bloom & Crabtree, 2006: 319). Whiting **(**2008; 39) agrees with Levine's (1981) emphasis, that "the information that each participant shares with the researcher should not be passed on to others in any form, unless specific consent has been given". The researcher therefore ensured that all recorded conversations (audio and written), like the hard copies of data, were kept in the promoter's office in a safeguarded cabinet and scanned copies of data were kept in a "password-locked" file on the researcher's laptop. Following final transcription and validation exercises, the data were stored as explained, to be destroyed after five years. This was done in support of DiCicco-Bloom and Crabtree (2006: 318) who point out that recorded data should be protected from unauthorised access and must be

destroyed after transcriptions and analysis. In reducing the risk of exploitation, the researcher also avoided exploiting participants for his own interest, and rather acknowledged their contributions towards the success of the research (DiCicco-Bloom & Crabtree, 2006: 319).

4.6.2. The survey process

Two sets of anonymous questionnaires were used in the current research to collect quantitative data for the study (Wilkins & Woodgate, 2008: 27; Frykholm, 1999: 86; Rowley, 2014: 309). According to Rowley (2014: 309), questionnaires are frequently used by quantitative researchers to elicit the frequencies of the occurrence of people's opinions, attitudes, experiences, processes, behaviours, or predictions. This supported the reason for using questionnaires in this study. Researchers in the social sciences most especially, have found questionnaires to be very useful in ascertaining people's perceptions about the benefits they derive from, say, membership of a particular social network (Rowley, 2014: 310). The two questionnaires were the same in structure and content (Nicholas *et al.*, 2010: 280). "Before and after" surveys that measured teachers' beliefs about the nature of mathematics and students' learning; confidence regarding their own knowledge in mathematics; and their preparedness to teach mathematics given their learning outcomes in a mathematics PD programme have been conducted previous to the current study (Carney *et al.,* 2014: 13-14). Carney *et al.* (2014) remarked that this method of data collection is recommended, especially when evaluating changes in teachers' PD resulting from exposure to certain interventions or experiences. The only difference was that, while the questionnaire for the beginning of the academic year elicited PSTs' perceptions about the their own PD resulting from their learning experiences (i.e. the impact of all factors in the ecology on their PD)**,** the questionnaire for the end of the academic year (3rd year) elicited PSTs' perceptions about the influence of the ETE's teaching expertise on their beliefs, CK, and PCK during their 3rd-year learning experiences in the Foundation Phase mathematics module at the university.

The current survey was conducted at two different times (Hativa, 1998: 360-361) of the 2015 academic year, which was less than the four (4) series questionnaires administered to PSTs in Nicholas *et al.'*s (2010: 280) research in an academic year. The first survey was conducted at the beginning of the first semester in the 3rd year (February, 2015) of the 2015 academic year, and the second survey was conducted after the last lecture (October 2015) in this module in the 2015 academic year. The reason for conducting two surveys was to determine the change in the PSTs'

beliefs, CK, and PCK by comparing their perceptions before and after their learning experiences in the 3rd-year Foundation Phase mathematics module (Hudson & Ginns, 2007: 7; Thomas & Beauchamp, 2011: 764). In support of this, Chong *et al.* (2011: 62) said that "since the development of a teacher's professional identity begins even before they enter the pre-service programmes, there is a need to explore subjects' perceptions about teaching at the point of entry into the programmes and compare them with their perceptions at the point of exit".

In both surveys, the questionnaires were administered by the researcher himself (Rowley, 2014: 319). Administering and following up to retrieve the questionnaire by the researcher himself ensured a high rate of return (Mosoge & Taunyane, 2012: 192; Macnab & Payne, 2003: 56-57). This strategy was also very helpful, because the researcher had the opportunity to explain the purpose of the research to the PSTs who volunteered to respond to the questionnaire and clarify issues concerning completing the questionnaires responsibly and meaningfully (Mosoge & Taunyane, 2012: 192).

Detailed instructions were provided on the questionnaire, in addition to information about the purpose of the questionnaire. The researcher was available to address concerns and questions regarding the completion of the questionnaire. All terms and conditions that applied to the administration of the first questionnaire also applied to the administration of the second questionnaire.

4.6.3. The interviews

4.6.3.1. The interview instruments

Semi-structured interviews were used to collect qualitative data, (Wilkins & Woodgate, 2008: 27). The researcher used the interview protocol, audio tape recorder, and notebook to collect data during the interviews (Kaiser & Vollstedt, 2007: 5). The researcher ensured that the recorder was in good working order before the time of actual data collection, but had made provision for back-up recorders in case of any unforeseen malfunctioning of the instrument well in advance (DiCicco-Bloom & Crabtree, 2006: 318).

During the interview sessions, the researcher combined audio recording and note taking for collecting data; in Whiting's (2008: 36) view, these are recognised instruments. Though both

instruments were used, the researcher prioritised the use of the audio recorder throughout the process and only resorted to note taking when other interesting questions emerged from the conversation/dialogue (Whiting**,** 2008: 39).

4.6.3.2. The planning phase

Prior to actual interviews, the researcher planned the interviews according to the following guidelines:

- Constantly reminded the participants in advance of the designated time
- Agreed with the participants outside their busy events
- Basing the discussions on a set of predetermined questions
- Made provision for questions which could emerge from the dialogue
- Planned not to exceed one hour (DiCicco-Bloom & Crabtree, 2006: 315; Whiting**,** 2008: 36)

Guided by the highlights above the researcher conducted the interviews during the leisure hours of the PSTs; created an environment conducive to interviewing; and efficiently and effectively managed the duration within an hour to avoid inconveniencing the subjects and to ensure retrieving quality data.

The researcher practiced to develop and enhance the required personal skills for the interview in advance by identifying and practising with a "good informant" (Whiting, 2008: 36) – just to practise the technique with him. Morse, in Whiting (2008: 36), advises novices to identify someone "knowledgeable about the topic; able to reflect and provide detailed experiential information about the area under investigation" and enthusiastically ready to talk. Prior to the interview, the researcher tried to establish a healthy personal relationship with the interviewees in order to minimise the negative influence of differences in "gender, professional background, ethnicity and age" on the process (Whiting, 2008: 36).

4.6.3.3. The interview phase

In "Learning to Teach Mathematics", one of their research projects, Borko *et al.* (1992: 196) collected data via interviews to assess PSTs' subject matter knowledge and PCK at different times during the final year of their preparation, which is similar to the current study's aim of using semi-structured interviews to elicit PSTs' perceptions about the development of their CK, PCK, and the changes in their beliefs after interaction with an ETE. In order to achieve the goal of conducting this interview, the researcher was guided by a clearly determined objective, similar

to Brown *et al.*'s (1999) interview objectives: the first interviews elicited PSTs' perceptions about their PD before they were exposed to the ETE's teaching expertise, while the second (final) interviews elicited PSTs' perceptions about the "changes that occurred over the year in terms of knowledge and attitudes" (p. 303).

It should be noted that those were the main sources of reflection which evoked other related issues for discussion with reference to the problem under investigation (Bryman, 2007: 10). In other words, the main objective for the current interviews was to get wide and in-depth coverage of viewpoints to understand and interpret the PSTs' perceptions of the changes or improvements in their PD over one year, after having been exposed to the teaching expertise of an ETE. However, the number of interviews in the current study (i.e. two interviews) was fewer than Brown *et al.*'s semi-structured interviews conducted thrice (p. 303).

The researcher himself conducted the face-to-face semi-structured interviews with each member in the group of eight PSTs (Brown *et al.*, 1999: 303; Devlin & O'Shea, 2012: 388). Compared to structured interviews, a semi-structured interview allows the interviewee maximum opportunities to contribute to the discussion by expressing his/her personal opinion (DiCicco-Bloom & Crabtree, 2006: 314). More especially, using a semi-structured interview protocol facilitated the emergence of new ideas as the participants were able to influence their own views, and both the researcher and participants were able to detect the deeper meaning of the subjects' experiences, because the influences of past experiences on the current state of affairs become explicit through such interviews (Kerrigan, 2014: 8). DiCicco-Bloom and Crabtree (2006) also noted that semi-structured interviews are usually considered strong enough to constitute a study's component of qualitative data, compared to normal practices of combining participant observations with structured interviews which also constitute a set of qualitative data for research (p. 315). The authors' views above could find support in Jang *et al*. (2008), who are convinced that interview data could sometimes outweigh quantitative data because the qualitative data obtained from interviews potentially reveal "contextually sensitive information …" about the problem under investigation (p. 242). To say the least, the semi-structured interviews provided the entire study's source of data enrichment (Kaiser & Vollstedt, 2007: 5; Macnab & Payne, 2003: 57).

In this study, preference was given to individual over group face-to-face interviews for the following reasons (DiCicco-Bloom & Crabtree, 2006: 315). First, in order to obtain a reasonable amount of data sets and ensure quality in-depth information, the researcher did not consider the 6/5 PSTs involved in the qualitative data collection phase as one unit, but as individuals (Frykholm, 1999: 85). Secondly, though the data obtained in group interviews could be enriched by a variety of experiences and opinions in response to a particular interview question, in-depth information based on individual perspectives could be lacking in the quality of the data. Thirdly, there is the likelihood that the most outspoken individuals in the group would dominate the discussion, while the rest remain observers (DiCicco-Bloom & Crabtree, 2006: 315). Fourthly, the nature of group interviews makes it extremely difficult to obtain in-depth information from individuals at same time, because the group thought of as one unit just like an individual (DiCicco-Bloom & Crabtree, 2006: 315)., The set of research questions guiding this study moreover asked for the individual's perceptions about his/her PD, which could best be understood and answered satisfactorily by data obtained through individual in-depth interviews (DiCicco-Bloom & Crabtree, 2006: 316). Hence, the researcher interviewed the individuals in this group who volunteered to take part (Whiting**,** 2008: 36). This provided more insight into the issue under investigation (Smith & Strahan, 2004: 360).

Though small (Da Ponte & Chapman, 2008: 254), the researcher was convinced that, with this sample size (the interviewees), the participants' in-depth perspectives about the problem under study could give further insight for understanding and interpreting the perceptions of the PSTs (Macnab & Payne, 2003: 57 & 59; Doyle *et al*., 2009: 177). Due to the fact that the variables and issues investigated in mathematics teacher education "… are intimately related to personal meaning, institutional practices, traditions…", most research studies involving pre-service mathematics teacher education are done on a relatively small scale using qualitative approaches (Da Ponte & Chapman, 2008: 254). This is supported by Hesse-Biber's (2010: 456) claim that, "qualitative data allow for the experiences of respondents to be voiced within the research project".

The interviews were conducted in English with participants from the English-speaking group attending the module. Srnka and Koeszegi, (2007: 31) support this when they said that "…using a "lingua franca" (usually English) in data collection and transcription can be considered as a

good and pragmatic alternative". The researcher conducted two interviews in the entire study to be able to track changes in the PD of the PSTs over the period of one year (Thomas & Beauchamp, 2011: 764). The interview sessions and the survey sessions were conducted concurrently. The first interview was conducted after the first survey, and the second interview was conducted after the second survey. The interview questions (see appendices 3 and 4) were based on the research questions, aims and objectives, just like the survey items, for the purpose of learning from the self-perceptions of the student, in relative terms, about the level, change, improvement, growth, or progress in their PD with reference to the influence of the teaching expertise they experienced with their trainer (the ETE).

In order to obtain quality data, the researcher developed positive relationships with the participants in the interview processes, as suggested by DiCicco-Bloom and Crabtree (2006: 316-317). In their view, this relationship can last longer if it is accompanied by trust and respect for participants and the information they are sharing with the researcher. In the interviews, the researcher ensured that there was a safe and comfortable environment for sharing confidential information. Furthermore, the researcher monitored the progress of his personal rapport with the interviews by following DiCicco-Bloom and Crabtree's four phases suggested for managing personal relationships in in-depth interviews, which are the apprehension phase, exploration phase, co-operation phase and participation phase.

Apprehension describes the initial phase of the interview, and the researcher's main challenge was to break the strangeness and uncertainty of the interview context and to get the interviewee talking confidently. As the authors suggest, the researcher asked the first question, repeating it in several forms and allowing the interviewees time to listen and think about their responses. Then the researcher followed up on their responses with prompts to gain clarification of their responses, thus getting them in the mood for talking. The researcher was very careful not use leading prompts instead of prompts provoking reasoning. The researcher made sure that the interviewees shared more information at this stage and also ensured that the information given him were expressions of the participants' own opinions in their own words.

During the exploration phase of the interviews, the researcher explored the active interview environment for more information, having stimulated the participants to engage in the

discussion. In this phase the context of the interviews turned more into information sharing, as both the interviewer and participants were keenly learning, listening, testing, and sharing information. Then, during the co-operative phase, both the interviewer and the interviewees were in the comfort zone of interaction, it then was very easy for anyone to comfortably seek clarification and correction of misunderstandings and misinterpretations. The researcher managed the interaction at this phase, which made it possible for relatively sensitive questions to be asked best during this phase. The researcher ensured that interactions became very interesting during this phase. Eventually, the co-operative phase led into the participation phase during which the interviewer maximised quality data collection by taking advantage of the new role of the interviewees, who in the course of the interviews felt so comfortable sharing their experiences that they were deeply involved in giving out more information till the point of saturation was reached.

The interview questions required the respondents to reflect on self (Da Ponte & Chapman, 2008: 247) and describe their learning experiences in the module; the teaching they experienced from the expert teacher educator; and their perceptions of the influence of the exemplary teaching they experienced on their PD – beliefs, CK, and PCK. Da Ponte and Chapman explain that reflecting on self-learning experiences plays an important role in fostering the PD of PSTs , because it allows the PST to attend to his/her own ongoing PD as a mathematics teacher; it gives him/her the opportunity to explore the relationship between his/her personality, personal experiences and pedagogy; it becomes an alternative to formal and external feedback, assessment, or the evaluation mechanism which the PST uses to evaluate his/her own ongoing learning and development; and it assists the PSTs to construct and critique their own mathematical and educational identities (p. 247). To a greater extent, reflection is an invaluable asset in the package of the PSTs' PD, just like their knowledge of the discipline (Da Ponte & Chapman, 2008: 247).

The researcher effectively used 'prompt' questions to get the interviewees to repeat a key concept in their responses, thus getting clarification and in-depth information (Devlin & O'Shea, 2012: 388). Whiting (2008) was convinced that using "prompt questions can ensure that the key issues are addressed and the flow of the interview is maintained" (p. 37). But the author cautioned interviewers to be careful in planning and using prompt questions in order not to be

leading the participant to a response (p. 37). To a fair extent, the researcher phrased prompt questions that engaged the interviewees in reflecting and identifying their actual experiences and feelings (Whiting, 2008) and reconstructing meaningful responses to the main questions.

According to Whiting (2008: 37), citing Moser and Kalton (1979), "the interviewer's expectations can affect the participant's response" more often than not. The researcher minimised this effect to a fair extent by using 'probing questions' to explore the learning experiences of the PSTs in order to generate more knowledge about the problem under investigation (Whiting, 2008: 37). As DiCicco-Bloom and Crabtree (2006) and Whiting (2008: 37) suggested, engaging interviewees in in-depth descriptions of their experiences was extremely useful while the interview was in progress. Whiting (2008) has added that this was time when probing questions became very relevant in generating responses from the participants (p. 37).

Finally, the researcher transcribed the interviews by listening to the recordings repeatedly so as to maximise the chance of getting detailed results (Kaiser & Vollstedt, 2007: 5; Thomas & Beauchamp, 2011: 764). To ensure accuracy of the transcribed data for interpretation, the researcher further listened to the recording several times while reading the transcribed paper (DiCicco-Bloom & Crabtree, 2006: 318).

4.6.4. Validity and reliability of the interview

After the transcription of the audio recordings, the researcher returned the transcripts to the participants to verify whether the transcripts were a true representation or reflection of their own personal views (Wilkins & Woodgate, 2008: 28). The researcher's use of member checking to triangulate the data at this stage made it possible to obtain possible feedback from the interview participants and factor it in to ensure the reliability and validity of the data before analysing them (Jang *et al.*, 2008: 229; Brown *et al*., 1999: 303). After the analysis, the researcher repeated the member checking process by giving the PSTs a summary of the report for final verification before the interpretation of their perceptions in the overall findings (Onwuegbuzie & Leech, 2005: 380; Jang *et al*., 2008: 229). Jang *et al*. (2008) refer to this activity as "Parallel Integration for Member Checking". It was purposefully meant to engage the research participants in the verification phase of the quantitative and qualitative findings to ensure that the findings and interpretations actually reflected their own views about the phenomenon. The authors said that

"We asked for their critical comments on the preliminary findings, and the participants' feedback was addressed in the subsequent data analysis" (p. 233). The interview responses were compared with the questionnaire responses: this involved cross-checking responses for inconsistencies and bias, thus improving validity and enhancing triangulation. Validity in both data sources was increased by dropping the pilot group from the main sample (Brown *et al*., 1999: 303).

4.7. DATA ANALYSIS PROCEDURE

Data analysis followed immediately after the data collection phases. The quantitative and qualitative data were analysed separately, before merging them for the subsequent analysis (Hanson *et al.,* 2005: 227; Wilkins & Woodgate, 2008: 25; Kerrigan, 2014: 5) involving comparing and contrasting the results (statistical and qualitative comparisons of results).

4.7.1. The quantitative data analysis

Data from the survey series constituted the study's quantitative data. Each PST had two data entries (Carney *et al*., 2014: 12) from before and after their interaction with the ETE's teaching expertise. The researcher used both descriptive (Kerrigan, 2014: 8) and inferential statistical techniques (Hudson & Ginns, 2007) to analyse the data. The quantitative data obtained were entered into an Excel spread sheet to calculate percentages/frequencies (Nicholas *et al.*, 2010: 281). Mean scores of the major themes and their sub-themes were also computed. A mixed-model analysis of variance (ANOVA) and Fisher's Least Significant Differences (LSDs) were conducted to compare mean scores obtained for statistical difference (Kesicioğlu, 2015: 88). In addition, measures of reliability of the results (i.e. Cronbach's alpha) were also computed. The measures of percentages (frequencies) give the descriptive summaries of the PSTs' responses to individual items, while the computations of ANOVA measures and Least Significant Differences (LSD) were employed to highlight further and specific differences in the means of the variable scores, as well as the means of the themes harmonising those variables. The analyses were linked

to the research questions guiding the study, thus looking at question at a time for deeper understanding.

4.7.2. The qualitative data analysis

According to DiCicco-Bloom and Crabtree (2006: 314), when an interviewer elicits the perceptions – explore meanings and opinions in order to gain deeper understanding of an issue – of the subjects in an investigation, the latter share their experiences and opinions on the phenomenon under investigation, while the former does the analysis and interpretation in the light of guiding aims, objectives, theories, and questions. This can be achieved optimally through qualitative research (Krauss, 2005: 763), thus the PSTs' unique meanings and interpretations of their experiences about the influences of the ETE's teaching expertise on their PD could be well understood through the qualitative component of this research. It is through qualitative data analysis that the researcher is able to "generate new levels and forms of meaning, which can in turn transform perspective and actions" (Krauss, 2005: 764). In this phase of the research, the investigator was guided by the epistemological considerations which guide qualitative data analysis:

> i) that face-to-face interaction is the fullest condition of participating in the mind of another human being, understanding not only their words but the meanings of those words as understood and used by the individual, and
> ii) that one must participate in the mind of another human being in order to acquire social knowledge (Krauss, 2005: 764)

The author added that the epistemological considerations above can give the researcher opportunities to gain deeper insight into how and why the subjects in his investigations develop or draw meanings/interpretations from experiences or their social settings (p. 764).

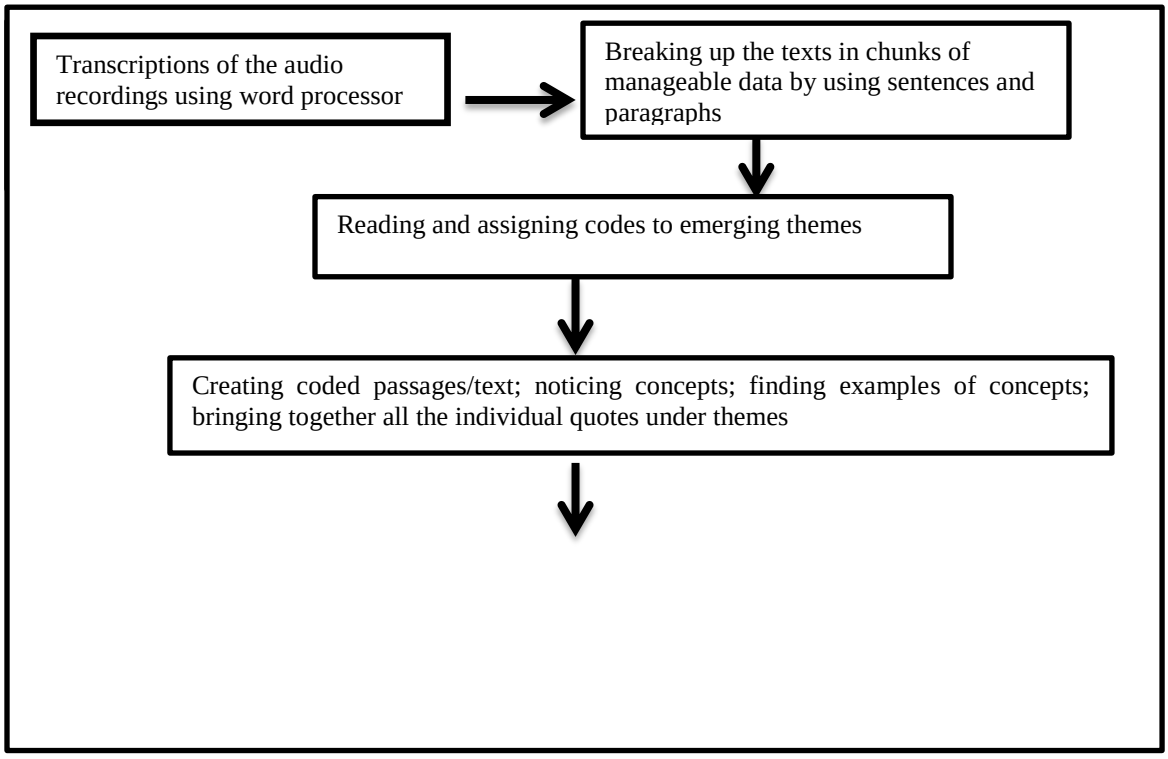
The provisional themes which were developed to guide the analysis of the survey data were also employed in the process of analysing the qualitative data (Brown *et al.*, 1999: 303). The audio records from the interviews first of all were manually transcribed verbatim (Thomas & Beauchamp, 2011: 765; Srnka & Koeszegi, 2007: 35; Frykholm, 1999: 85) to ensure that the transcripts were the true reflections of the PSTs' views for each question (DiCicco-Bloom & Crabtree, 2006: 318). The interview transcripts were manually analysed using the constant comparative method to generate conceptual themes from the subjects' responses (Thomas & Beauchamp, 2011: 765; Wilkins & Woodgate, 2008: 28; Bryman, 2007: 10; Kerrigan, 2014: 8).

In this method the transcripts were read carefully and notes were taken about significant impressions from the responses – regularities and patterns in the responses were explored by the researcher (Rowley, 2014: 326; Frykholm, 1999: 87). This enabled the researcher to effectively label phrases, sentences and words that were relevant, thus coding/indexing PSTs' opinions about what they were asked (Rowley, 2014: 326; Jang *et al.,* 2008: 230). The coding actually focused on ideas that were repeatedly emphasised in the responses or explicitly stated opinions relating to a particular question (Rowley, 2014: 326). Additionally, phrases, sentences and words that were related to literature sources and related theories or concepts were coded. Major themes representing PSTs' views about the influence of the ETE's teaching expertise on their PD were created from sub-categories of such opinions obtained during coding (Rowley, 2014: 326; Frykholm, 1999: 87; Kaiser & Vollstedt, 2007: 5). The researcher also looked for connections between the themes for deeper understanding of opinions expressed (Rowley, 2014: 326). This rigorous data analysis approach helped to maximise the potential for generating meanings and interpretations of the PSTs' perceptions about the influences of the ETE's teaching expertise on their PD (Krauss, 2005: 765).

The themes obtained from the transcripts were used to provide detailed descriptions of the results obtained from the interviews (Rowley, 2014: 326; Thomas & Beauchamp, 2011: 765). The descriptions were based on the connections and differences in opinion as expressed by the PSTs – not the opinions of the researcher. In all the above data analysis phases, the researcher was able to maximise the reliability and validity of the results by controlling his personal views and any preconceived knowledge from being imposed on the PSTs' interpretations of their experiences (Krauss, 2005: 764). Figure **4.3** presents a summary of this process, which is supported by Krauss' (2005: 764) opinion that qualitative researchers need to describe the processes of their data analysis approaches so as to guide our understanding of how conclusions are drawn in the study, because there are no standard templates for qualitative data analysis. The analysis of the data was done manually, as shown in Figure **4.3** below.

Figure 4.3: A manual step-by-step approach in qualitative data analysis

Source: Rowley (2014: 326)



In the subsequent chapters, the results obtained are used in the extensive interpretation and discussion of all the research results in the light of the literature review and the research questions**.**

4.7.3. Merging quantitative and qualitative results: towards interpreting the findings

The researcher understood and assumed that perceptions of the influence of the ETE's teaching expertise on their PD may differ from one PST to the other. It was therefore possible to find differing degrees of response (Kerrigan, 2014: 5) in the PSTs' perceptions regarding the influence of the ETE's teaching expertise on their PD. Kerrigan (2014) explains that some cases in a convergent parallel mixed method study may produce similar results while other cases may produce contradictory results. Based on the assumptions mentioned above, the researcher envisaged the possibility of any of the two outcomes – convergence or divergence – occurring from merging the quantitative and qualitative results. The probability of such occurrences is one of the reasons why both the quantitative and qualitative results were equally prioritised (Small,

2011: 64; Hanson *et al.*, 2005: 227; Hall & Howard, 2008; 251) as sources for drawing the study's conclusions, especially when the results diverged substantially (Kerrigan, 2014: 13). This could be similar to studies conducted by Jegede *et al*. (2000), Yeşilyurt (2013), Hudson (2009) and Hudson and Ginns (2007) in which only quantitative results were used in drawing conclusions.

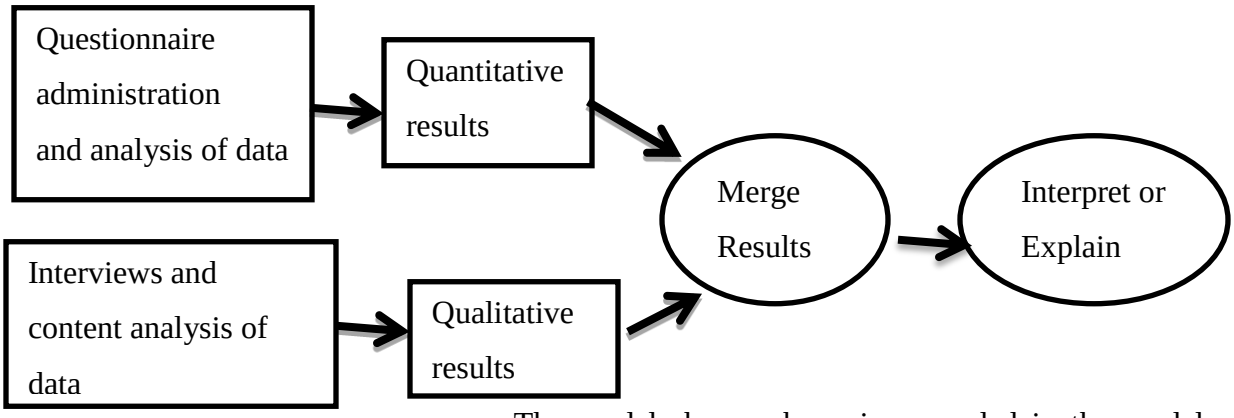
Beyond those possibilities, the second reason for merging the results was to find out how the two informed one another (support/explain each other), when both results converged, confirmed, or complemented each other (Krauss, 2005: 761; Small, 2011: 63-64; Wilkins & Woodgate, 2008: 25 & 28; Kerrigan, 2014: 6). This was achieved by comparing the results side-by-side and jointly displaying the results (Kerrigan, 2014: 13), for example in a table, to highlight the logical relationships between the converging findings and the theoretical propositions of the study more explicitly (Östlund *et al*., 2011: 371). With either convergent or complementary findings (Krauss, 2005: 761), the study's conclusions or inferences were made by drawing on both results (Jang *et al.*, 2008: 222; Wilkins & Woodgate, 2008: 28). Also, to enhance clarity or transparency in comparing and making inferences, the researcher transformed the quantitative findings into qualitative forms (Wilkins, & Woodgate, 2008: 28), thus "creating narrative descriptions" from the quantitative findings (Jang *et al.*, 2008: 229 and 233).

Having explained what, why, and how this critical stage of the mixed method contributed to achieving the aims and objectives of this study, it would be expedient to elaborate explicitly on the procedure. The researcher employed the convergent parallel design in the data collection and analysis. This design allowed data to be collected and analysed independently by both the quantitative and the qualitative methods before combining or merging these results for subsequent interpretation, inference and explanation with reference to the research problem and questions (Creswell, 2013: 40; Östlund *et al*., 2011: 370; Small, 2011: 68; Jang *et al.*, 2008: 222-223; Wilkins & Woodgate, 2008: 28). To enhance effective analysis and interpretation, the researcher compared PSTs' perceptions from all the data in the study to find out where these perceptions converge, diverge, confirm or contradict one another (Guest, 2013: 148; Östlund *et al.*, 2011: 370; Wilkins & Woodgate, 2008: 26). Beyond the point where the two sets of findings confirm or contradict each other, the merging phase was an opportunity to engage both in mutual debate or conversations about the phenomenon under investigation (Wilkins & Woodgate, 2008:

26). The figures (**4.4** and **4.5**) presented below show how the researcher utilised the convergent parallel designs in collecting, analysing and interpreting the data that were generated (Wilkins & Woodgate, 2008: 29; Kerrigan, 2014: 2). Wilkins and Woodgate (2008) have argued that graphically representing the design applied in the study would enhance understanding of the mixed methods better than word descriptions would. Guest (2013: 149) has argued that complexities in handling data (data collection and analysis) in mixed methods designs can be simplified by following a clearly defined model such as shown in Figures **4.4** and **4.5**.

Figure 4.4: Convergent Parallel Design

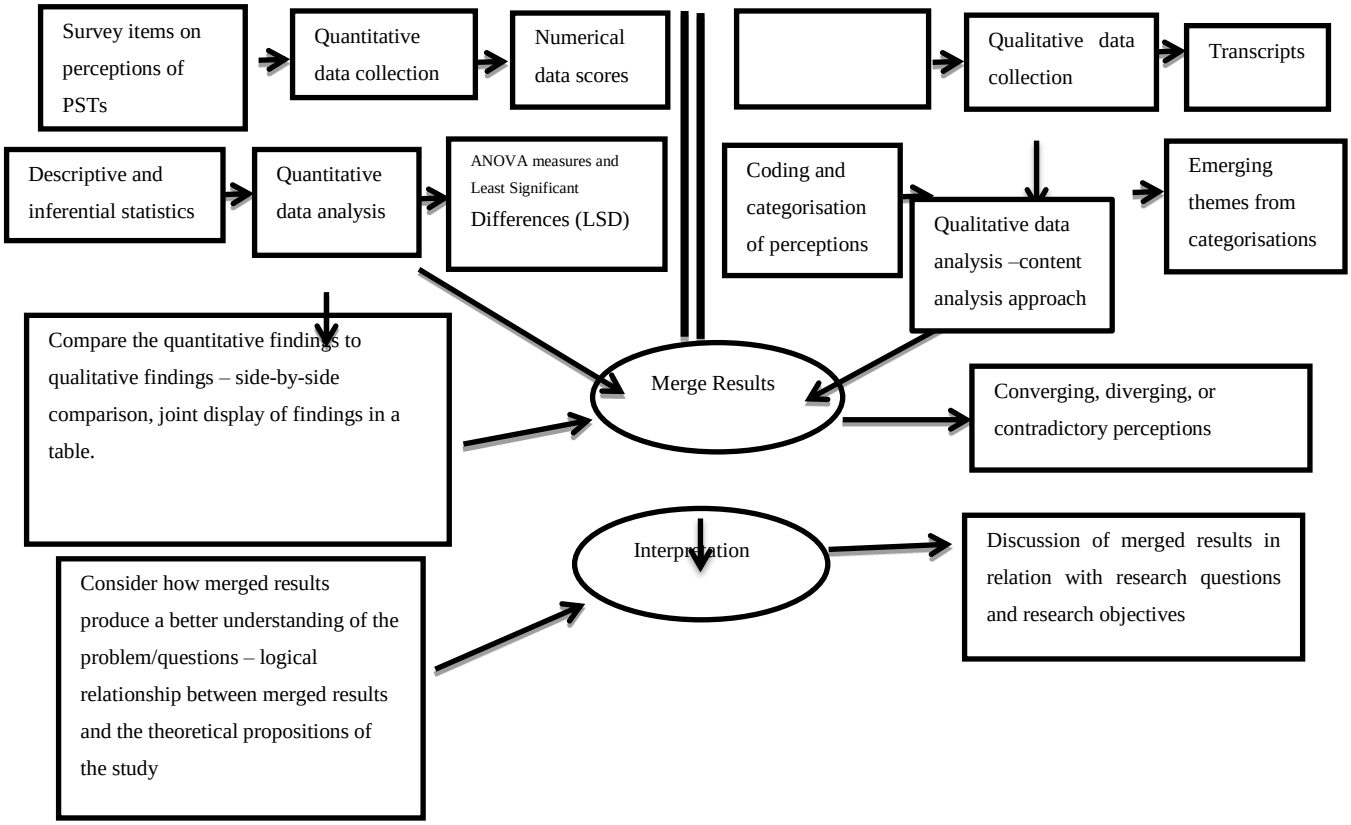
Source: Creswell (2013: 40)



The model shown above is expanded in the model shown below.

Figure 4.5: Details of the Convergent Parallel Design

Source: Creswell (2013: 45), as cited in Wittink *et al*. (2006)



4.8. CONCLUSION

In this chapter, the researcher declared that the overall design used was a mixed method comprising quantitative and qualitative approaches. The researcher was of the view that the research problem could be understood and explained or interpreted well by combining both quantitative and qualitative findings.

Questionnaires were used to collect quantitative data while semi-structured interviews were used to collect qualitative data. Both data sets were collected at the same time and analysed separately before merging the findings to draw meaningful conclusions about the problem under study. The

quantitative data were analysed using both descriptive and inferential statistical techniques, and the constant comparative approach was used to analyse the qualitative data. The major issues of ensuring the reliability and validity of the research data have also been explained in this chapter.

The interpretation of the findings from the two methods was optimised by comparing the results side-by-side and jointly displaying the results in a table. The methods supported one another in providing complementary data for understanding the problem under investigation.

5. CHAPTER 5
PRESENTATION, DISCUSSION AND INTERPRETATION OF THE RESULTS

5.1. INTRODUCTION

PSTs, as aspiring mathematics teachers, begin their professional training with different beliefs about the subject matter of mathematics (i.e. their views about what mathematics is) and how it should be taught and learnt, which they may eventually intellectually approve or disapprove of due to new experiences they encounter, such as the curriculum they learn, their lecturer's expertise, or different views/opinions they interact with during discussions. Similarly, prospective mathematics teachers begin their professional training with some understanding of the CK (mathematical concepts, procedures, facts, skills) they are learning to teach, which they may eventually intellectually approve or disapprove of, relearn, or unlearn when they encounter ecological teacher education experiences like the above. Equally important, future mathematics teachers begin their professional training with some apprenticeship understanding of how mathematics must be taught or how teaching mathematical concepts, procedures, facts, skills, are dealt with, from their experiences during school mathematics lessons or even with their parents, which they may eventually intellectually approve or disapprove of due to their exposure to new experiences such as those listed above. Such learning experiences and their accompanying outcomes in the teacher education setting motivated this investigation.

Against the background presented above, this study investigated the perceived changes/improvement in the PD (i.e. the learning outcomes) of prospective Foundation Phase mathematics teachers, who presumably experienced at least one of the scenarios of change in PD in the teacher education ecology described above. This chapter, in particular, presents and discusses the results obtained from the PSTs' perceived improvement in their entry characteristics after the impact of the teaching expertise experienced in the 3rd-year Foundation Phase mathematics module. The implications of the observed perceived improvement in the participants' PD for their future mathematical instructional capabilities are discussed simultaneously. In the following sections, results/findings for each method (i.e. Quantitative and Qualitative methods) are presented separately in the light of the research questions guiding this study. In the final section, both findings are merged to ascertain any likely confirmatory and/or

contradictory findings guided by the research questions. This was done for data collected in the two time series – results from PST's two-year learning experiences and results from PSTs' 3rd-year learning experiences.

To clearly delineate the extent to which the teaching expertise [in the 3rd-year module] experienced by these PSTs impacted on their PD, the findings from the assessment of the impact of the two-year training on the PSTs' PD were compared with findings from assessment of the impact of teaching expertise on the PSTs' PD.

5.2. ASSESSMENT OF THE PSTs' PD (PHASE A)

5.2.1. Survey Results (Phase A)

The PSTs responded voluntarily to the survey questions eliciting their perceptions of the impact of the two-year training on their PD while they were learning to teach mathematics. The data obtained from the survey were analysed to find empirical evidence from the subjects' responses in the survey to justify possible answers to the questions below:

i. What change(s)/improvement do the PSTs' perceive in their beliefs about mathematics and teaching and learning of mathematics?
ii. What affordance(s) do the PSTs perceive from the improvement they perceive in their beliefs about mathematics and teaching and learning of mathematics?
iii. What change(s)/improvement do the PSTs' perceive in their understanding of the mathematics CK and development of their PCK for Foundation Phase mathematics?
iv. What affordance(s) do the PSTs perceive from the improvement they perceive in their understanding of the mathematics CK and development of their PCK for Foundation Phase mathematics?
v. Which of the three dimensions of their professional development (i.e. beliefs, CK, PCK) is most or least enhanced?

The researcher is well informed that dealing with survey/questionnaire data/responses is an iterative process (Rowley, 2014: 309), similar to the analysis of qualitative data or interview responses. For this reason, the researcher pre-determined analytic themes to guide the quantitative data analysis. Pre-determining the analytic themes was very helpful in guiding the

analysis of overall patterns in the perceptions of the PSTs about their PD (Rowley, 2014: 310). The analytic themes comprise clusters of questions, in some cases single-item statements, to enhance the effectiveness of the data analysis procedure. First, the pre-determined analytic themes for the survey data were classified under two primary categories: perceived changes/improvement in PSTs' PD and perceived affordance(s) of the improvement in PSTs' PD. Under the primary theme ***perceived improvement in PSTs' PD***, two secondary themes were developed: *perceived changes/improvement in PSTs' beliefs about the subject matter of mathematics and the teaching and learning of mathematics*, and *perceived improvement in PSTs' CK* and *PCK*. To effectively manage and streamline the chunks of data, specific themes were further developed from the two secondary themes mentioned above.

Similarly, the primary theme ***perceived affordances of the improvement in PSTs' PD*** was expanded to generate the secondary themes: *perceived affordances of the changes/improvement in PSTs' beliefs about the subject matter of mathematics and the teaching and learning of mathematics,* and *perceived affordances of the improvement in PSTs' CK* and *PCK*. To make the analysis clearer, specific themes were also generated from the later themes. Table 5.1 summarises the themes and their connections:

Table 5.1: Thematic headings for statistical analysis

PRIMARY THEME: **Perceived improvement** in PSTs' PD	PRIMARY THEME: **Perceived affordances** of the improvement in PSTs' PD
Secondary Themes: Perceived improvement in beliefs/perception about subject matter of mathematics and teaching and learning of mathematics.	**Secondary Themes:** Perceived affordances of the changes in PSTs' beliefs about subject matter of mathematics and the teaching and learning of mathematics
Specific sub-themes Enhance reflections on learning and actions Enhance mathematical competence Critical about learner needs Improve content-focused	Specific sub-themes Promote learning mathematics for meaningful understanding Desire to adapt learner-centred approach Overcome anxieties and incompetence in learning Focus instructional decisions on learners' interests Create ample opportunities for active learner participation
Secondary Themes: Perceived improvement in PSTs' understanding of CK and development of PCK	**Secondary Themes:** Perceived affordances of the improvement in PSTs' understanding of CK and development of PCK
Specific sub-themes Improvement in understanding of CK a. Understanding of foundation mathematical concepts and procedures b. Understand how learners learn number operations and relationships c. Solve problems using different strategies d. Explain why procedures work they way they do Improvement in developing PCK a. Make connections between ideas and strategies in solving problems in teaching and learning b. Accessing and assessing learners' thinking and understanding in teaching and learning	Specific sub-themes Working with (articulate/demonstrate in teaching and learning) understanding of CK a. Can explain concepts and procedures to enhance learners' understanding b. Can implement problem-centered teaching and learning approach Working with (articulate/demonstrate in teaching and learning) PCK a. can effectively facilitate thinking and meaningful understanding of contents b. can select appropriate teaching and learning activities and resources

The statistical results are presented under the thematic headings in the Table **5.1**.

5.2.1.1. Overview of statistical analysis

The statistical analysis of the data obtained from the responses in the survey was aimed at generating both descriptive and inferential statistics. The researcher was interested specifically in reporting statistics involving percentages/frequencies; comparing mean scores for themes through the computations of mixed-model analysis of variance (ANOVA) measures and Least Significant Differences (LSD); and measures of reliability of the results (i.e. Cronbach's alpha). The measures of percentages (frequencies) gave the descriptive summaries of the PSTs'

responses to individual items under the respective secondary themes in tables. The emphasis of the tabular presentations was to show the overall trends revealed in the obtained responses for individual items, which could enhance the comparisons between the different viewpoints of the subjects in rating those variable/items. The significance of employing the mixed-model analysis of variance (ANOVA) measures and Least Significant Differences (LSD) were to highlight further and specific differences in the means of the variable scores, as well as the means of the themes harmonising those variables, thus ascertaining which learning outcomes improved over which. The results emerging from these analyses succinctly rated the thematic means and the variables constituting them. This helped to draw fairly accurate conclusions about the learning outcomes with reference to the guiding research questions.

The researcher needed the Chronbach's alpha outputs for the various themes (except single-item themes) to demonstrate the reliability of the instrument developed (questionnaire) for collecting the data – showing that the items/scales could produce a consistent and reliable measure of the elicited responses for worthy and trusted conclusions/inferences. Table **5.2** shows the Chronbach alpha outputs for the various themes:

Table 5.2: Chronbach's alpha for scales

Scale	Alpha	Number of items	N (sample size)
Perceived improvement in beliefs/perception about subject matter of mathematics and teaching and learning of mathematics	α = 0.767138	7	71
Enhance reflection on learning and actions	α = 0.617728	3	71
Enhance mathematical competence	-	1	71
Critical about learner needs	α = 0.598458	2	71
Improve content-focused	-	1	71
Perceived affordances of the changes in PSTs' beliefs about subject matter of mathematics and the teaching and learning of mathematics	α = 0.835941	7	71
Capable of learning mathematics for meaningful understanding	-	1	71
Capable of adapting learner-centred approach	-	1	71
Overcome anxieties and incompetence in learning	α = 0.828222	3	71
Focus instructional decisions on learners' interests	-	1	71
Create ample opportunities for active learner participation	-	1	71
Perceived improvement in PSTs' understanding of CK	α = 0.631022	4	71
Understanding of foundation mathematical concepts	-	1	71
Understand how learners learn number operations and relationships	-	1	71
Solve problems using different strategies	-	1	71
Explain why procedures work they way they do	-	1	71
Perceived improvement in PSTs' development of PCK	α = 0.756675	6	71
Make connections between ideas and strategies in solving problems	α = 0.645624	2	71
Accessing and assessing learners' thinking and understanding	α = 0.455342	2	71
Ability to work/articulate with understanding of CK	α = 0.657695	7	71
Can explain concepts and procedures to enhance learners' understanding	α = 0.473214	3	71
Can implement problem-centered teaching and learning approach	α = 0.518322	4	71
Ability to work/articulate with PCK	α = 0.765953	7	71
Can effectively facilitate learners' thinking and meaningful understanding of contents	α = 0.559262	3	71
Can select appropriate teaching and learning activities and resources	α = 0.608373	4	71

5.2.1.2. Presentation of Descriptive Statistics (Percentages and Frequencies)

Respondents' (PSTs) perceived transformations/changes in their beliefs about the subject matter of mathematics and the teaching and learning of it

The above theme was one of the major learning outcomes associated with the respondents' PD. Under this theme, PSTs evaluated their beliefs about mathematics and teaching and learning of mathematics. The PSTs indicated the extent to which the evaluation statements were relevant to the perceived transformation in their beliefs about mathematics and the teaching and learning of it. The Cronbach alpha measure for this major theme was 0.767138 with seven items and those of its sub-themes *enhance reflections on learning and actions* consisted of three items (α = 0.617728), while *critical about learner needs*, with two items, was 0.598458; both were slightly below the acceptable alpha co-efficient of 0.7 and above. The low alpha coefficients for the two scales could be due to the number of items being small. Moreover, this was a newly developed instrument for which such low alpha coefficients could be accepted. However, that being said, further analysis and inferences with these scales were articulated with caution. Table **5.3** presents the frequencies (percentages) of the PSTs' responses to all the items under this major theme and its sub-themes:

Table 5.3: Perceived transformation/changes in PSTs' beliefs about the subject matter of mathematics and the teaching and learning of it

Statement	**Scale**			
	SA	**A**	**D**	**SD**
Reflection to correct misconceptions about teaching	22 (31%)	46 (65%)	3 (4%)	0%
Reflection to correct misconceptions about child's learning	26 (37%)	45 (63%)	0%	0%
Reflection to correct misconceptions about subject matter of mathematics	9 (13%)	53 (75%)	9 (13%)	0%
Overcome feelings of incompetency	8 (11%)	41 (58%)	21 (30%)	1 (1%)
Critical about the needs and characteristics of children	25 (35%)	46 (65%)	0%	0%
Effective decisions to cater for children's needs and characteristics	28 (39%)	40 (56%)	3 (4%)	0%
Profound interest in CK	16 (23%)	49 (69%)	6 (8%)	0%

Key: SA = Strongly Agree; A = Agree: D = Disagree; SD: Strongly Disagree

Generally, the responses displayed in Table **5.3** seem to show that the PSTs perceived fair improvement in almost all seven (7) equally important indicators of change. However, the most improvement occurred, as the PSTs' claimed, in:

- *reflection to correct misconceptions about teaching (65%)*
- *reflection to correct misconceptions about child's learning (63%)*
- *being critical about the needs and characteristics of children (65%))*
- *taken effective decisions to cater for children's needs and characteristics (56%)*

The response pattern showed that almost all the PSTs either Agreed or Strongly Disagreed with the four claims above. The popularly recognised improvements registered above could contribute to the understanding of, or to answering the research question related to the major theme above: "what/which changes/improvement do the PSTs' perceive in their beliefs about the subject matter of mathematics and teaching and learning of mathematics?"

Respondents' (PSTs) perceived affordances of the changes in their beliefs about the subject matter of mathematics and the teaching and learning of mathematics

This theme represented the complementary component or manifestation of the major learning outcomes associated with the respondents' developing PD presented in Table **5.3**. Under this construct, PSTs assessed the impacts of the changes/improvement in their beliefs, above, on their teaching capacities. The PSTs indicated the extent to which the evaluation statements were relevant to the perceived affordances of their beliefs about the subject matter of mathematics and the teaching and learning of it. This major theme itself had a relatively high Cronbach alpha score of 0.835941 with seven (7) items. This theme consists of five (5) sub-themes of which four (4) have single items. The PSTs' responses to the three items constituting *overcome anxiety and incompetence* showed a relatively high Cronbach alpha ($\alpha = 0.83$). It should be added that the researcher was well informed about the necessity of being cautious about the single-item themes in any further analysis and inferences that would involve them. Table **5.4** below summarises the frequencies (percentages) of the responses under this theme:

Table 5.4: Perceived affordances of the transformation/changes in the PSTs' beliefs about the subject matter of mathematics and the teaching and learning of it

Statement	Scale			
	SA	**A**	**D**	**SD**
Can facilitate learners' meaningful understanding	15 (21%)	51 (72%)	5 (7%)	0%
Can promote learner-centred approach	21 (30%)	49 (69%)	1 (1%)	0%
Can overcome learners' anxieties through problem solving	23 (32%)	39 (55%)	8 (11%)	1 (1%)
Can use manipulatives to overcome learners' anxieties	17 (24%)	45 (63%)	9 (13%)	0%
Can overcome learners' incompetency through problem solving	17 (24%)	44 (62%)	9 (13%)	1 (1%)
Can take instructional decisions to suit learners' interest/needs	22 (31%)	45 (63%)	4 (6%)	0%
Can promote active learner participation and discussion	30 (42%)	35 (49%)	6 (8%)	0%

Key: SA = Strongly Agree; A = Agree: D = Disagree; SD: Strongly Disagree

The results shown in Table **5.4** reveal that the majority of the PSTs seemed to either Agree or Strongly Agree with all the evaluation statements. However, out of the seven equally important indicators of effective teaching behaviour, the PSTs seemed to be very convinced in their perceptions that the two-year training developed them adequately so that they would be able to:

- *facilitate learners' meaningful understanding (72%)*
- *promote learner-centred approach (69%)*
- *promote active learner participation and discussions (49%)*
- *can take instructional decisions to suite learners' interest/needs (63%)*

The recognised effective teaching capabilities registered above could contribute to understanding or answering the research question related to the major theme above: "what affordance(s) do the PSTs perceive from the improvement they perceive in their beliefs about mathematics and teaching and learning of mathematics?"

Evaluation of PSTs' perceived improvement in their understanding of mathematics CK and development of PCK

As with the major themes above, this theme also constituted major learning outcomes associated with the respondents' developing PD. Under this component of their PD, the PSTs evaluated the improvement in their understanding of the mathematics CK and development of their PCK for Foundation Phase mathematics. Accordingly, the PSTs indicated the extent to which the evaluation statements were relevant to the improvement they perceived in their understanding of the mathematics CK and the development of their PCK. The two (2) sub-themes under this theme had the following reliability measures and frequencies: *improvement in understanding of CK* (four items, $\alpha = 0.631022$) and *development of PCK* (six items, $\alpha = 0.756675$).

Table 5.5: Perceived improvement in PSTs' mathematics understanding CK and development of their PCK

Statement	**Scale**			
	SA	**A**	**D**	**SD**
Understand mathematical concepts, facts, and procedures	11 (15%)	55 (77%)	4 (6%)	1 (1%)
Understand how young children learn math	16 (23%)	48 (68%)	7 (10%)	0%
Understand how to assist learners to work with different strategies	18 (25%)	42 (59%)	11 (15%)	0%
Understand how to explain procedures	7 (10%)	33 (46%)	30 (42%)	1 (1%)
Understand how to explain solution methods in problem solving	6 (8%)	51 (72%)	13 (18%)	1 (1%)
Understand how to explain similarities and differences among different representations, solutions, or methods	13 (18%)	45 (63%)	13 (18%)	0%
Understand how to assist learners to solve problems requiring multiple ideas and strategies	8 (11%)	50 (70%)	12 (17%)	1 (1%)
Understand how to access learners' thinking	8 (11%)	47 (66%)	15 (21%)	1 (1%)
Understand how to help learners to connect their mathematical ideas in problem solving	9 (13%)	41 (58%)	21 (30%)	0%
Understand how to assess learners' understanding of mathematical ideas and procedures	6 (8%)	55 (77%)	9 (13%)	1 (1%)

Key: SA = Strongly Agree; A = Agree: D = Disagree; SD: Strongly Disagree

The results displayed in Table **5.5** show that the majority (between 55 and 33 of 71 respondents) of the PSTs seemed to "Agree" with all the evaluation statements, rather than "Strongly Agree", "Disagree" or "Strongly Disagree". This means that at least 50% of the PSTs agreed that they perceived improvement in those indicators of change or improvement against which they

assessed their PD. The result further shows that out of the 10 equally important indicators of change, the improvement seemed to be higher in their perception that the teaching expertise experienced adequately improved their understanding of:

- *how to assess learners' understanding of mathematical ideas and procedures (77%)*
- *mathematical concepts, facts, and procedures (77%)*
- *how to explain solution methods in problem solving (72%)*
- *how to assist learners to solve problems requiring multiple ideas and strategies (70%)*

It could be said that the dominant improvements registered above could contribute to understanding or answering the research question related to the theme above, of: what change(s)/improvement do the PSTs' perceive in their understanding of CK and development of their PCK in Foundation Phase mathematics? It could be said that the PSTs perceived fair improvement regarding all the indicators of change, however, the majority seemed to claim more improvement in the four (4) indicators of improvement highlighted above.

Interestingly, these four improved aspects could be compatible and it can be said that they, as such, could effectively facilitate one another. One obvious reason could be that the PSTs' *understanding of mathematical concepts, facts, and procedures* could be a necessary and sufficient condition to enable them to *assess how others understand* them. Similarly, improvement in a teacher's understanding of *how to explain solution methods in problem solving* would require some *understanding of the mathematical concepts, facts, and procedures*. It is an equally necessary and sufficient condition that a teacher understands *how to explain solution methods in problem solving* in order to productively *assist learners to solve problems requiring multiple ideas and strategies*.

Again, it could be inferred that the subjects' previous claims that they perceived improvement in their *reflection and correction of misconceptions they had about mathematics subject matter* and *the teaching and learning of it*, as found in Table **5.3,** above, could possibly motivate the four development discovered above. Certainly, when PSTs *reflect and correct their misconceptions about the subject matter* they are learning to teach, it could manifest in the improvement reported here.

Categorically, while *improvement in their understanding of mathematical concepts, facts, and procedures* concern their improving CK, *improvement in their understanding of how to assess learners' understanding of mathematical ideas and procedures; how to explain solution methods in problem solving;* and *how to assist learners to solve problems requiring multiple ideas and strategies* could be associated with their developing PCK.

PSTs' perceived affordances of the improvement in their understanding of mathematics CK and development of their PCK

This theme was the complementary component or manifestation of the major learning outcomes associated with the respondents' developing PD discussed above (see table **5.5**). Under this component of their PD, PSTs assessed their abilities to deliver as mathematics teachers given their perceived improvements in their CK and PCK. They indicated the extent to which the evaluation statements were relevant to the perceived affordances of the perceived improvements in their CK and PCK. The two (2) sub-themes under this theme, had the following measures of reliabilities: ability to work with /articulate understanding of content knowledge (i.e. *Working with CK*) (7 items, $\alpha = 0.612597$); ability to work with /articulate pedagogical content knowledge (i.e. *Working with PCK*) (7 items, $\alpha = 0.765953$).The frequencies of the PSTs' responses to all the statements under this theme are shown in table **5.6** below.

Table 5.6: Perceived affordances of improvement in the PSTs' mathematics CK and PCK

Statement	Scale			
	SA	A	D	SD
Can explain why mathematical procedures work	3 (4%)	38 (54%)	30 (42%)	0%
Can provide a problem-solving learning context	11 (15%)	48 (68%)	12 (17%)	0%
Can assist learners to finding answers using different strategies	8 (11%)	57 (80%)	6 (8%)	0%
Can explain solution methods or strategies to learners	6 (8%)	57 (80%)	8 (11%)	0%
Can explain the similarities and differences among children's representations, solutions,	9 (13%)	48 (68%)	14 (20%)	0%
Can assist learners to solve problems using ideas and strategies known or unknown to them	8 (11%)	48 (68%)	15 (21%)	0%
Can assist learners to solve problems requiring multiple ideas and strategies	6 (8%)	51 (72%)	14 (20%)	0%
Can help young children connect their mathematical ideas	7 (10%)	55 (77%)	8 (11%)	1 (1%)
Can select appropriate activities and resources for effective learning	12 (17%)	48 (68%)	11 (15%)	0%
Can use effective questioning skills to access learners' thinking	11 (15%)	48 (68%)	12 (17%)	0%
Can plan and implement mathematics lessons that suit learner needs	15 (21%)	28 (39%)	27 (38%)	1 (1%)
Can critically reflect on the effectiveness of my teaching methodology	11 (15%)	45 (63%)	15 (21%)	0%
Can use concrete materials to improve meaningful understanding	22 (31%)	47 (66%)	2 (3%)	0%
Can assess learners' understanding	6 (8%)	55 (77%)	9 (13%)	1 (1%)

Key: SA = Strongly Agree; A = Agree: D = Disagree; SD: Strongly Disagree

The results shown in Table **5.6,** above, revealed that the majority (between 57 and 28 out of 71 respondents) of the PSTs seemed to "Agree" with all the evaluation statements rather than "Strongly Agree", "Disagree" or "Strongly Disagree". This means that above 50% (excepting one indicator that scored below 50%) of the PSTs agreed that they perceived they could deliver those indicators of effective teaching capability in a Foundation Phase mathematics classroom. With these dominant views, however, concerning the 14 equally important indicators of effective teaching behaviour, the PSTs seemed to be very convinced in their perceptions that the teaching expertise they experienced had adequately developed them to be able to:

- *assess learners' understanding (77%)*
- *help young children connect their mathematical ideas (77%)*
- *explain solution methods or strategies to learners (80%)*

- *assist learners to solve problems requiring multiple ideas and strategies (72%)*
- *assist learners in finding answers using different strategies (80%)*
- *use concrete materials to improve meaningful understanding (66%)*

It is worth noting that the best improvement occurred in the PSTs' claims that they were able to use concrete materials to improve meaningful understanding. The pattern in their responses show that almost all the PSTs either Agreed or Strongly Agreed that they perceived that they could use concrete materials to improve meaningful understanding.

The recognised effective teaching behaviours registered above could contribute to understanding or answering the research question related to the major theme above, of: "what affordance(s) do the PSTs perceive from the improvement they perceive in their understanding of CK and development of their PCK in Foundation Phase mathematics?"

Undoubtedly, these affordances, too, could be very compatible with PSTs' perceived improvement discussed in Table **5.5**. For example, the *improvement in their understanding of mathematical concepts, facts, and procedures,* as well as *improvement in their understanding of how to assess learners' understanding of mathematical ideas and procedures* could effectively facilitate their capability in *helping young children connect their mathematical ideas*; *assisting learners to find answers using different strategies; assisting learners to solve problems requiring multiple ideas and strategies;* and *explaining solution methods or strategies to learners.* That is to say that their perceived *understanding of mathematical concepts, facts, and procedures* as well as *understanding how to assess how learners' understand* them constitute the necessary and sufficient conditions to enable PSTs in *helping young children connect their mathematical ideas*; *assisting learners to find answers using different strategies; assisting learners to solve problems requiring multiple ideas and strategies;* and *explaining solution methods or strategies to learners.*

In addition, it could be envisaged that, for example, perceived improvement in their *reflection and correction of the misconceptions they had about mathematics subject matter and the teaching and learning of it,* could facilitate the perceived changes and affordances of the changes the PSTs are claiming at this stage. Indeed, when they *reflect on and correct their*

misconceptions about the subject matter they are learning to teach, it could manifest in the chain of effects (i.e. improvement and affordances) reported here.

5.2.1.3. Observations from the pattern of response

Overall, the results displayed in Tables **5.3, 5.4, 5.5,** and **5.6** show that below 50% of all the PSTs in themselves have confidence that they perceived changes/improvement in their PD on the "Strongly Agree" scale. While beyond 50% of the PSTs in themselves have confidence that they perceived changes/improvement in their PD on the "Agree" scale. The vast differences in their responses on the "Strongly Agree" and "Agree" scales could mean that the PSTs could claim, to a relatively fair extent, that they perceive improvement in all the indicators of their PD on which they evaluated themselves, but could not confidently claim beyond this extent, given their interaction with the teaching expertise of the Foundation Phase mathematics ETE. This could account for the higher scores on the "Agree" scale than the "Strongly Agree" scale. It is also worth noting that the responses displayed in Tables **5.3, 5.4, 5.5,** and **5.6** could show the trends in the PSTs' perceptions about their PD and hence could contribute, though not strongly reliably, to some fair understanding or answering of the research questions.

5.2.1.4. Presentation of Inferential Statistics for the Comparison of the Means of the Themes

In addition to the frequencies obtained, further analysis was carried out on those responses to generate averages (i.e. means cores) to enable more accurate comparison of the PSTs' responses or views. To achieve this goal, a mixed model repeated measures ANOVA and Fisher's Least Significant Differences (LSD) were computed from the responses. While the mixed model repeated measures ANOVA measures show, though not very specific, whether or not the mean scores of the responses have any significant differences, the Least Significant Differences (LSD) could enable the researcher to highlight the significant differences in the means, between and within the themes harnessing those responses or views. Thus, the later analysis provided deeper and more accurate insight into how the PSTs' responses to the indicators of change compared with each other. In using these inferential statistics, decisions and conclusions on the comparison of the means depended on both the generated p-values from the ANOVA and the p-values for the pair-wise means calculated at 95% confidence level. In all the interpretations and discussions related to this section, both the descriptive and inferential statistics were combined to give more

meaning to the interpretation of the PSTs' responses with reference to the research questions guiding this study.

Respondents' (PSTs) perceived transformation/changes in their beliefs about the subject matter of mathematics and the teaching and learning of it

The p-value ($p = 0.0000$; $F(3, 210) = 21.884$) obtained from the ANOVA for means of the variables analysed under this theme show that there was strong evidence of significant differences between the means at 95% confidence interval. Thus, at least one of the variables has a higher or lower mean score than some of the variables, hence that particular construct (variable/theme) might have improved (or not) more than the other indicators of perceived improvement in the PSTs' PD. Table **5.7** shows the computed means of the learning outcomes under comparison.

Table 5.7: Perceived transformation or improvement in beliefs

Effect	Level of Factor	N	Score Mean	Score Std. Dev.	Score Std. Err	Score −95.00%	Score +95.00%
Total		284	3.123239	0.553278	0.032831	3.058615	3.187863
Scale	reflection on learning and actions	71	3.211268	0.383134	0.045470	3.120581	3.301954
Scale	mathematical competence	71	2.788732	0.652807	0.077474	2.634216	2.943249
Scale	critical about learners' needs	71	3.352113	0.442351	0.052497	3.247410	3.456815
Scale	content-focused	71	3.140845	0.542370	0.064367	3.012468	3.269222

In support of the evidence above, further analysis with the calculated LSDs at 95% confidence intervals also confirmed that significant differences were observed regarding the perceived improvement in the following paired learning outcomes:

PSTs' perceived improvement in their *reflection on learning and actions* was better or higher than their perceived improvement in their *mathematical competence* (with $p = 0.000000$ and mean difference = 0.422535).

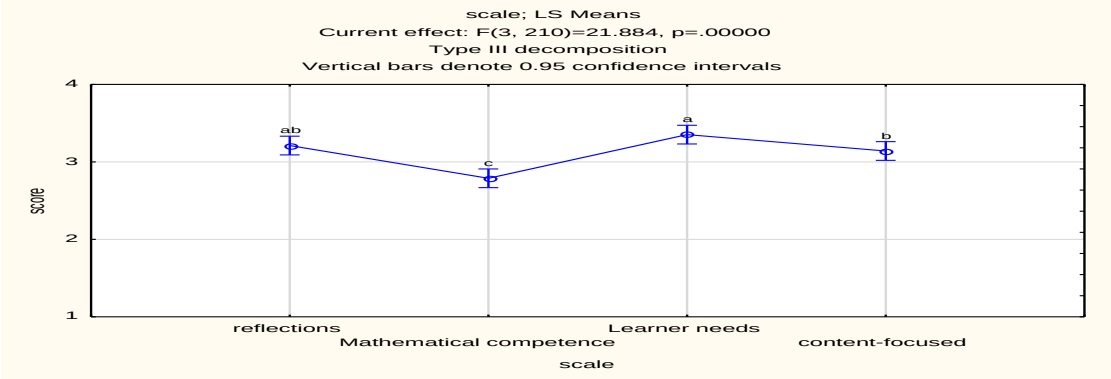
PSTs' perceived improvement that they were being *critical about learners' needs* improved significantly (with $p = 0.000000$) over improvement in their *mathematical competence*, with mean difference of 0.563380.

PSTs' perceived improvement that they were being *content-focused* in teaching and learning also improved significantly (with p = 0.000002) over improvements in their *mathematical competence* with a mean difference of 0.352113.

PSTs' perceived improvement in being *critical about learners' needs* in teaching and learning was significantly higher (with p = 0.003933) than their perceived improvement in being *content-focused*, with mean difference of 0.211268.

The evidence seemed to confirm the earlier evidence presented above and in particular seemed to show that all three (i.e. *reflection on learning and actions;* being *critical about learners' needs* and being *content-focused*) have shown better improvement than *overcoming their mathematical incompetence*. In addition, the graphical display in Figure **5.1,** below, also confirm evidence being confirmed above. It seemed to confirm that there could be no apparent significant differences between the perceived improvement in their *reflection on learning and actions;* being *critical about learners' needs* and being *content-focused*. Thus, all three seemed to have improved equally. However, all three could be observed to have improved significantly over perceived improvement in *overcoming their mathematical incompetence*.

Figure 5.1: Perceived transformation or improvement in beliefs



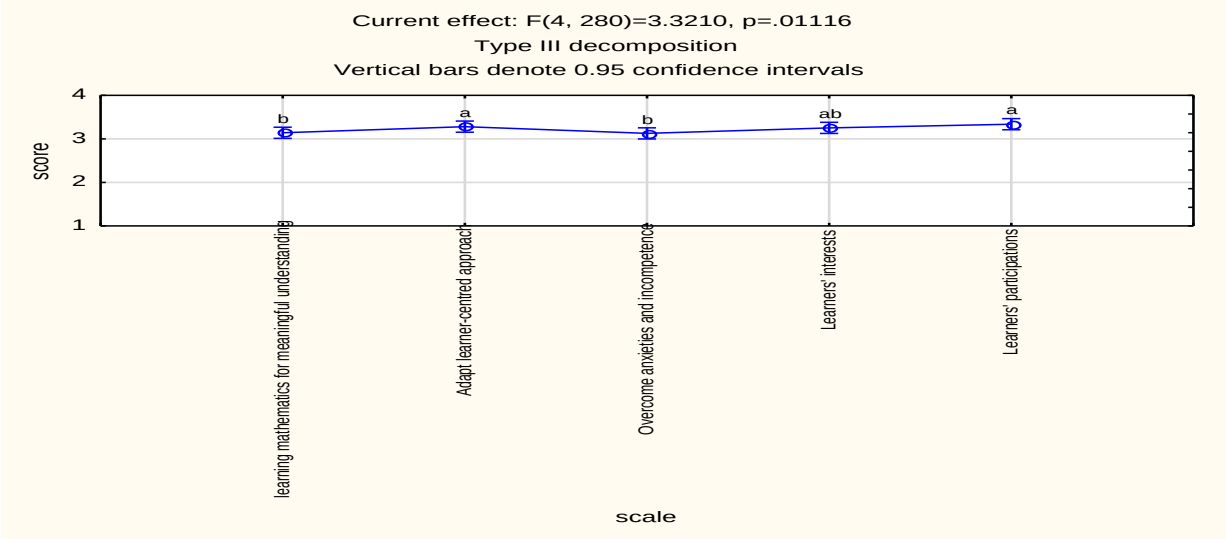
In line with the proofs and confirmations above, further evidence from the calculated LSDs at 95% confidence intervals seemed to show that no significant differences (with p = 0.053251) were observed between the PSTs' perceived improvement in their *reflection on learning and actions* (i.e. about mathematics, teaching young children, and how they learn) and improvement in being *critical about learners' needs and their entry characteristics* in mathematical instructions. Similarly, no significant differences (with p = 0.332209) were observed between the

PSTs' perceived improvement in their *reflection on learning and actions* and improvement in their willingness to be *content-focused* in their mathematical instructions. These could mean that there was fairly equal improvement among these three (3) indicators of change against which the PSTs evaluated their PD. Thus, the PSTs perceive as much improvement in their *reflection on learning and actions* as in their willingness to be *content-focused* and being *critical about learners' needs and their entry characteristics* in their mathematical instructions.

The interesting revelations above could collectively contribute to the understanding or answering the research question of what/which change(s)/improvement do the PSTs' perceive in their beliefs about mathematics and teaching and learning of mathematics? It could be said that the PSTs perceived fairly equal improvement in their *reflections on learning and actions* (i.e. about mathematics, teaching young children, and how they learn); *critical about learners' needs and their entry characteristics* and willingness to be *content-focused* in their mathematical instructions.

Respondents' (PSTs) perceived affordances of the changes in their beliefs about subject matter of mathematics and the teaching and learning of mathematics

Figure 5.2: Perceived affordances of the transformation or improvement in beliefs



The graphical display in Figure **5.2** above shows comparisons between the different viewpoints of the subjects under this theme. It shows that most of the perceived teaching capabilities overlap one another; as such there seemed not to be clear differences between the means being

compared, though the p-value showed some significant difference. The visual representation above seems to show that the PSTs perceived almost equal appreciation in all the teaching capabilities on which they assessed their PD. The measures of the teaching capabilities could be said to have improved equally above any apparent significant difference. Thus, the PSTs perceived better and equal improvement in their abilities to *create ample opportunities for active learner participation; promote learning mathematics for meaningful understanding; overcome learners' anxieties and improve learners' competence in learning;* and *adapt learner-centred approach.*

The above observations seemed to be confirmed by the computations of the LSDs at 95% confidence intervals which showed that no statistically significant differences were observed between the following perceived capabilities: PSTs' perceived capabilities in *facilitating learning mathematics for meaningful understanding* and *overcoming learners' anxieties and improve learners' competence in learning* (p = 0.842903); *facilitating learning mathematics for meaningful understanding* and *focusing instructional decisions on learners' interests* (p = 0.113658); *focusing instructional decisions on learners' interests* and *adapting learner-centred approach* (p = 0.691868)*; creating ample opportunities for active learner participation* and *adapting learner-centred approach* (p = 0.428180)*; overcoming learners' anxieties and improve learners' competence in learning* and *focusing instructional decisions on learners' interests* (p = 0.075296)*; creating ample opportunities for active learner participation* and *focusing instructional decisions on learners' interests* (p = 0.234978). Thus, they all seemed to be fairly equally improved. The means are shown below, in Table **5.8**.

Table 5.8: Perceived affordances of the transformation or improvement in beliefs

Effect	Level of Factor	N	Score Mean	Score Std. Dev.	Score Std. Err	Score −95.00%	Score +95.00%
Total		355	3.228169	0.553101	0.029356	3.170436	3.285902
Scale	promote learning mathematics for meaningful understanding	71	3.140845	0.515358	0.061162	3.018862	3.262828
Scale	adapting learner-centred approach	71	3.281690	0.4835332	0.057385	3.167240	3.396140
Scale	overcoming anxieties and incompetence	71	3.126761	0.555967	0.065981	2.995165	3.258356
Scale	Learners' interests	71	3.253521	0.553387	0.065675	3.122537	3.384506
Scale	Learners' participation	71	3.338028	0.631182	0.074907	3.188630	3.487426

Overall, the computed ANOVA with p = 0.01116 (F (4, 280) = 3.3210) further showed that there was no evidence of strong or significant differences between the means of the learning outcomes compared at the 95% confidence interval. Thus, the PSTs perceived being fairly equally improved in all the learning outcomes, as observed above.

Overall the computed ANOVA, to the contrary, showed strong evidence of significant differences in the observed means above, at the 95% confidence interval. Thus, some of the variables or learning outcomes may have higher or lower mean measures than others, hence some of them could be said to have improved significantly over others. Specifically, for the calculated LSDs at the 95% confidence interval, the following differences were observed:

Both the PSTs' perceived capabilities in *adapting a learner-centred approach* and *creating ample opportunities for active learner participation* have improved significantly over their perceived capabilities in *facilitating learning mathematics for meaningful understanding*. Thus *promoting learning mathematics for meaningful understanding* vs *adapting learner-centred approach* (p = 0.048271, mean difference = 0.140825); *facilitating learning mathematics for meaningful understanding* vs *creating ample opportunities for active learner participation* (p = 0.005855, mean difference = 0.197183).

Similarly, PSTs' perceived capabilities in *adapting learner-centred approach* have improved significantly over their capabilities to *overcome learners' anxieties and improve learners' competence in learning* (p = 0.029939, mean difference = 0.154930). This inference has been made with great caution, since *adapting learner-centred approach* has a single variable while *overcome learners' anxieties and improve learners' competence in learning* has multiple items. Also, the PSTs' perceived capabilities in *creating ample opportunities for active learners' participations* have improved over their capabilities to *overcome learners' anxieties and improve learners' competence in learning* (p = 0.003181, mean difference = −0.211268). This inference has been made with great caution since *creating ample opportunities for active learners' participations* has a single variable while *overcome learners' anxieties and improve learners' competence in learning* has multiple items.

It is worth acknowledging and accepting all the evidence of existence and non-existence of some statistical significant differences; the visual display seemed to emphasise that all perceived teaching capabilities claimed by the PSTs could be much closer in their levels of improvement than they seemed to differ as in the computational evidence. Therefore, to conclude that the PSTs perceived fairly equal improvement in their capabilities to *create ample opportunities for active learner participation; promote learning mathematics for meaningful understanding; overcome learners' anxieties and improve learners' competence in learning;* and *adapt learner-centred approach* may be justifiable. Such interesting evidence could contribute to understanding or answering the research question of "what affordances do the PSTs perceive from the improvement they perceive in their beliefs about mathematics and teaching and learning of mathematics?"

PSTs' perceived improvement in their understanding of mathematics CK and development of PCK

To succinctly present the PSTs' perceived achievements with regard to this theme, their responses were considered under the following sub-themes associated with improvement in their perceived understanding of the CK: *understanding of foundation mathematical concepts and procedures*; *understand how learners learn number operations and relationships*; *solve problems using different strategies*; and *explain why procedures work they way they do*. These four themes are single-item themes, hence any inferences or conclusions involving them were treated with extra caution. Similarly, their perceived developing PCK for Foundation Phase mathematics was considered under the following sub-themes: *make connections between ideas and strategies in solving problems in teaching and learning*; and *accessing and assessing learners' thinking and understanding in teaching and learning*.

The computed means of the sub-themes discussed above were compared to ascertain whether the PSTs perceived any differences in the achievements of those learning outcomes on which they assessed their PD. In this analysis, the p-value was 0.00000 ($F(5, 350) = 11.835$) from the ANOVA computations, indicating that there was strong evidence of statistically significant differences between the mean scores of the learning outcomes analysed under this theme, at the 95% confidence interval. Thus, the PSTs perceived that some of the achievements above were

higher or lower than others, hence that particular learning outcome might have improved (or not) more than the others. Table **5.9** below shows the computed means of the learning outcomes under comparison.

Table 5.9: Perceived improvement in CK and PCK for Foundation Phase mathematics

Effect	Level of Factor	N	Score Mean	Score Std. Dev.	Score Std. Err	Score −95.00%	Score +95.00%
Total		426	2.958529	0.570381	0.027635	2.904211	3.012847
Scale	Section **C_1**	71	3.070423	0.516138	0.061254	2.948255	3.192590
Scale	Section **C_2**	71	3.126761	0.558814	0.066319	2.994491	3.259030
Scale	Section **C_3**	71	3.098592	0.635945	0.075473	2.948066	3.249117
Scale	Section **C_4**	71	2.647887	0.678203	0.080488	2.487359	2.808415
Scale	understanding of how to make connections between ideas and strategies in solving problems in teaching and learning	71	2.873239	0.452037	0,053647	2.766244	2.980235
Scale	understanding of how to access and assess learners' thinking and understanding in teaching and learning	71	2.934272	0.400871	0.047575	2.839388	3.029157

Section **C_1** represents the PSTS' perceived *understanding of foundation mathematical concepts and procedures*. Section **C_2** represents the PSTS' perceived *understanding of how learners learn number operations and relationships.* Section **C_3** represents the PSTS' perceived *understanding of how to solve problems using different strategies*. Section **C_4** represents the PSTS' perceived *understanding of how to explain why procedures work they way they do*.

In support of the evidence presented above, further analysis with the calculated LSDs at 95% confidence intervals also seemed to show that significant differences were observed between the perceived improvement in the following paired learning outcomes:

PSTs' perceived improvement in *understanding of foundation mathematical concepts and procedures* to have improved significantly over their perceived *understanding of how to explain why procedures work they way they do*; and *understanding of how to make connections between ideas and strategies in solving problems in teaching and learning* (with p = 0.000000, and a mean difference of 0.422535; p = 0.008610, and mean difference of 0.197183, respectively).

PSTs' perceived improvement in their *understanding of how learners learn number operations and relationships* was significantly better than their perceived *understanding of how to explain why procedures work they way they do; understanding of how to make connections between ideas and strategies in solving problems in teaching and learning;* and *understanding of how to access and assess learners' thinking and understanding in teaching and learning*: ($p = 0.000000$ and mean difference of 0.478873; $p = 0.000760$ and mean difference of 0.253521; $p = 0.010312$ and mean difference of 0.192488, respectively).

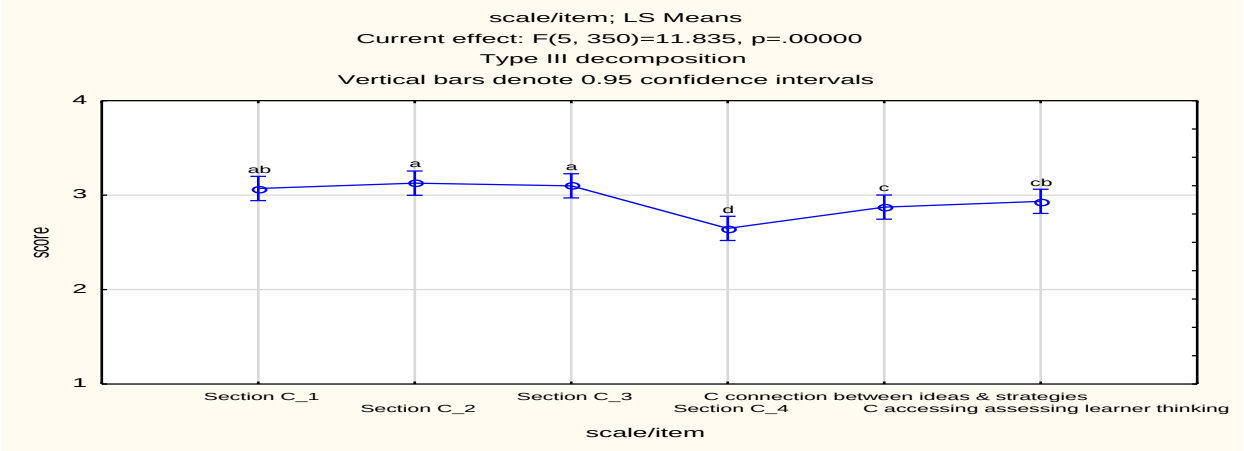
PSTs' perceived improvement in their *understanding of how to solve problems using different strategies* has improved significantly over the perceived *understanding of how to explain why procedures work they way they do; understanding of how to make connections between ideas and strategies in solving problems in teaching and learning;* and *understanding of how to access and assess learners' thinking and understanding in teaching and learning* ($p = 0.000000$ and mean difference of 0.450704; $p = 0.002718$ and mean difference of 0.225352; $p = 0.028337$ and mean difference of 0.164319, respectively).

PSTs' perceived improvement in both their *understanding of how to make connections between ideas and strategies in solving problems in teaching and learning;* and *understanding of how to access and assess learners thinking and understanding in teaching and learning* have significantly improved over the perceived *understanding of how to explain why procedures work they way they do*: ($p = 0.002718$ and mean difference of 0.225352; $p = 0.000148$ and mean difference of 0.286385, respectively).

In addition to the proofs and confirmations presented above, the graphical display in Figure **5.3,** below, also seems to confirm that the viewpoints of the PSTs differed with regard to achieving those learning outcomes. The visual representation seems to show that the PSTs perceived equally greater improvement in *understanding foundation mathematical concepts and procedures; understanding how learners learn number operations and relationships*; and *solving problems using different strategies*, than in *understanding how to access and assess learners' thinking and understanding in teaching and learning* and *understanding how to make connections between ideas and strategies in solving problems in teaching and learning*. As declared earlier, *understanding foundation mathematical concepts and procedures;*

understanding how learners learn number operations and relationships; and *solving problems using different strategies*, are single-item scales, hence the results could seem to appear this way. The graph further shows that their perceived *understanding of how to explain why procedures work the way they do* was the least improved.

Figure 5.3: Perceived improvement in CK and PCK for Foundation Phase mathematics



Similarly, the evidence above was confirmed by further analysis with the calculated LSDs at 95% confidence intervals, which also showed that no evidence of strong statistical significant differences were observed between the following paired learning outcomes or achievements:

PSTs' perceived improvement in their *understanding of foundation mathematical concepts and procedures* was equal to as their perceived improvement in *understanding of how learners learn number operations and relationships* (with p = 0.450830); and *understanding of how to solve problems using different strategies* (p = 0.706077).

PSTs' perceived improvement in their *understanding of how learners learn number operations and relationships* and their perceived improvement in *understanding of how to solve problems using different strategies* were at the same level of improvement, with p = 0.706077.

Contrary to revelations above, PSTs' perceived improvement in their *understanding of foundation mathematical concepts and procedures* were equal to their perceived improvement in and *understanding of how to access and assess learners' thinking and understanding in teaching and learning* (p = 0.068961). The PSTs' perceived improvement in their *understanding of how to access and assess learners' thinking and understanding in teaching and learning* and their

perceived *understanding of how to make connections between ideas and strategies in solving problems in teaching and learning* were at the same level of improvement with p = 0.414037.

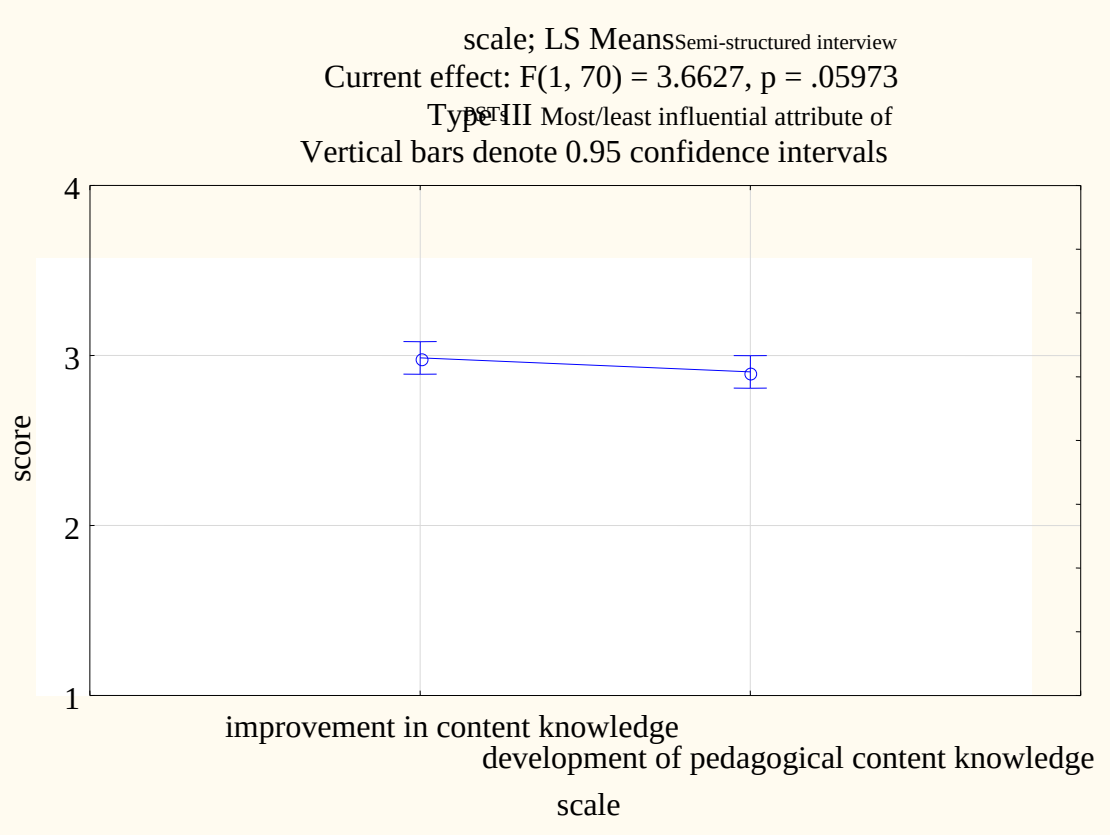
The researcher was also interested in ascertaining which of the broader themes were most enhanced to triangulate the findings from the sub-themes above. In this analysis, the p-value (p = 0.05973; F (1, 70) = 3.6627) obtained from the ANOVA for the means of the broader themes (learning outcomes), seemed to show that the observed mean scores of the two constructs were not statistically significantly different at 95% confidence interval. Table **5.10** shows the computed means of the learning outcomes under comparison.

Table 5.10: Overall perceived improvement in CK and PCK for Foundation Phase mathematics

Effect	Level of Factor	N	Score Mean	Score Std. Dev.	Score Std. Err	Score −95.00%	Score +95.00%
Total		142	2.944836	0.404234	0.033923	2.877777	3.011898
Scale	Improvement in understanding of CK	71	2.985915	0.413796	0.049109	2.88797	3.083859
Scale	Development of PCK	71	2.903756	0.393057	0.046647	2.81072	2.996791

This could mean that both compared learning outcomes have improved equally: the perceived *improvement in the PSTs' understanding of CK* was the same as their perceived *improvement in developing PCK*, as shown in Figure **5.4** below.

Figure 5.4: Overall perceived improvements in CK and PCK for Foundation Phase mathematics



This seemed to contradict the earlier findings under this theme (above) that there were differences between those knowledge components. On one hand, this may be possible because the single-item themes cautioned earlier might have led to the earlier conclusions that there were significant differences. However, the earlier claim could also be possible.

Interestingly, either of the factual conclusions above could contribute to gaining insight into the PSTs' perceived improvement in the development of their PCK for Foundation Phase mathematics, as well as the improvement in their understanding of the Foundation Phase mathematics CK. Thus, the research question "what/which improvement do the PSTs' perceive in their understanding of the mathematics CK and development of their PCK for Foundation Phase mathematics?" could be answered in light of the findings above: PSTs' much more perceived improvement in *understanding foundation mathematical concepts and procedures; understanding how learners learn number operations and relationships*; *solving problems using*

different strategies; *understanding of how to access and assess learners' thinking and understanding in teaching and learning; understanding of how to make connections between ideas and strategies in solving problems in teaching and learning,* than they did in *understanding of how to explain why procedures work the way they do.*

PSTs' perceived affordances of the improvement in their mathematics understanding of CK and development of their PCK

Table 5.11: Perceived affordances of the improvement in CK and PCK

Effect	Level of Factor	N	Score Mean	Score Std. Dev.	Score Std. Err	Score −95.00%	Score +95.00%
Total		284	2.949824	0.394058	0.023383	2.903797	2.995851
Scale	Can explain concepts and procedures to enhance learners understanding	71	2.887324	0.318447	0.037793	2.811949	2.962699
Scale	Can implement problem-centred teaching and learning approach	71	2.924883	0.395198	0.046901	2.831341	3.018424
Scale	Can facilitate learners' thinking and meaningful understanding of contents	71	2.954225	0.364275	0.043231	2.868003	3.040448
Scale	Can select appropriate teaching and learning activities and resources	71	3.032864	0.475277	0.056405	2.920368	3.145360

Table **5.11,** above, shows the mean measures of the PSTs' perceived affordances or teaching capabilities of the improvement they perceived in their CK and PCK. Further analysis was done on those responses to ascertain the existence of any strong evidence of statistical significance in the PSTs' perceived teaching capabilities. The statistical computations showing how those affordances compared with each other (i.e. the computed ANOVA with $p = 0.02400$, $F(3, 210) = 3.2101$) revealed that there was evidence of strong significant statistical differences (at 95% confidence intervals) between the teaching capabilities they perceived as improved, as shown in Table **5.11**.

In support of the evidence above, the calculated LSDs at 95% confidence intervals also confirmed evidence of statistically significant differences between the perceived affordances in the following paired teaching behaviours:

PSTs' perceived capabilities in *selecting appropriate teaching and learning activities and resources* had improved significantly over both their capabilities to *explain concepts and procedures to enhance learners understanding* ($p = 0.003168$, mean difference = 0.145540) and their capabilities in *implementing problem-centred teaching and learning approach* ($p = 0.027834$ and mean difference of 0.107981).

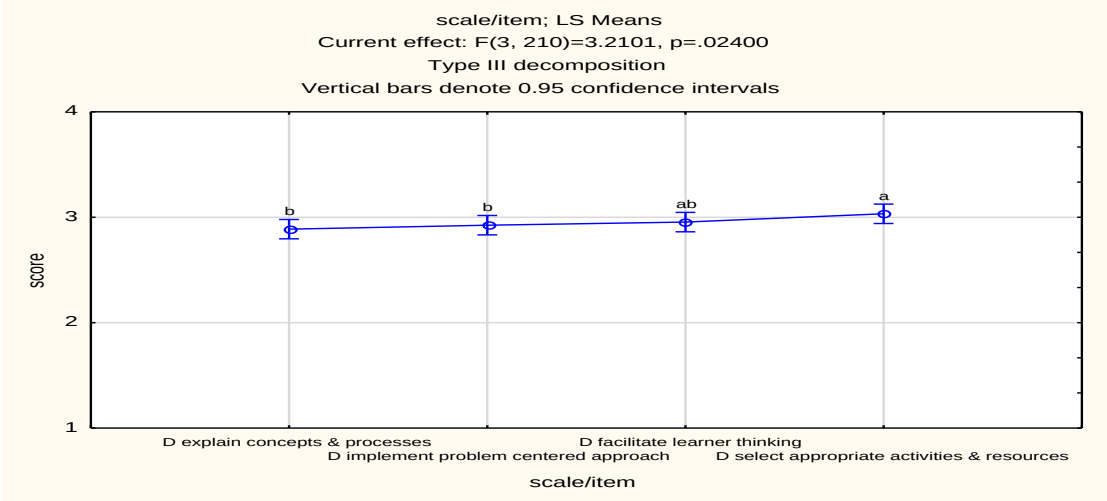
In contrast with the evidence presented above, the calculated LSDs at 95% confidence intervals also showed that no statistically significant differences were observed between the following paired perceived teaching capabilities, which could be nullifying the claims made above:

PSTs' perceived capabilities in *facilitating learners' thinking and meaningful understanding of contents* were as improved as both their *perceived affordances of implementing problem-centred teaching and learning approach,* with $p = 0.547886$, and their *perceived affordances of selecting appropriate teaching and learning activities and resources*, which were at the same level of improvement, with $p = 0.108223$.

PSTs' perceived capabilities in *explaining concepts and procedures to enhance learners' understanding;* were at the same level of improvement as their *facilitating learners' thinking and meaningful understanding of contents* and *implementing problem-centred teaching and learning approach* (with $p = 0.171420$ and p =, 0.0.441905, respectively).

Though some differences were perceived, as shown above, but these could not over emphasised. It seemed, therefore, that the PSTs perceived more equal improvement in those teaching capabilities than the perceived differences. The graphical display in Figure **5.5,** below, also confirms what is revealed above. This visual representation emphasises the comparisons between the different viewpoints of the subjects.

Figure 5.5: Perceived affordances of the improvement in CK and PCK



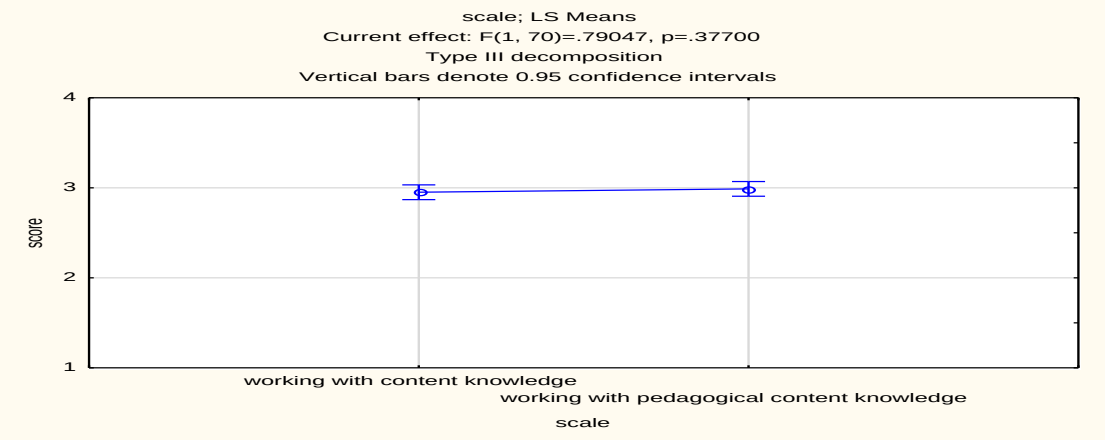
The graph shows that the PSTs' perceived teaching capabilities compared here seem to overlap. These interesting results could also contribute to the understanding or answering of the research question of what/which affordance(s) do the PSTs perceive from the improvement (they perceived) in their understanding of CK and development of PCK in Foundation Phase mathematics? Thus, the PSTs perceived their capabilities in *selecting appropriate teaching and learning activities and resources; implementing problem-centred teaching and learning approach; facilitating learners' thinking and meaningful understanding of contents;* and *explaining concepts and procedures to enhance learners' understanding* to have improved equally, rather than any one being better than the rest.

The conclusion derived above could also be supported by the overall analysis of the major themes themselves (in Table **5.12**), which showed the computed ANOVA with p = 0.37700 (F (1, 70) = 0.79047), which means that there was no strong evidence of any statistically significant differences between the PSTs' perceived affordances of their CK and PCK for Foundation Phase mathematics (at 95%, or even 90%, confidence intervals). This inference was also evident in the graphical displayed in **Figure 5.6,** below.

Table 5.12: Overall perceived affordances of the improvement in CK and PCK

Effect	Level of Factor	No.	Score Mean	Score Std. Dev.	Score Std. Err	Score −95.00%	Score +95.00%
Total		142	2.969316	0.344398	0.028901	2.91218	3.026452
Scale	Working with the understanding of CK	71	2.950704	0.305238	0.036225	2.87846	3.022953
Scale	Working with their developing PCK	71	2.987928	0.380843	0.045198	2.89778	3.078072

Figure 5.6: Overall perceived affordances of the improvements in CK and PCK



The means of the learning outcomes under discussion thus could be the same, suggesting **fairly equal improvement** in the affordances or the capabilities of the PSTs to articulate or explore the perceived improvement in their understanding of CK and development of their PCK in teaching Foundation Phase mathematics. It appears therefore that the PSTs' perceived ability to work with /articulate their developing pedagogical content knowledge, as well as their understanding of the CK, had improved equally.

PSTs' perceptions about the most improved dimension(s) of their PD

In this analysis, the p-value was 0.0000 (F (5, 350) = 18.496) from the ANOVA computations, indicating that there was strong evidence of significant differences between the mean scores of the variables analysed under this theme, at the 95% confidence interval. Thus, at least one of those dimensions of the PSTs' PD had a higher or lower mean measure than the others, hence that particular learning outcome might have improved (or not) more than the other dimensions of

the PSTs' PD. Table **5.13** shows the computed means of the learning outcomes under comparison.

Table 5.13: Most improved component of PD

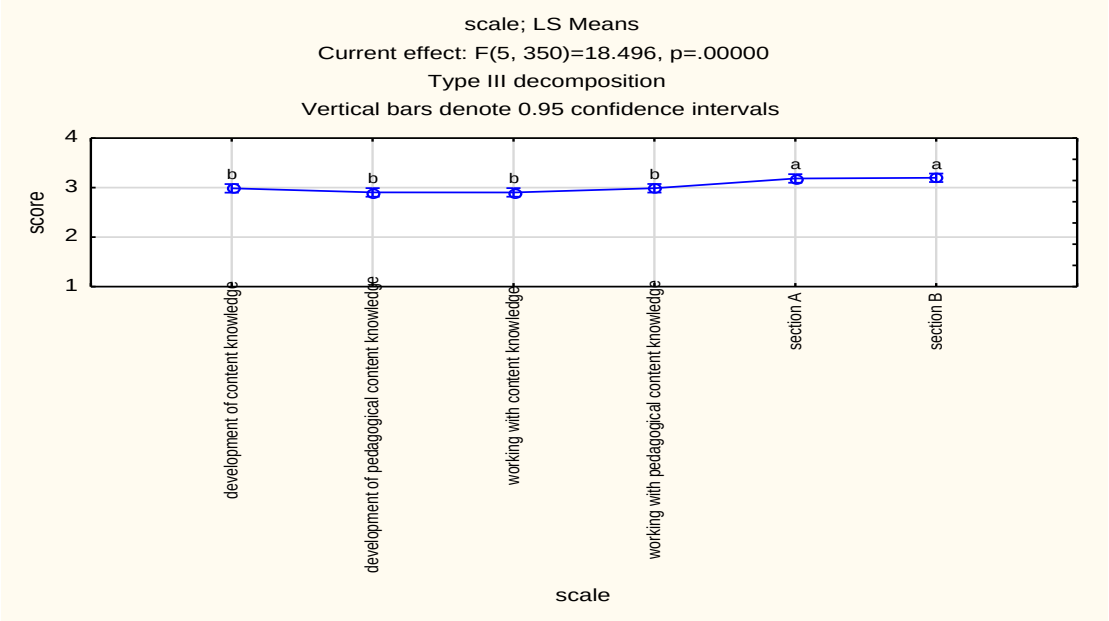
Effect	Level of Factor	N	Score Mean	Score Std. Dev.	Score Std. Err	Score −95.00%	Score +95.00%
Total		426	3.027610	0.387361	0.018768	2.990721	3.064499
Scale	*improvement in their beliefs (Section A)*	71	3.185446	0.286674	0.034022	3.117591	3.253301
Scale	*affordances of improvement in their beliefs or perceptions (Section B)*	71	3.199195	0.419967	0.049841	3.0999791	3.298600
Scale	*improvement in understanding CK*	71	2.985915	0.413796	0.049109	2.887972	3.083859
Scale	*Development of PCK*	71	2.903756	0.393057	0.046647	2.810721	2.996791
Scale	*Affordances/working with CK*	71	2.903421	0.303310	0.035996	2.831628	2.975213
Scale	*Affordances/working with PCK*	71	2.987928	0.380843	0.045198	2.897783	3.078072

In support of the evidence above, further analysis with the calculated LSDs at 95% confidence intervals confirmed that the PSTs' *perceived improvement in their beliefs about subject matter of mathematics and teaching and learning of mathematics* had improved significantly over their perceived improvement in understanding the CK of mathematics, with p = 0.000007 and a mean difference of 0.199531. The PSTs' *perceived improvement in their beliefs about subject matter of mathematics and teaching and learning of mathematics* also was significantly better than their perceived capabilities in articulating their understanding of the CK in teaching: p = 0.000000 and a mean difference of 0.282025. Similarly, the PSTs' *perceived improvement in their beliefs about subject matter of mathematics and teaching and learning of mathematics* had improved significantly over the perceived development of their PCK: p = 0.000000 and mean difference of 0.281690. In much the same way, the PSTs' *perceived improvement in their beliefs about subject matter of mathematics and teaching and learning of mathematics* improved significantly over their perceived capabilities in utilising their developing PCK: p = 0.000009 and mean difference of 0.197518. Thus, it could be said that the PSTs perceived much improvement in their *beliefs about subject matter of mathematics and teaching and learning of mathematics*; more so than with the rest of the dimensions of their PD.

Undoubtedly, the affordances of the PSTs' *perceived improvement in their beliefs about subject matter of mathematics and teaching and learning of mathematics* could be expected to be significantly better than their *perceived improvement and affordances of their CK and PCK*. This was evidenced as shown here: *perceived affordances of the improvement in their beliefs about subject matter of mathematics and teaching and learning of mathematics* vs *perceived improvement in understanding the CK of mathematics*, with $p = 0.000002$ and mean difference of 0.213880; *perceived affordances of the improvement in their beliefs about subject matter of mathematics and teaching and learning of mathematics* vs *perceived affordances of the improvement in understanding the CK of mathematics*, with $p = 0.000000$ and mean difference of 0.295775; *perceived affordances of the improvement in their beliefs about subject matter of mathematics and teaching and learning of mathematics* vs *perceived improvement in the development of their PCK for mathematics*, with $p = 0.000000$ and mean difference of 0.295439; *perceived affordances of the improvement in their beliefs about subject matter of mathematics and teaching and learning of mathematics* vs *perceived affordances of their developing PCK for mathematics*, with $p = 0.000002$ and mean difference of 0.211268.

In line with the evidence above, further analysis with the calculated LSDs at 95% confidence intervals also seemed to show that there was no significant difference (with $p = 0.753402$) between the PSTs' *perceived improvement in their beliefs about subject matter of mathematics and teaching and learning of mathematics* and their *perceived affordances* of these particular improvements. This could be possible because the extent of their improvement could be commensurate with, or determine their capabilities in, executing tasks demanding such improvement. Hence, both the perceived changes and the affordances of the changes were at an equal level. The above proof and confirmation are also supported in the graphical display in Figure **5.7** below, which also confirms that the PSTs perceived greater improvement in the transformation of their beliefs and their affordances than improvement in CK and PCK and their affordances.

Figure 5.7: Most improved component of PD



In addition to all the evidence above which shows that the PSTs' perceived improvement in beliefs and their affordances have greatly improved over CK and PCK, the analysis further confirmed that no significant differences were observed between the PSTs' perceived improvement and affordances of their mathematics CK and their PCK for mathematics as shown here: *perceived improvement in understanding the CK of mathematics* **vs** *perceived improvement in the development of their PCK for mathematics*, with p = 0.061109, at 95% confidence intervals; *perceived improvement in understanding the CK of mathematics* **vs** *perceived affordances of the improvement in understanding the CK of mathematics,* with p = 0.060066, at 95% confidence intervals; *perceived improvement in understanding the CK of mathematics* vs *perceived affordances of the improvement in the development of their PCK for mathematics,* with p = 0.963328, at 95% confidence intervals; *perceived improvement in the development of their PCK for mathematics* **vs** *perceived affordances of the improvement in understanding the CK of mathematics,* with p = 0.0993886, at 95% confidence intervals; *perceived improvement in the development of their PCK for mathematics* vs *perceived affordances of the improvements in the development of their PCK for mathematics,* with p = 0.055069, at 95% confidence intervals; and *perceived affordances of the improvement in understanding the CK of mathematics* **vs** *perceived affordances of the improvement in the development of their PCK for mathematics*, with p = 0.054113, at 95% confidence intervals. Thus, it can be said that the PSTs perceived equal

improvement in the two knowledge components of their PD presented above. Altogether, the evidence seemed to confirm that the most improved dimension of the PSTs' PD was their *perceived improvement in their beliefs about subject matter of mathematics and teaching and learning of mathematics*. Hence, to answer the research question "Which of the three dimensions of their professional development (i.e. beliefs, content knowledge and pedagogical content knowledge) is most or least enhanced?" it can be said that the PSTs *perceived improvement in their beliefs about subject matter of mathematics and teaching and learning of mathematics* was significantly improved over the other two components of their PD

5.2.2. Summary of findings (Phase A)

The results presented here have offered some insight into the changes/transformations in PSTs' beliefs about mathematics and the teaching and learning of it and improvement in their CK and development of their PCK, during their two-year training in the Foundation Phase mathematics module. The answers to the research questions that have been discovered above, have been justified in light of the empirical evidence emerging from the statistical analysis of the PSTs' responses in the survey. The review is given here:

What/which change/improvement do the PSTs' perceive in their beliefs about mathematics and teaching and learning of mathematics?

There was appreciable improvement in all the indicators of the changes on which they evaluated their PD, but it was found from their responses that they perceived considerable improvement in *reflection on learning and actions* (i.e. about mathematics, teaching young children, and how they learn); *critical about learners' needs and their entry characteristics* (take *effective decisions to cater for children's needs and characteristics*) and willingness to be *content-focused* in their mathematical instructions.

What/which affordances do the PSTs perceive from the improvement they perceive in their beliefs about mathematics and teaching and learning of mathematics?

There was appreciable improvement in all the indicators of the changes on which they evaluated their PD, but the findings from their responses revealed that, the PSTs perceived they could *create ample opportunities for active learners' participation in their mathematics instructions;*

promote learning mathematics for meaningful understanding; overcome learners' anxieties and improve learners' competence in learning; and *adapt a learner-centred approach in teaching mathematics.*

What/which improvement do the PSTs' perceive in their understanding of CK and development of their PCK in Foundation Phase mathematics?

There was appreciable improvement in all the indicators of the changes on which they evaluated their PD, but the findings from the analysis of their responses to the survey items showed that the PSTs perceived improvement in *understanding foundation mathematical concepts and procedures; understanding how learners learn number operations and relationships*; *solving problems using different strategies, understanding of how to access and assess learners thinking and understanding in teaching and learning;* and *understanding of how to make connections between ideas and strategies in solving problems in teaching and learning,*

What/which affordance(s) do the PSTs perceive from the improvement in their understanding of CK and development of their PCK in Foundation Phase mathematics?

There was appreciable improvement in all the indicators of the changes on which they evaluated their PD, but the findings revealed that the PSTs perceived that, with the improvement reported above, they were capable of *selecting appropriate teaching and learning activities and resources; implementing problem-centred teaching and learning approach; facilitating learners' thinking and meaningful understanding of contents,* and *explaining concepts and procedures to enhance learners' understanding;*

Which of the three dimensions of their professional development (i.e. beliefs, content knowledge and pedagogical content knowledge) is most or least enhanced?

The PSTs perceived fair improvement in all the indicators of change, however, *perceived improvement in their beliefs about subject matter of mathematics and teaching and learning of mathematics* was significantly improved over the other two components of their PD.

Essentially, the findings presented above have highlighted that the PSTs to a fair extent perceived improvement in their PD during their two-year training in Foundation Phase

mathematics modules. The mean ratings specifically showed that they perceived that their *beliefs about mathematics and the teaching and learning of it* had improved more than the improvement in their *CK and PCK* in Foundation Phase mathematics. Consequently, the affordances of the improvement in former aspects of their PD outweigh the affordances of the improvement in the later aspects of their PD. The discussions further draw our attention to two equally important levels of achievement in the PSTs' learning trajectories: those indicators of the aspects of the PSTs' PD which have improved or developed relatively or appreciably and some other aspects of the PSTs' PD which need the teacher educator's attention for improvement.

5.2.3. Interview Results (Phase A)

The results of the interviews with the English-speaking group of six (6) PSTs who volunteered to participate in this study are presented here. The interviews were aimed at eliciting detailed explanations or interpretations of the PSTs' PD during their two-year experiences in learning to teach mathematics, from their own responses to the interview questions. In addition, their responses in the interview could give in-depth understanding of the research problem and provide wider and more detailed answers to the following questions:

i. What change(s)/improvement do the PSTs' perceive in their beliefs about mathematics and teaching and learning of mathematics?
ii. What affordance(s) do the PSTs perceive from the improvement they perceive in their beliefs about mathematics and teaching and learning of mathematics?
iii. What change(s)/improvement do the PSTs' perceive in their understanding of the mathematics CK and development of their PCK for Foundation Phase mathematics?
iv. What affordance(s) do the PSTs perceive from the improvement they perceive in their understanding of the mathematics CK and development of their PCK for Foundation Phase mathematics?
v. Which of the three dimensions of their professional development (i.e. beliefs, content knowledge and pedagogical content knowledge) is most or least enhanced?

The interview responses were analysed under themes similar to those used in analysing the responses to the survey. These themes were developed through iterative processes (method of constant comparison) described in Chapter 4. The analytical themes include the respondents'

a. perceived change/improvement in their perceptions about mathematics and their attitudes towards mathematics and the affordance(s) of such changes/improvement;
b. perceived changes/improvement in their views about effective teaching and learning of mathematics and the affordances of those changes/improvements;
c. perceived improvement in their understanding of the mathematics CK and the affordances of those improvements;
d. perceived development of their PCK and the affordances of such development.
e. Perceptions about most or least developed dimension (s) of their PD

The themes listed above were in line with the inquiry questions guiding this investigation, as well as with the two major themes: ***perceived changes/improvement in PSTs' PD*** and ***perceived affordances of the changes/improvement in PSTs' PD***. ***Perceived changes/improvement in PSTs' PD*** comprised perceived changes/improvement in PSTs' perceptions about mathematics and their attitudes towards mathematics; perceived changes/improvement in PSTs' views about effective teaching and learning of mathematics; PSTs' perceived improvement in their understanding of the mathematics CK; and PSTs' perceived development in their PCK. ***perceived affordances of the changes/improvement in PSTs' PD*** also comprised perceived affordance(s) of the changes/improvement in PSTs' perceptions about mathematics and their attitudes towards mathematics; perceived affordances of the changes/improvement in PSTs' views about effective teaching and learning of mathematics; PSTs' perceived affordances of the improvement in their understanding of the mathematics CK; and PSTs' perceived affordances of their developing PCK. This categorisation aligns the interview themes with the themes used in analysing the survey results. In accordance with the themes above, the following sections present the findings from the interviews.

5.2.3.1. PSTs' entry views/believes and attitudes towards mathematics

The researcher started the interview by asking the PSTs about (to describe) their pre-existing perceptions about mathematics and their attitudes towards mathematics, at the point of entry into the BEd programme. The respondents shared the following perceptions about mathematics when they entered the BEd programme: they perceived mathematics as a regimented set of ideas; mathematics as just a challenging subject. For example, the quotation below describes what one of the interviewees' entry perceptions about the subject matter of mathematics was like.

> PST 1: "... I had a very singular view about math ... I viewed it like a regimented subject, you have to do it this way if we don't do it that way then it's wrong ..."

Their responses further showed that they entered into the BEd programme with two popular negative attitudes displayed by most learners of mathematics: "they had anxieties towards mathematics; and lacked confidence in their mathematical abilities". The following extracts confirm those attitudes towards mathematics at the point of starting to learn teaching mathematics:

> PST 2 said "... coming into the 2nd-year module I had block about mathematics ..."
>
> PST 3 said "I almost had a 'mental block' towards math ..."
>
> PST 4 said "I was sceptical about mathematics ..."

The seriousness of the personal and frank statements by the interviewees above could have uncountable repercussions beyond the claimants themselves. As teacher educators, we probably should show the deepest concern about legitimate questions like "if the prospective teacher has a robotic view of the subject matter of mathematics, then what happens to her student(s)?"; "if the prospective teacher is not fascinated with or has no joy in learning mathematical ideas, then what happens to her student(s)?"; "if the prospective teacher feels learning mathematics is just a form of frustration and fears to learn it, then what happens to her student(s)?". In short, they could finish their training without improvement in those perceptions and attitudes and would transmit the same counterproductive perceptions and attitudes to their students, if not worse. In that case, their training would have no impact on them. The interviewees, For example, were emphatic that their 1st-year mathematics learning experiences at the university had not changed their views

and attitude towards mathematics since their school mathematics learning experiences. If this situation continues, the initial teacher training in its totality will not be able to turn out effective teachers of mathematics for the community.

This introductory question in one way or another helped to expose the PSTs' perceptions about mathematics and their attitudes towards the mathematics they were learning to teach. With reference to the set of research questions and the purpose of this investigation, further questions were asked to ascertain the status of their entry perceptions and attitudes (both explicit and implied) towards mathematics. These perceptions and attitudes were also assessed in the survey items/statements enquiring about PSTs' perceived transformation in their perceptions about mathematics. However, the scope of the possible perceptions and attitudes with which most PSTs enter into initial teacher education considered in the survey items/statements is wider than those mentioned above by the respondents. The analyses of follow-up questions to this introductory question are given below.

5.2.3.2. PSTs' perceived change(s)/improvement in their perceptions and attitudes towards mathematics and teaching and learning mathematics:

Follow-up on the interviewees' responses given above, the researcher made further enquiries about the impact of the two-year training on their pre-existing perceptions and attitudes towards mathematics and what such changes could enable them to do. When asked whether the views and attitudes expressed above had changed/improved, after their two-year training in the mathematics modules, the PSTs unanimously claimed that they perceived some improvement because they were developing views and attitudes to make them more productive in teaching and learning mathematics.

They were, however, emphatic that those changes actually happened when they began learning to teach Foundation Phase mathematics in the 2nd year. This is strong evidence that their 1st-year training could not produce a recognisable impact on their counterproductive entry perceptions of mathematics and attitudes towards mathematics. Very common among the changes they perceived over this two-year period is the developing of their confidence in doing mathematics and viewing mathematics as a body of interrelated ideas used to solve problems in everyday activities. Their developing confidence, as they claim, is an indication of positively changing

attitudes towards learning/teaching the subject matter of mathematics. Recognising and exploring relationships between mathematical ideas is a sign of positive drift from viewing mathematics as existing outside the human mind, to perceiving mathematics as an expression of the human mind. The value of mathematics in solving real-life problems is an indicator of what the preceding changes (changing views about mathematics and changing attitudes towards mathematics) could afford them to do as prospective teachers. Evidence of this is encountered in how they described their perceived changes and what they can achieve with the changes:

> PST 1 said, "... it (math) is a whole gray area, it's not just black and white, there is a grey area ...that you can use."
>
> PST 4 said, "I am beginning to see math as less challenging, ..."
>
> PST 2 said, "I find that block is slowly diminishing, ... now I can see where a mathematical idea came along and why ... e.g. I learnt my number concept isn't wrong because my approach is different from someone else's ..."
>
> PST 5 said, "... I am interested in looking at the reasoning behind it [the subject matter knowledge] instead of just like trying to find an answer ..."
>
> PST 3 said, "... my mental block towards math is gradually diminishing, ... I will be "encouraging" learners to do math and appreciate math..."

The claims by PSTs 1, 2, and 5 seem to emphasise perceived improvement in exploring the relationships between mathematical ideas for deeper understanding and for effective problem-solving strategies – exploring multiple but coherent methods and strategies in solving problems, thus exhibiting in-depth understanding of mathematical ideas and their applications. Similarly, the views of PSTs 3 and 4 could be emphasising how their perceived mathematical competence is improving, probably due to some of the changes discussed above – developing their confidence and attitudes in learning/teaching mathematics.

5.2.3.3. Perceived affordances of the change(s)/improvement in PSTs' perceptions and attitudes towards mathematics and teaching and learning mathematics

The researcher further enquired whether the changes these PSTs were articulating had an influence on their views and attitudes towards how the subject matter knowledge of mathematics should be perceived and how mathematics should be taught or learnt effectively. Their responses were that PSTs as well as teachers should view mathematics as a body of interconnected ideas that are less challenging. This is evidence confirming that their changing views from mathematics as robotic subject matter (a regimented set of ideas) to mathematics as a collection of integrated ideas, is indeed impacting perceptions about how mathematics should be viewed/learnt. Thus there seems to be a strong positive relationship between their perceived changes and perceived affordances of the changes.

The interviewees' responses to the same inquiry further revealed that teachers, in the work of teaching, should exhibit these orientations: every child can learn mathematics; teaching mathematics should be fun; allowing children to struggle and figure out the ideas for themselves is necessary; and teacher and learners should be seeing math as a problem-solving subject. These perceived affordances articulated here by the PSTs are evidence of the change in their perceptions about mathematics and the teaching and learning of it, including: perceptions drifting from the subject matter of mathematics as robotic to mathematics as an expression of the human mind and activities; drifting away from teaching and learning mathematics as a challenging and frustrating activity to learning mathematics for the joy of it; drifting away from doing mathematics to get wrong/right answers to exploring mathematical ideas in solving real-life problems; and drifting away from teaching and learning mathematics by transmission (telling-and-doing and/or take it or leave it) to transferring/sharing (recognising and exploring relationships between mathematical ideas) of mathematical ideas. The emphasis in their responses is worth considering for promoting effective teaching and meaningful learning of mathematics, more so with the understanding that mathematical ideas are not independent of one another; they are related and these relationships are as important as the ideas themselves; and as such their relationships should be explored. Further evidence of the discussions are presented in their personal statements below:

PST 1 said, "... teachers should be open to different manners in which people interpret mathematics, ...so give them the problem and see how they would handle it, ... we should creating more cognitive thinking within the learner..."

PST 3 said, "... learning math from the point of view of the child; learn how they are going to learn it; understand how they might understand it; and learn what she can do to make it as easy as possible for them to understand"

PST 5 said, "... learners figure out their own methods to find an answer, instead of trying to apply someone else's method ... approach teaching like each child discovering and understanding learning for themselves with guidance from the teacher"

PST 2 said, "...teaching and learning of math has to be fun; teachers should let the kids solve the problem themselves"

PST 4 said, "... teaching and learning should be done through problem solving approach, ... guided by the principle that there is no one definite way of figuring out an answer ... the teacher should allow learners to come out with their approaches to solving the problems not to interfere with their processes ... "

PST 6 said, "... math should be taught from the perspective of the learner, ... see it through the way children think ... understand it in the different ways in which they are thinking, ... explain to them why they are thinking of it that way, ... ask certain questions for them to think in a different way and to get to that answer, ..."

The claims by PSTs 1, 2, 4, and 5 seem to be emphasising perceived improvement/affordances in a teaching and learning approach whereby learners are given opportunities to express their understanding of the mathematical ideas they are learning or the problems they are solving. The teaching activities should involve encouraging learners to explore multiple views and strategies. Similarly, the views of PSTs 3 and 6 could be emphasising a teaching and learning approach intensively focusing on the learner and the learning experiences as against evaluation of teaching or assessing teaching performance or exhibition of teaching skills for the sake of doing so.

5.2.3.4. PSTs' perceived improvement in their CK and PCK:

The PSTs were asked whether their understanding of CK and development of PCK improved over against their understanding from school mathematics experiences, as a result of their two-year training in the mathematics modules. Their responses indicated that most of them began noticing improvement in their CK when they started learning to teach Foundation Phase mathematics. Here is yet another proof supporting their earlier claims that the 1st-year mathematics learning experiences at the university did not change the views and attitudes they had adopted towards mathematics from their school mathematics learning experiences. For example:

> PST 1 said, "I think I understand concepts and procedures a lot better ... just the thought of how to teach it, the procedures that the teacher should go through improved my CK ...
>
> PST 2 said, "... I feel knowing how to teach math has really helped me with my mathematics CK because I understand what is going on behind the scenes... I think a lot more about it and think of different ways I will teach it and when I am thinking of different ways I will teach it I am fixing my mathematical knowledge and coming up with new ideas for myself ..."
>
> PST 6 said, "... I understand why we do it the way we do and why it carries on and interlinks with the things that we do in high school so it has improved and I understand it more ..."

The common message emerging from the quotations above is that the PSTs had the opportunity to improve their understanding of the CK they will be teaching at the end of their training through learning to teach. This may be due to reduced emphasis on promoting their understanding of the CK they are to teach during the first year's training, compared to the focus of their training during the second year. What is surprising is that their learning experiences during the first year, where deeper and more advanced mathematics content is taught, could not improve their understanding of the CK they were to teach, while their learning experiences (learning to teach) in the second year did. It is worth noting that prospective teachers'

understanding of CK could to some extent be better enhanced when they are leaning to teach it than merely learning to acquire CK.

Despite the above claims by some of them that their CK had improved, others did not seem to be convinced that their learning experiences in mathematics in the 1st and 2nd years improved their CK as much as they expected. For example,

> PST 5 said, "... there is like still gaps in my knowledge [CK]". "Some of subject matter are like missing a bit ..."

> PST 4 said, "... I don't feel that I have grown so much completely in my CK, ... to a certain extent and I think to even a large extent, I don't feel that the concepts and definitely procedures I knew from my school mathematics experiences have been challenged over past few years ... I think I have a very high expectation of what I receive ..."

These interviewees' responses could be emphasising that they have probably experienced a different understanding of the CK during their two-year learning at the university from what and how they understood the CK from their school mathematics experiences. From all indications and through critically reviewing their claims, these two PSTs in particular had relatively high expectations about improving their CK during their training. They had the feeling that their university training could enhance their CK much better than their 12 years of school experience, hence they were pointing at the inadequacies in their CK at this stage of their training. The PSTs' expectations expressed here are supported by Ball's (1990: 10) convictions that PSTs need to experience learning mathematics differently and much better than through their school mathematics experiences (i.e. the acquired knowledge and skills), which have been noted as lacking the desired in-depth understanding and beliefs or orientations. Towards realising this shifting focus, Lampert and Ball (1999: 33) emphasise that mathematics teacher education should focus on improving PSTs' knowledge of "what it means to know mathematics and what is worthwhile knowing about mathematics". Furthermore, Borko *et al.* (1992: 195) and Ball (1990: 14) believe that PSTs could develop in-depth or conceptual understanding of mathematical principles and thorough explanations of mathematical procedures (why they work the way they work), through this new emphasis, as well demonstrate the understanding of

explicit and implicit connections between mathematical concepts, facts and procedures. Kagan (1992: 162) perceives that it is in this kind of understanding that the developmental needs of PSTs are rightly positioned.

5.2.3.5. PSTs' perceived affordances of the improvement in their CK and development in their PCK:

The interviewees were asked about the affordances of the improvement above development of their PCK after their two-year training in the mathematics modules. Indications from some of their responses were that they felt that they had not developed their PCK adequately (compared to the improvement in their CK) for effective teaching. It should be noted that these respondents claimed earlier that their CK were improving when they started learning to teach Foundation Phase mathematics. Undoubtedly, an observer would expect that their PCK were developing by virtue of that opportunity (i.e. learning to teach in the 2nd year). However, their perceptions about their developing PCK seemed to disappoint obvious expectations, which could probably be due to their dual focus while learning to teach. That is to say, their attention might have been divided due to simultaneously trying to gain in-depth understanding of the CK and develop their PCK. Another possibility could be that they may have focused more on the new understanding of CK they were gaining while learning to teach, instead of focusing on developing their PCK. This could have been a relatively perfect opportunity of "killing two birds with one stone", but the results unfortunately turned out to be different. What is meant is that it would have been ideal for the PSTs to improve their CK and develop their PCK simultaneously in learning to teach, because they, through such an opportunity, could encounter the real instructional situations/settings in which they either observe/learn or participate in the procedures (PCK in action) of transferring the CK. For example,

> PST 1said, "... I think in that my understanding of how to teach is probably still a bit limited but I feel confident that I know the concepts and the procedures..."

> PST 4 said ""... I think there are some things that I still need to experience to improve my PCK ..."

Generally, though, the respondents felt that they had not developed their PCK adequately. They nonetheless seemed to be advocating for a learner- and learning-centred teaching approach, which became significant in their description of a "good/effective" teaching and learning approach. The researcher noted that the PSTs' conceptions of a "good way to teach math", as an indicator of their developing PCK, seemed to encompass the perceived affordances they were describing here. For example,

> PST 6 said, "... learn out of the mistakes of my teachers ... adjusting your mind to how a small child thinks about an idea he/she is learning ..."
>
> PST 5 said, "... guiding the learner from the prior knowledge to understand what the teacher is trying to get across, ... use like physical objects or like real life situations that are motivating the learner and the learning experiences..."
>
> PST 3 said, "... allowing them to solve a problem using a strategy that they feel comfortable with whether it is drawing their answer or working it out with whichever method that they feel comfortable ..."
>
> PST 1 said, "... then ask questions to make them think deeper ... understand what they are thinking and using how they are thinking to guide them ..."
>
> PST 2 said, "... I want them to think, discuss it, battle with it, to try and figure it out ..."
>
> PST 4 said, "... encourage learners to work in smaller groups ..."

Coincidentally, the unanimous message emerging from the PSTs' descriptions of good/effective teaching is that good/effective teaching should prioritise how children think about mathematical ideas/concepts and procedures; effective teaching should provide learners with opportunities to express their understanding of the mathematical ideas they are learning or the problems they are solving, then help them to form connections between their ideas; encourage learners to explore

multiple views and strategies; explain similarities and differences among children's solution strategies; and assess the learner and the learning experiences.

5.2.3.6. PSTs' perceptions about the most improved dimension(s) of their PD

Some of the respondents seemed uncertain about a particular dimension of their PD that was most improved during their two-year experience in learning to teach Foundation Phase mathematics. The excerpts below show such responses:

> PST 1 said, "... I think that my understanding of how to teach (PCK) is probably still a bit limited but I feel confident that I know the concepts and the procedures [CK]"
>
> PST 4 said, "... I think there are some things that I still need to experience to improve my PCK ..."

Those who identified a particular dimension of their PD as the most improved did so with little confidence, while others did this with great confidence.

> PST 1 said, "I think I understand concepts and procedures [CK] a lot better ..."
>
> PST 2 said, "I feel knowing how to teach math has really helped me with my mathematics CK."
>
> PST 6 said: "I understand why we do it the way we do and why it carries on and interlinks with the things that we do in high school so it [CK] has improved and I understand it more ..."
>
> PST 4 said, "I am beginning to see (beliefs) math as less challenging ..."
>
> PST 2 said, "I find that block (belief/perceptions/attitude/anxiety) is slowly diminishing..."
>
> PST 3 said, "... my mental block towards math (belief/perceptions/attitude/anxiety) is gradually diminishing ..."

Drawing from the views expressed in the quotations above, the interviewees seemed to perceive that their entry beliefs as well as their CK were much improved, compared to their developing

PCK. Therefore, it could be concluded that their beliefs and CK were the most improved dimension of their PD.

5.2.4. Summary of findings from the interviews (Phase A)

From the preceding discussions of the PSTs' responses to the interview questions, the following conclusions could be drawn with reference to the research questions introduced above:

- What change(s)/improvement do the PSTs' perceive in their beliefs about mathematics and teaching and learning of mathematics?

From their responses, it was found that they perceived:

i. the subject matter knowledge of mathematics as body of interrelated ideas; mathematics as a problem-solving activity;
ii. improvement in their confidence in learning/doing mathematics;
iii. they were reasoning with the subject matter knowledge they were learning;
iv. they were overcoming their mental blocks in learning mathematics;
v. they were developing the interest/attitude to encourage learning and appreciation of mathematics;
vi. they were gaining deeper understanding of mathematical ideas by exploring the relationships between mathematical ideas;
vii. improvement in their abilities to explore mathematical ideas and relations for clearer understanding;
viii. improvement in their anxieties and competence;
ix. improvement in their understanding of the relationships between mathematical ideas.

- What affordance(s) do the PSTs perceive from the improvement they perceive in their beliefs about mathematics and teaching and learning of mathematics?

The findings from their responses reveal that the PSTs perceived that they were able to:

i. reason with the subject matter knowledge of mathematics as a body of interconnected ideas that are less challenging;
ii. see teaching and learning mathematics as a problem-solving activity;
iii. facilitate children's ability to learn mathematics;
iv. facilitate teaching and learning of mathematics as fun;
v. allow/guide children to struggle and figure out ideas and solutions by themselves;
vi. create opportunities for children to participate and discuss their understanding of the mathematical ideas;
vii. assess children's thinking and understanding of ideas or problems;
viii. explain children's thinking, solutions, and procedures;
ix. create a problem-solving learning environment for children's learning effectiveness – children to explore their solution methods/strategies with guidance from teacher;
x. promote a learner-centred approach in teaching – teach mathematics from the perspective of the learner, considering how they think, interpret and understand ideas and problems;
xi. create more cognitive thinking within the learners;
xii. learn mathematical ideas from the perspective of the child – understand how they understand it and think about their thinking about the ideas;
xiii. encourage learners to express their solution methods;
xiv. create opportunities for learners to be responsible for their own learning – discovering and understanding ideas by themselves.

❖ What change(s)/improvement do the PSTs' perceive in their understanding of CK and development of their PCK in Foundation Phase mathematics?

From the analysis of their responses to the interview questions, the PSTs perceived:

i. improvement in their understanding of mathematical concepts and procedures;
ii. relationships and connections between concepts and procedures;

iii. conceptual understanding of ideas – understanding what is going on behind the scenes about the ideas; thinking about the multiple embodiments of the ideas and procedures; generate new ideas; reflecting and correcting their misconceptions about ideas;

iv. understanding how procedures work, why they work the way they do, explain connections among ideas.

❖ What affordance(s) do the PSTs perceive from the improvement [they perceive] in their understanding of CK and development of their PCK in Foundation Phase mathematics?

The findings below were drawn from the responses of the PSTs. They perceived that, due to the improvements above, they have become capable of:

i. adapting the teaching and learning environment/activities to suit children's learning needs – e.g. adjusting your thinking to understand how children think about mathematical ideas;

ii. guiding children's learning and understanding from the known to the unknown – e.g. helping children to explore new ideas from their prior knowledge and understanding;

iii. using manipulatives or real life situations to motivate learners and enhance their learning experiences;

iv. creating opportunities for children to explore their own methods or strategies in solving problems they encounter;

v. stimulating or encouraging children's thinking abilities through questioning and prompting;

vi. understanding children's thinking and using their own thinking to improve their thinking;

vii. assisting children to think, discuss their thinking and test their thinking in problem-solving situations;

viii. encouraging children to work cooperatively – e.g. talking about individuals' ideas, understanding the different ways individuals think about ideas and procedures, contributing to the collective and better understanding of all learners in the group;

ix. focusing on how children think about mathematical ideas/concepts and procedures;

x. giving learners opportunities to express their understanding of the mathematical ideas they are learning or the problems they are solving;
xi. helping children to form connections between their ideas;
xii. encouraging learners to explore multiple views and strategies;
xiii. explaining similarities and differences among children's solution strategies
xiv. assessing the learner and the learning experiences.

❖ Which of the three dimensions of their professional development (i.e. beliefs, CK and PCK) is most or least enhanced?

The responses from the interviewees seemed to show that their beliefs about mathematics and the teaching and learning of it and CK had improved more than their PCK, therefore it could be concluded that their beliefs and CK were the most improved dimensions of the PSTs' PD during their two-year experience of learning to teach Foundation Phase mathematics.

5.2.5. Quantitative and Qualitative findings merged (Phase A)

In the tables below, the PSTs' perceptions about their PD (perceived improvement) and their potential success (perceived affordances of the improvement) in their future classrooms are presented and compared in accordance with the themes and the research questions guiding this study (Thomas & Beauchamp, 2011: 767).

Table 5.14: Merged findings regarding PSTs' perceived improvement in their beliefs (Phase A)

Research question	**Findings from survey results**	**Findings from interview results**	**Similarities/differences in findings – confirmation, supplementary insight, additional information, detailed interpretations**
What transformations do the PSTs' perceive in their beliefs about mathematics and teaching and learning of mathematics?	It was found that the PSTs perceived the following considerable improvements in their beliefs ... *reflection on learning and actions* (i.e. about mathematics, teaching young children, and how they learn); being *critical about learners' needs and their entry characteristics* (taking *effective decisions to cater for children's needs and characteristics*) willingness to be *content-focused* in their mathematical instructions.	The interviewees perceived the following improvements in their beliefs: They perceived the subject matter knowledge of mathematics as a body of interrelated ideas. They perceived mathematics as a problem-solving activity. They perceived improvement in their confidence in learning/doing mathematics. They were reasoning with the subject matter knowledge they are learning. They were overcoming their mental blocks in learning mathematics. They were developing the interest/attitude to encourage	The PSTs' changing perceptions of the subject matter knowledge of mathematics as body of interrelated ideas confirm the survey findings that the PSTs claimed considerable improvement in their *reflection and correction of their misconceptions about subject matter of mathematics*. This new perception about mathematics further explains why the PSTs perceived improvement in their *conceptual understanding of mathematics* or *gaining deeper understanding of mathematical ideas by exploring the relationships between mathematical ideas*. The interviewees' confidence in perceiving *mathematics as a problem-solving activity* complements the survey findings that the PSTs perceived considerable improvement in being *critical about learners' needs and their entry characteristics.* The interviewees' claims that they were developing the interest and attitudes to encourage learning and appreciating mathematics could explain why the PSTs perceived appreciable improvement in their *reflection to correct their misconceptions about subject matter of mathematics* in teaching mathematics, in the survey findings. The survey findings that the PSTs were developing interest to focus on the *content* in their mathematical instructions is supported by the interviewees' perceptions that they were *gaining deeper understanding of mathematical ideas by exploring the relationships*

		learning and appreciation mathematics. They are gaining deeper understanding of mathematical ideas by exploring the relationships between mathematical ideas. They perceive improvements in their anxieties and competence.	*between mathematical ideas*; The survey findings that the PSTs' deliberate *reflection to correct their misconceptions about subject matter of mathematics* had improved could be explained by the interviewees' claims that they perceived improvement in *gaining deeper understanding of mathematical ideas by exploring the relationships between mathematical ideas*; *reasoning with the subject matter knowledge* they are learning. The interviewees' conviction that they were overcoming their mental blocks to learning mathematics, that they perceived improvement in their confidence in learning mathematics, and improvement in their anxieties and competence, confirm the survey finding that the PSTs' *reflection to correct their misconceptions about the subject matter of mathematics* were improving.

Table 5.15: Merged findings regarding the affordances of the improvement in their beliefs (Phase A)

Research question	Findings from survey results	Findings from interview results	Similarities in findings – confirmation, supplementary insight, additional information, detailed interpretations
What affordance(s) do the PSTs perceive from the transformations they perceive in their beliefs about mathematics and teaching and learning of mathematics?	The findings reveal that the PSTs perceived that they were able to *create ample opportunities for active learner participation in their mathematics instruction* *promote learning mathematics for meaningful understanding* *overcome learners' anxieties and improve learners' competence in learning* *adapt to a learner-centred approach in teaching mathematics* .	The interviewees perceived that they were able to: promote reasoning with the subject matter knowledge of mathematics as a body of interconnected ideas that are less challenging. promote teaching and learning mathematics as a problem-solving activity; facilitate children's ability to learn mathematics; facilitate teaching and learning of mathematics as fun. guide children to struggle and figure out ideas and solutions by themselves. create opportunities for children to participate and discuss their understanding of mathematical ideas. assess children's thinking and understanding of ideas or problems; explain children's thinking, solutions, and procedures. create a problem-solving learning environment for children's learning effectiveness – guide children to explore their solution methods/strategies; promote a learner-centred approach in teaching; teach mathematics from the	The interviewees' convictions that they could *reason with the subject matter knowledge of mathematics as a body of interconnected ideas that are less challenging* confirms the survey findings that the PSTs believed they could facilitate *learning mathematics for meaningful understanding*. The interviewees' confidence that they could promote teaching and learning mathematics as a problem solving activity supports the survey findings that the PSTs perceived that they could *facilitate learners' meaningful understanding of mathematics*; *adapt to the learner-centred approach in teaching mathematics* and *create ample opportunities for active learners' participations in their mathematics instructions*. The interviewees' claims that they could learn mathematical ideas from the perspective of the child, understand how children understand mathematics and think about children's thinking about the ideas and encourage learners to come out with their solutions could explain the survey findings that the PSTs perceived that they could assist learners to *overcome their own anxieties and improve learners' competence in mathematics.* The interviewees' convictions that they could facilitate children's abilities to learn mathematics, guide children to struggle and figure out ideas and solutions by themselves and facilitate teaching and learning of mathematics as fun complement the survey findings that the PSTs perceived that they could *facilitate learners' meaningful understanding of mathematics, adapt to the learner-centred approach in teaching mathematics, create ample opportunities for active learner participation in their mathematics instruction*. The interviewees' perceptions that they could promote teaching and learning mathematics as a problem-solving

		perspective of the learner; consider how they think, interpret and understand ideas and problems; create more cognitive thinking within the learners. learn mathematical ideas from the perspective of the child – understand how children understand mathematics and think about learners' thinking about ideas. create opportunities for learners to be responsible for their own learning – discovering and understanding ideas by themselves.	activity, explain children's thinking, solutions, and procedures, understand how children understand mathematics and think about their thinking confirm the survey finding that the PSTs believed they could *facilitate learners' meaningful understanding* of mathematics. The interviewees' views that they could create opportunities for children to participate and discuss their understanding of the mathematical ideas could be in line with the survey findings that the PSTs perceived they could *create ample opportunities for active learner participation in their mathematics instruction* and *facilitate learners' meaningful understanding of mathematics*. The interviewee's confidence that they could assess children's thinking and understanding of ideas or problems and explain children's thinking, solutions, and procedures could explain the survey findings that the PSTs perceived that they could *facilitate learners' meaningful understanding of mathematics.* The interviewees' perceptions that they could create a problem-solving learning environment, guide children to explore their own methods/strategies, promote a learner-centred approach, teach mathematics from the perspective of the learner, consider how they think, interpret ideas and problems; create more cognitive thinking within the learners explain the survey findings that the PSTs perceived they can *facilitate learners' meaningful understanding of mathematics, adapt to learner-centred approach* and *create ample opportunities for active learner participation in their mathematics instruction*.

Table 5.16: Merged findings concerning the PSTs' perceived improvement in their CK and PCK (Phase A)

Research question	**Findings from survey results**	**Findings from interview results**	**Similarities/differences in findings – confirmation, supplementary insight, additional information, detailed interpretation**
What improvements do the PSTs' perceive in their understanding of CK and development of their PCK for Foundation Phase mathematics?	The findings show that the PSTs perceived appreciable improvement in the following: *understanding of mathematical concepts, facts, and procedures, understanding how learners learn number operations and relationships, understanding of how to solve problems using different strategies. understanding of how to access and assess learners' thinking and understanding in teaching and learning, understanding of how to make connections between ideas and strategies in solving problems in teaching and learning*	The interviewees perceived improvement in their... conceptual understanding of the contents – *understanding what is going on behind the scenes about the ideas*; *relationships and connections between concepts and procedures; multiple embodiments of the ideas and procedures*; *generating new ideas; understanding of how procedures work, why they work the way they do; explanations of the connections between concepts and procedures* *thinking about the: reflections and corrections of their misconceptions about ideas*	The interviewees' claims that they perceived improvement in their understanding of mathematical concepts and procedures, and understanding of relationships between concepts and procedures, confirm the survey findings that the PSTs perceived improvement in their *understanding of mathematical concepts, facts, and procedures*. The survey findings that the PSTs perceived improvement in their *understanding of how to assess learners' understanding of mathematical ideas and procedures*, as well as improvements in their *understanding of mathematical concepts, facts, and procedures*, could be explained by the interviewees' claims that they perceived improvements in their - *understanding of what is going on behind the scenes concerning the ideas, the multiple embodiments of the ideas and procedures, generating new ideas*. The interviewees' views that they perceived improvement in their *understanding of relationships between concepts and procedures* supports the survey findings that the PSTs perceived that they understand how to *solve problems using different strategies* and *understand how to make connections between ideas and strategies in solving problems in teaching and learning.* The interviewees' convictions that they perceived improvement in their *understanding of how procedures work, why they work the way they do*, and how to *explain connections between ideas* confirm the survey findings that the PSTs perceived improvement in their *understanding of mathematical concepts, facts, and procedures*; and their *understanding of how to assess learners' understanding of mathematical ideas and procedures.*

Table 5.17: Merged findings about the PSTs' perceived affordances of the improvement in their CK and PCK (Phase A)

Research question	Findings from survey results	Findings from interview results	Similarities/differences in findings- confirmation, supplementary insights, additional information, detailed interpretations
What affordances do the PSTs perceive from the improvement in their understanding of CK and development of their PCK in Foundation Phase mathematics?	The findings reveal that the PSTs perceived that they were able to: *assist learners to find answers using different strategies, explain solution methods or strategies to learner – explain concepts and procedures to enhance learners' understanding, select appropriate teaching and learning activities and resources, implement a problem-centred teaching and learning approach, facilitate learners' thinking and meaningful understanding of contents.*	The interviewees perceived that they were able to: adapt the teaching and learning activities to suit children's learning needs, adjust their thinking to understand how children think about mathematical ideas; guide children's learning and understanding from the known to the unknown – e.g. helping children to explore new ideas from their prior knowledge and understanding; use manipulatives or real-life situations to motivate the learner and enhance their learning experiences; create opportunities for children to explore their own methods or strategies in solving problems they encounter; encourage children's thinking abilities through questioning and prompting; use the learners' own thinking to improve the learners' thinking and understanding; encourage children to discuss their thinking and test their thinking in problem-solving situations;	The interviewees' convictions that they were able to use manipulatives or real-life situations to motivate the learners and enhance their understanding complements the survey findings that the PSTs believed they were able to *assist learners to find answers using different strategies, select appropriate teaching and learning activities and resources,* and *implement problem centered teaching and learning approach*. The interviewees' confidence that they were able to explain similarities and differences among children's solution strategies supports the survey findings that the PSTs believed they were able to *explain concepts and procedures to enhance learners' understanding; explain solution methods or strategies to learners,* and *assist learners to find answers using different strategies*. The interviewees' claims that they were able to encourage learners to explore multiple views and strategies complements the survey findings that the PSTs believed they were able to *assist learners to find answers using different strategies*; *implement a problem-centred teaching and learning approach,* and *facilitate learners' thinking and meaningful understanding of contents*. The interviewees' confidence that they were able to create opportunities for children to explore their own methods or strategies for solving problems they encounter could explain the survey findings that the PSTs were able to *select appropriate teaching and learning activities and resources, implement a problem-centred teaching and learning approach,* and *facilitate learners' thinking and meaningful understanding of content*. The interviewees' certainty that they were able to encourage children's thinking abilities through questioning and prompting confirms the survey findings that the PSTs believed they were able

		encourage children to work cooperatively – e.g. talk about individuals' ideas, understand the different ways individuals think about ideas and procedures, contribute to the collective and better understanding of all learners in the group; focus on how children think about mathematical ideas/concepts and procedures; give learners opportunities to express their understanding of the mathematical ideas they are learning or the problems they are solving; help children to form connections between their ideas; encourage learners to explore multiple views and strategies; explain similarities and differences among children's solution strategies; assess the learner and the learning experiences.	to *implement a problem-centred teaching and learning approach*, and *facilitate learners' thinking and meaningful understanding of contents*. The interviewees' convictions that they were able to help children to make connections between their ideas confirms the survey findings that the PSTs believed they were able to *explain concepts and procedures to enhance learners' understanding, facilitate learners' thinking and meaningful understanding of contents, assist learners to find answers using different strategies*, and *explain solution methods or strategies to learners*. The interviewees' claims that they were able to understand learners' thinking and use the learners' own thinking to improve such thinking and understanding supports the survey findings that the PSTs perceived that they were able to *assist learners to find answers using different strategies*, *explain methods or strategies for solutions to learners*, *facilitate learners' thinking and meaningful understanding of contents*, and *explain concepts and procedures to enhance learners' understanding*. The interviewees' confidence that they were able to encourage children to think, discuss their thinking and test their thinking in problem-solving situations, confirms the survey findings that the PSTs believed that they were able to *implement a problem-centred teaching and learning approach* and *facilitate learners' thinking and meaningful understanding of contents*. The interviewees' claims that they were able to encourage children to work cooperatively – e.g. talk about individuals' ideas, understand the different ways individuals think about ideas and procedures, contribute to the collective and better understanding of all learners in the group, complement the survey findings that the PSTs believed that they were able to *select appropriate teaching and learning activities and resources, implement a problem-centred teaching and learning approach, facilitate learners' thinking and meaningful understanding of contents.* The interviewees' perceptions that they were able to focus on how children think about mathematical ideas/concepts and procedures could be in line with the survey findings that the PSTs perceived

			that they were able to *select appropriate teaching and learning activities and resources, implement a problem-centred teaching and learning approach, facilitate learners' thinking and meaningful understanding of contents*. The interviewees' convictions that they were able to give learners the opportunity to express their understanding of the mathematical ideas they are learning or the problems they are solving confirm the survey findings that the PSTs perceived that they were able to *implement a problem-centred teaching and learning approach and facilitate learners' thinking and meaningful understanding of contents.* The survey findings that the PSTs believed they were able to *assist learners to find answers using different strategies* are explained by the interviewees' claims that they believe they were able to create opportunities for children to explore their own methods or strategies in solving problems they encounter, encourage children's thinking abilities through questioning and prompting, explain similarities and differences among children's solution strategies, encourage learners to explore multiple views and strategies, and help children to explore new ideas from their prior knowledge and understanding.

Table 5.18: Merged findings about the most or least enhanced dimension(s) of their PD (Phase A)

Research question	Findings from survey results	Findings from interview results	Similarities/differences in findings- confirmations, supplementary insights, additional information, detailed interpretations
Which of the three dimensions of their professional development (i.e. beliefs, content knowledge and pedagogical content knowledge) is most or least enhanced?	The PSTs perceived fair improvement in all the indicators of change; they, however, perceived that their *beliefs about the subject matter of mathematics and teaching and learning of mathematics* were significantly improved over the two knowledge components of their PD.	The interviewees seemed to claim that their entry beliefs and CK were much improved compared to their PCK.	The two findings seemed to confirm that the PSTs perceived greater improvement in their *beliefs about the subject matter of mathematics and teaching and learning of mathematics*. It is also clear that both findings confirm that the PSTs did not perceive much improvement in their PCK. However, some of the interviewees' perceived improvement in their CK contradicted the survey findings that the PSTs did not perceive improvement in their CK over their beliefs and PCK.

5.3. SUMMARY OF FINDINGS FROM THE MERGED FINDINGS (Phase A)

The side-by-side comparison of the quantitative and qualitative findings showed that the qualitative findings confirmed the quantitative findings. Furthermore, the qualitative findings provided more insight into the PSTs' interpretation of their PD during the two-year training as Foundation Phase mathematics teachers. The merged findings are presented under the research questions guiding this study, as follows:

- What change(s)/improvement do the PSTs' perceive in their beliefs about mathematics and teaching and learning of mathematics? The integrated findings revealed that the PSTs perceive:

  a. *the subject matter knowledge of mathematics as body of interrelated ideas;*
  b. *mathematics as a problem-solving activity;*
  c. *improvement in their reflection on and corrections of misconceptions about subject matter of mathematics;*
  d. *improvement in their focus on learner needs and their characteristics in instructional decision making as well as during instructions;*
  e. *improvement in their interest and attitudes to encourage learning and appreciation of mathematics and more focus on learning the content of mathematics;*
  f. *improvement in their appreciation and adoption of the learner-centred instructional approach;*
  g. *improvement in overcoming their anxieties and incompetence, mental blocks to learning mathematics, and confidence in learning/doing mathematics*.

- What affordance(s) do the PSTs perceive from the improvement perceived in their beliefs about mathematics and teaching and learning of mathematics? The PSTs perceive they were able to:

  a. *reason with the subject matter knowledge of mathematics as a body of interconnected ideas that are less challenging*;

b. *facilitate learning mathematics for meaningful understanding;*
c. *understand teaching and learning mathematics as a problem-solving activity;*
d. *understand how children understand mathematics and think about their thinking about the ideas; and explain children's thinking, solutions, and procedures;*
e. *teach mathematics from the perspective of the learner and consider how they think, interpret and understand ideas and problems, create opportunities for children to participate and discuss their understanding of the mathematical ideas, create more cognitive thinking within the learners, assess children's thinking and understanding of ideas;*
f. *facilitate teaching and learning of mathematics as fun,; guide children to struggle and figure out ideas and solutions by themselves, and encourage learners to discover their own solution methods;*
g. *adapt learner-centred approach in teaching; and focus on learners' interests, overcome learners anxieties and improve learners' competence.*

❖ What change(s)/improvement do the PSTs' perceive in their understanding of the mathematics CK and development of their PCK for Foundation Phase mathematics? PSTs perceive

a. *improvement in their understanding of mathematical concepts, facts, and procedures; the relationships and connections between concepts and procedures; and conceptual understanding of ideas – understand what is going on behind the scenes concerning the ideas*;
b. *improvement in thinking about the multiple embodiments of the ideas and procedures*;
c. *improvement in generating new ideas*;
d. *improvement in their understanding of how procedures work, why they work the way they do, and explaining connections between ideas*;
e. *improvement in their understanding of how to assist learners to work with different strategies*;
f. *understanding of how to assess learners' understanding of mathematical ideas and procedures.*

- What affordance(s) do the PSTs perceive from the improvement (they perceive) in their understanding of the mathematics CK and development of their PCK for Foundation Phase mathematics? PSTs believe they were able to:

  a. *use manipulatives or real-life situations to motivate the learner and enhance their learning experiences (improve meaningful understanding);*
  b. *create opportunities for children to explore their own methods or strategies in solving problems they encounter; assist learners to find answers using different strategies; encourage learners to explore multiple views and strategies;*
  c. *encourage children's thinking abilities through questioning and prompting; give learners opportunities to express their understanding of the mathematical ideas they are learning or the problems they are solving;*
  d. *explain similarities and differences among children's solution strategies;*
  e. *help children to explore new ideas from their prior knowledge and understanding; help children to form connections between their ideas;*
  f. *assist children to think, discuss their thinking and test their thinking in problem-solving situations;*
  g. *adapt the teaching and learning environment/activities to suit children's learning needs; understand learners' thinking and use the learners' own thinking to improve learners' thinking and understanding;*
  h. *assess the learner and the learning experiences.*

- Which of the three dimensions of their professional development (i.e. beliefs, content knowledge and pedagogical content knowledge) is most or least enhanced?

Though there were confirmatory findings for the questions discussed above, contradictory findings were observed with reference to the question of which of the three dimensions of their professional development (i.e. beliefs, content knowledge and pedagogical content knowledge) was most or least enhanced? The quantitative results show that the PSTs perceived that significant *improvement in their beliefs about subject matter of mathematics and teaching and*

learning of mathematics compared to their CK and PCK, while the qualitative results show that the interviewees claimed that their beliefs and CK were more improved than their PCK, thus, their beliefs and CK were the most improved dimensions of their PD. The contradictory claims here would not mean that the PSTs have neglected some aspects of their own PD. In fact, the narratives rather show that they were making all efforts to improve holistically. This was also evidenced in the survey results showing that the PSTs perceived fair improvement in the learning outcomes on which they assessed themselves. Most importantly, the fact still remains that balanced improvement in all three learning outcomes is necessary to ensure growth in their PD, as the confirmatory results discussed above are showing. Therefore, the contradictory claims could not be considered counterproductive towards achieving the desired PD in their learning trajectories. Instead, they should be regarded as progress the PSTs were making in their transition from learners to teachers of mathematics. Such in-depth information about the PSTs' PD could be useful to teacher educators in their efforts and planning to facilitate effective PD of PSTs.

5.4. ASSESSMENT OF THE PSTs' PD (PHASE B)

5.4.1. Survey Results (Phase B)

The PSTs voluntarily responded to the survey questions eliciting their perceptions about the impact on their PD of the teaching expertise they experienced while they were learning to teach mathematics in the 3rd-year Foundation Phase Mathematics module. The survey data obtained were analysed to find empirical evidence from the subjects' responses in the survey to justify possible answers to the questions below:

i. What change(s)/improvement do the PSTs' perceive in their beliefs about mathematics and teaching and learning of mathematics?
ii. What affordance(s) do the PSTs perceive from the improvement they perceive in their beliefs about mathematics and teaching and learning of mathematics?
iii. What change(s)/improvement do the PSTs' perceive in their understanding of CK and development of their PCK in Foundation Phase mathematics?

iv. What affordance(s) do the PSTs perceive from the improvement they perceive in their understanding of CK and the development of their PCK in Foundation Phase mathematics?

v. Which of the three dimensions of their professional development (i.e. beliefs, content knowledge and pedagogical content knowledge) is most or least enhanced?

vi. Which of the dimensions of the teaching expertise they experienced influenced the PSTs' PD most or least?

vii. Which of the two experiences impacted more/less on the dimensions of their PD?

As in to the first survey, the analytic themes in Table **5.19** were used to analyse the collected data.

Table 5.19: Thematic headings for statistical analysis

PRIMARY THEME: **Perceived improvement in PSTs' PD**	PRIMARY THEME: **Perceived affordances of the improvement in PSTs' PD**
Secondary Themes: *Perceived improvement in beliefs/perceptions about subject matter of mathematics and teaching and learning of mathematics*	**Secondary Themes:** *Perceived affordances of the changes in PSTs' beliefs about subject matter of mathematics and the teaching and learning of mathematics*
Specific sub-themes Enhance reflections on learning and actions Enhance mathematical competence Critical about learner needs Improve content focused	Specific sub-themes Promote learning mathematics for meaningful understanding Desire to adapt learner-centred approach Overcome anxieties and incompetence in learning Focus instructional decisions on learners' interests Create ample opportunities for active learner participation
Secondary Themes: *Perceived improvement in PSTs' understanding of content knowledge and development of pedagogical content knowledge*	**Secondary Themes:** *Perceived affordances of the improvement in PSTs' understanding of content knowledge and development of pedagogical content knowledge*
Specific sub-themes Improvement in understanding of content knowledge a. Understanding of foundation mathematical concepts and procedures b. Understand how learners learn number operations and relationships c. Solve problems using different strategies d. Explain why procedures work they way they do Improvement in pedagogical content knowledge a. Make connections between ideas and strategies in solving problems b. Accessing and assessing learners' thinking and understanding	Specific sub-themes Working (articulate/demonstrate in teaching and learning) with understanding of content knowledge a. Can explain concepts and procedures to enhance learners' understanding b. Can implement a problem-centred teaching and learning approach Working (articulate/demonstrate in teaching and learning) with pedagogical content knowledge a. can effectively facilitate thinking and meaningful understanding of contents b. can select appropriate teaching and learning activities and resources

The statistical results are presented above under the thematic headings in Table **5.19**.

5.4.1.1. Summary of Statistical Analysis

As with the statistical analysis of data from the first survey, both descriptive and inferential statistics were computed from the data obtained. The statistics were percentages/frequencies; mean ratings obtained through the computations of mixed-model analysis of variance (ANOVA) measures and Least Significant Differences (LSDs); and measures of reliability of the results (i.e.

Cronbach's alpha). The measures of percentages (frequencies) gave descriptive summaries of the PSTs' responses to each evaluation statement within the themes in Table **5.19,** above. The emphasis of the tabular presentations was to show the overall trends in the obtained responses for individual items, which could also enhance comparison between the different viewpoints of the subjects in rating those variables/items. The computations of the mixed model repeated measures ANOVA and Fisher's Least Significant Differences (LSDs) were employed to highlight further and specific mean differences within and between themes representing the evaluation statements. The emerging results of these analyses succinctly rated the thematic means and the variables constituting them. This helped to draw fairly accurate conclusions with reference to the guiding research questions.

The researcher needed the Chronbach alpha outputs for the various themes (except single-item themes) to demonstrate the reliability of the instrument developed (questionnaire) for collecting the data – showing that the items/scales could produce a consistent and reliable measure of the responses being elicited, for worthy and trusted conclusions/inferences. Table **5.20** below shows the Chronbach alpha outputs for the various themes:

Table 5.20: Chronbach alpha for scales

Scale	Alpha	Number of items	N (sample size)
Perceived improvement in beliefs/perception about subject matter of mathematics and teaching and learning of mathematics	α = 0.767138	7	59
Enhance reflection on learning and actions	α = 0.601290	3	59
Enhance mathematical competence	-	1	59
Critical about learner needs	α = 0.771520	2	59
Improve content-focused	-	1	59
Perceived affordances of the changes in PSTs' beliefs about subject matter of mathematics and the teaching and learning of mathematics	α = 0.767138	7	59
Capable of learning mathematics for meaningful understanding	-	1	59
Capable of adapting learner-centred approach	-	1	59
Overcome anxieties and incompetence in learning	α = 0.757021	3	59
Focus instructional decisions on learners' interests	-	1	59
Create ample opportunities for active learner participation	-	1	59
Perceived improvements in PSTs' understanding of CK	α = 0.731663	4	59
Understanding of foundation mathematical concepts	-	1	59
Understand how learners learn number operations and relationships	-	1	59
Solve problems using different strategies	-	1	59
Explain why procedures work they way they do	-	1	59
Perceived improvement in PSTs' development of PCK	α = 0.742616	6	59
Make connections between ideas and strategies in solving problems	α = 0.657907	2	59
Accessing and assessing learners' thinking and understanding	α = 0.430268	2	59
Ability to work/articulate with understanding of CK	α = 0.798471	7	59
Can explain concepts and procedures to enhance learners' understanding	α = 0.659694	3	59
Can implement problem-centred teaching and learning approach	α = 0.698665	4	59
Ability to work/articulate with PCK	α = 0.770740	7	59
can effectively facilitate learners' thinking and meaningful understanding of contents	α = 0.561760	3	59
can select appropriate teaching and learning activities and resources	α = 0.688964	4	59

5.4.1.2. Presentation of Descriptive Statistics (Percentages and Frequencies)

Respondents' (PSTs) perceived transformations/changes in their beliefs about the subject matter of mathematics and the teaching and learning of it

This theme encompasses learning outcomes associated with the respondents' developing PD. In evaluating their own beliefs about mathematics and teaching and learning of mathematics under this theme, the PSTs indicated the extent to which the evaluation statements were relevant to their perceptions or thinking. The Cronbach alpha measure for this major theme was 0.832355 with seven items; those of its sub-themes *enhance reflections on learning and actions* consisted of three items ($\alpha = 0.601290$) and *critical about learner needs* with two items had $\alpha = 0.771520$. *Enhance reflection on learning and actions* had a Cronbach alpha measure slightly below the acceptable alpha co-efficient of 0.7 and above. This was a newly-developed instrument for which such low alpha coefficients could be accepted. However, that being said, further analysis and inferences with these scales would be articulated with strong caution. Table **5.21** below is the summary of the frequencies (percentages) of the PSTs' responses to all the items under this major theme:

Table 5.21: Perceived transformation/changes in their beliefs about the subject matter of mathematics and the teaching and learning of it

Statement	**Scale**			
	SA	**A**	**D**	**SD**
Reflection to correct *misconceptions* about teaching	15 (25%)	44 (75%)	0%	0%
Reflection to correct *misconceptions* about child's learning	25 (42%)	34 (58%)	0%	0%
Reflection to correct *misconceptions* about subject matter of mathematics	12 (20%)	44 (75%)	2 (3%)	1 (2%)
Overcome feelings of incompetency	11 (19%)	47 (80%)	1 (2%)	0%
Critical about the needs and characteristics of children	10 (17%)	40 (68%)	8 (14%)	1 (2%)
Effective decisions to cater for children's needs and characteristics	20 (34%)	35 (59%)	4(7%)	0%
Profound interest in CK	20 (34%)	34 (58%)	5 (8%)	0%

Key: SA = Strongly Agree; A = Agree: D = Disagree; SD: Strongly Disagree

Overall, the responses displayed above in Table **5.21** show that the PSTs perceived fair improvement in almost all seven (7) equally important indicators of change. However, most improvement occurred in following, in which the PSTs' claimed to have perceived improvement:

- *reflection to correct misconceptions about teaching (75%)*
- *reflection to correct misconceptions about child's learning (58%)*
- *reflection to correct misconceptions about subject matter of mathematics (75%)*
- *overcoming feelings of incompetency (80%)*

The response pattern showed that almost all the PSTs either Agreed or Strongly Disagreed with the four claims above.

The improvement registered above could contribute to understanding or answering the research question related to the major theme of: "what changes/improvement do the PSTs' perceive in their beliefs about the subject matter of mathematics and teaching and learning of mathematics?"

Respondents' (PSTs) perceived affordances of the changes in PSTs' beliefs about subject matter of mathematics and the teaching and learning of mathematics

This theme consists of learning outcomes associated with the respondents' evolving PD. The learning outcomes in this category represent the manifestations of the major learning outcomes associated with the respondents' developing PD discussed above. Hence, the evaluation statements here were used to elicit the PSTs own assessments of the impact of the changes/improvement in their beliefs (above) on their perceived teaching capabilities. The PSTs indicated the extent to which the evaluation statements were relevant to the perceived affordances of their beliefs about the subject matter of mathematics and the teaching and learning of it. This major theme itself had a relatively high Cronbach alpha score of 0.819383 with seven (7) items. This theme consisted of five (5) sub-themes of which four (4) had single items. The PSTs' responses to the three items constituting *overcome anxiety and incompetence* showed a relatively high Cronbach alpha ($\alpha = 0.757021$). The researcher was cautious about the single-

item themes in any further analysis and inferences that involved them. Table **5.22** summarises the frequencies (percentages) of their responses under this theme:

Table 5.22: Perceived affordances of the transformation/changes in the PSTs' beliefs about the subject matter of mathematics and the teaching and learning of it

Statement	**Scale**			
	SA	**A**	**D**	**SD**
Can facilitate learners' meaningful understanding	10 (17%)	49 (83%)	0%	0%
Can promote learner-centred approach	16 (27%)	38 (64%)	5 (8%)	0%
Can overcome learners' anxieties through problem solving	20 (34%)	31 (53%)	8 (14%)	0%
Can use manipulatives to overcome learners' anxieties	12 (20%)	43 (73%)	4 (7%)	0%
Can overcome learners' incompetency through problem-solving	17 (29%)	35 (59%)	7 (12%)	0%
Can take instructional decisions to suite learners' interest/needs	16 (27%)	41 (69%)	2 (3%)	0%
Can promote active learner participations and discussions	23 (39%)	34 (58%)	2 (3%)	0%

Key: SA = Strongly Agree; A = Agree: D = Disagree; SD: Strongly Disagree

The results shown above in Table **5.22** revealed that the majority of the PSTs seemed to either Agree or Strongly Agree with all the evaluation statements. However, regarding the seven equally important indicators of effective teaching behaviour, the PSTs seemed to be seriously convinced in their perceptions that the two-year training had adequately developed them and so they:

- *can facilitate learners' meaningful understanding (83%)*
- *can take instructional decisions to suit learners' interest/needs (69%)*
- *can promote active learner participation and discussions (58%)*
- *can use manipulatives to overcome learners' anxieties (73%)*

The popularly recognised effective teaching capabilities claimed by the PSTs above could contribute to understanding or answering the research question related to the major theme above: "what affordance(s) do the PSTs perceive from the improvement they perceive in their beliefs about mathematics and teaching and learning of mathematics?"

Evaluation of PSTs' perceived improvement in their understanding of mathematics CK and development of PCK

Similar to the major themes above, this theme was also one of the major learning outcomes associated with the respondents' developing PD. Under this component of their PD, the PSTs evaluated the improvement they perceived in their understanding of the mathematics CK and development of their PCK for Foundation Phase mathematics. Accordingly, the PSTs indicated the extent to which the evaluation statements were relevant to the improvement they perceived in their understanding of CK and the development of their PCK. The two (2) sub-themes under this major theme had the following reliability measures and frequencies: *improvement in understanding of CK* (4 items, $\alpha = 0.731663$) and *development of PCK* (6 items, $\alpha = 0.742616$).

Table 5.23: Perceived improvements in their mathematics understanding CK and development of PCK

Statement	**Scale**			
	SA	**A**	**D**	**SD**
Understand mathematical concepts, facts, and procedures	10 (17%)	42 (71%)	5 (8%)	2 (3%)
Understand how young children learn math	12 (20%)	42 (71%)	4 (7%)	1 (2%)
Understand how to assist learners to work with different strategies	15 (25)	37 (63%)	7 (12%)	0%
Understand how to explain procedures	0%	44 (75%)	13 (22%)	2 (3%)
Understand how to explain solution methods in problem solving	6 (10%)	49 (83%)	4 (7%)	0%
Understand how to explain similarities and differences among different representations, solutions, or methods	13 (22%)	43 (73%)	3 (5%)	0%
Understand how to assist learners to solve problems requiring multiple ideas and strategies	12 (20%)	43 (73%)	4 (7%)	0%
Understand how to access learners' thinking	7 (12%)	45 (76%)	7 (12%)	0%
Understand how to help learners to connect their mathematical ideas in problem solving	8 (14%)	44 (75%)	7 (12%)	0%
Understand how to assess learners' understanding of mathematical ideas and procedures	9 (15%)	47 (80%)	3 (5%)	0%

Key: SA = Strongly Agree; A = Agree: D = Disagree; SD: Strongly Disagree

The results displayed above in Table **5.23** show that the majority [between 49 and 37 out of 59 respondents] of the PSTs seemed to "Agree" with all the evaluation statements, rather than "Strongly Agree", "Disagree" or "Strongly Disagree". This means that more than 50% of the PSTs agreed that they perceived improvement in those indicators of change or improvement on

which they assessed their PD. In these mass views, however, out of the 10 equally important indicators of change, the improvement seemed to be very pronounced in their perceptions that the teaching expertise they experienced had adequately improved their understanding of:

- *how to explain solution methods in problem solving (83%);*
- *how to assess learners' understanding of mathematical ideas and procedures (80%);*
- *how to access learners' thinking about concepts, procedures (76%);*
- *how to help learners to connect their mathematical ideas in problem solving (75%);*
- *how to explain procedures (75%);*
- *how to assist learners to solve problems requiring multiple ideas and strategies (73%);*
- *how to explain similarities and differences among different representations, solutions, or methods (73%);*
- *how young children learn math (71%);*
- *mathematical concepts, facts, and procedures (71%).*

The greatest improvement registered above could contribute to understanding or answering the research question related to the major theme above: "what change(s)/improvement do the PSTs' perceive in their understanding of CK and development of their PCK in Foundation Phase mathematics?"

PSTs' perceived affordances of the improvement in their mathematics understanding of CK and development of their PCK

Like the preceding themes above, this theme was one of the major learning outcomes associated with the respondents' developing PD. It consisted of learning outcomes showing the affordability, in teaching and learning, of the perceived improvement in the PSTs' CK and PCK

assessed above. Under this component of their PD, the PSTs assessed their abilities to deliver as mathematics teachers, given their perceived improvement in their CK and PCK. The PSTs indicated the extent to which the evaluation statements were relevant to the perceived affordances of their perceived improvement in their CK and PCK. The two (2) sub-themes under this theme had measures of reliabilities and frequencies presented here: ability to work with /articulate understanding of content knowledge (i.e. *Working with CK*) (7 items, $\alpha = 0.798471$); ability to work with /articulate pedagogical content knowledge (i.e. *Working with PCK*) (7 items, $\alpha = 0.770740$). The frequencies of the PSTs' responses to all the statements under this theme are shown below in Table **5.24**.

Table 5.24: Perceived affordances of improvement in their mathematics CK and PCK

Statement	**Scale**			
	SA	**A**	**D**	**SD**
Can explain why mathematical procedures work	1 (2%)	46 (78%)	12 (20%)	0%
Can provide a problem-solving learning context	16 (27%)	42 (71%)	1 (2%)	0%
Can assist learners in finding answers using different strategies	13 (22%)	43 (73%)	3 (5%)	0%
Can explain solution methods or strategies to learners	9 (15%)	47 (80%)	3 (5%)	0%
Can explain the similarities and differences among children's representations, solutions	12 (20%)	41 (69%)	6 (10%)	0%
Can assist learners to solve problems using ideas and strategies known or unknown to them	11 (19%)	42 (71%)	6 (10%)	0%
Can assist learners to solve problems requiring multiple ideas and strategies	12 (20%)	45 (76%)	2 (3%)	0%
Can help young children connect their mathematical ideas	13 (22%)	37 (63%)	9 (15%)	0%
Can select appropriate activities and resources for effective learning	20 (34%)	32 (54%)	7 (12%)	0%
Can use effective questioning skills to access learners' thinking	17 (29%)	31 (53%)	11 (19%)	0%
Can plan and implement mathematics lessons that suit learner needs	10 (17%)	37 (63%)	12 (20%)	0%
Can critically reflect on the effectiveness of my teaching methodology	9 (15%)	45 (76%)	5 (8%)	0%
Can use concrete materials to improve meaningful understanding	27 (46%)	31 (53%)	1 (2%)	0%
Can assess learners' understanding	8 (14%)	48 (81%)	3 (5%)	0%

Key: SA = Strongly Agree; A = Agree: D = Disagree; SD: Strongly Disagree

Generally, the responses displayed above in Table **5.24** show that the PSTs perceived fair improvement in almost all seven (7) equally important indicators of change. However, the greatest improvement occurred, as the PSTs' claimed, in their ability to

- *use concrete materials to improve meaningful understanding (53%);*
- *assess learners' understanding (81%);*
- *assist learners to solve problems requiring multiple ideas and strategies (76%);*
- *explain solution methods or strategies to learners (80%);*
- *assist learners in finding answers using different strategies (73%);*
- *provide a problem-solving learning context (71%).*

More importantly, the response pattern showed that almost all the PSTs either Agreed or Strongly Disagreed with the four claims above. The recognised effective teaching behaviours registered above could contribute to understanding or answering the research question related to the major theme discussed above: "what affordance(s) do the PSTs perceive from the improvement they perceive in their understanding of CK and development of their PCK in Foundation Phase mathematics?"

5.4.1.3. Observations from the pattern of response

Overall, the results displayed above in Tables **5.21**, **5.22**, **5.23**, and **5.24** show that fewer than 50% of all the PSTs had sufficient confidence in themselves to indicate that they perceived changes/improvement in their PD on the "Strongly Agree" scale. While more than 50% of the PSTs did have enough confidence in themselves to perceive changes/improvement in their PD on the "Agree" scale. The vast difference in their responses on the "Strongly Agree" and "Agree" scales could mean that the PSTs could claim, to a **relatively fair extent**, that they perceived improvement in all the indicators of their PD on which they evaluated themselves, but could not confidently claim beyond this extent, given their interaction with the teaching expertise of the Foundation Phase mathematics ETE. This could account for higher scores on the "Agree" scale than on the "Strongly Agree" scale. It is also worth noting that the responses presented above, could show the trends in the PSTs' perceptions about their PD and hence could contribute, though not strongly reliably, to some fair understanding or answering of the research questions.

5.4.1.4. Presentation of Inferential Statistics for the Comparison of the Means of the Themes

Aside from the descriptive results interpreted above, mixed model repeated measures ANOVA and Fisher's Least Significant Differences (LSDs) were computed from the same responses to enable more accurate comparison of the PSTs' responses. While the mixed model repeated measures ANOVA measures show, though not very specifically, whether or not the mean scores of the responses have any significant differences, the Least Significant Differences (LSDs) could enable the researcher to highlight the significant differences in the means between and within the themes harnessing those responses. Thus, these further analyses and their results provided deeper and accurate insight into how the PSTs' responses to the indicators of change compare with one another. In using these inferential statistics, decisions and conclusions on the comparison of the means depended on both the generated p-values from the ANOVA and the p-values for the paired means calculated at the 95% confidence level. In all the interpretations and discussions related to this section, both the descriptive and inferential statistics were combined to give more meaning to the interpretation of the PSTs responses with reference to the research questions guiding this study.

Respondents' (PSTs') perceived transformation/changes in their beliefs about the subject matter of mathematics and the teaching and learning of it

The p-value ($p = 0.00030$; $F(3, 174) = 6.6119$) obtained from the ANOVA for means of the learning outcomes compared under this theme, showed that there was strong evidence of significant differences between the means under observation at the 95% confidence interval. Thus, at least one of the learning outcomes, in Table **5.25,** below, had a higher or lower mean measure than some of the learning outcomes. Those learning outcomes, hence, could be said to show better improvement [or not] than the other indicators of perceived improvements in the PSTs' PD. Table **5.25** shows the computed means of the learning outcomes under comparison.

Table 5.25: Perceived transformations or improvement in beliefs

Effect	Level of Factor	N	Score Mean	Score Std. Dev.	Score Std. Err	Score −95.00%	Score +95.00%
Total		236	3.209746	0.548071	0.035676	3.139459	3.280032
Scale	reflection on learning and actions	59	3.271186	0.368670	0.047997	3.175110	3.367262
Scale	mathematical competence	59	3.000000	0.615882	0.080181	2.839500	3.160500
Scale	critical about learners' needs	59	3.313559	0.524390	0.068270	3.176902	3.450216
Scale	content-focused	59	3.254237	0.604387	0.078684	3.096733	3.411741

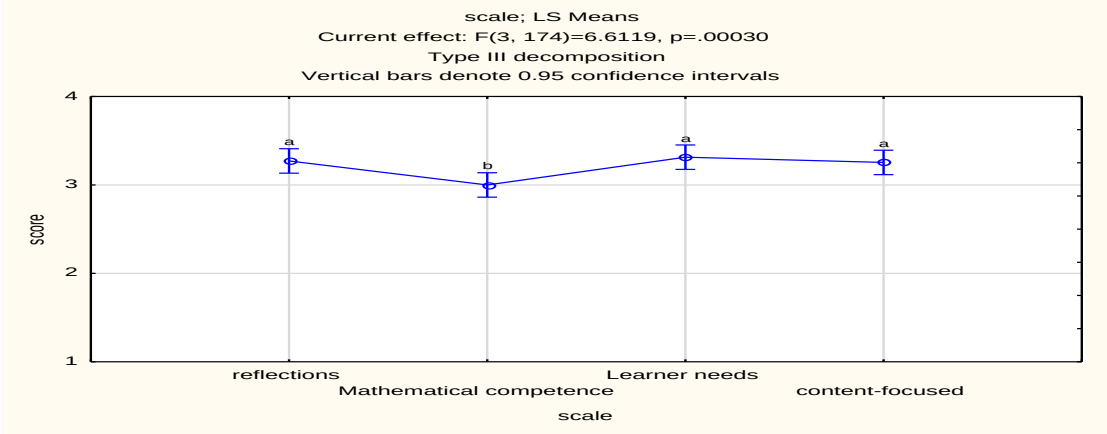
The observed differences noted above seemed to be confirmed by rigorous analysis with the calculated LSDs at 95% confidence intervals, which indicated that the PSTs' perceived significantly higher improvement in their *reflections on learning and actions* (their misconceptions and attitudes) than the improvement in their feelings of *mathematical competence* to engage in problem solving (p = 0.000653, and mean difference of 0.271186). The PSTs similarly perceived significant improvement in *being critical about their learners' needs and characteristics* – more so than perceived improvement in their *mathematical competence to engage in problem solving* (p = 0.000089: 0.313559). The PSTs also perceived significantly higher improvement in their *interest in focusing on the mathematics content* than the perceived improvement in their *mathematical competence* to engage in problem solving (p = 0.001365: -0.254237).

The evidence seemed to confirm the earlier proof and specifically to show that PSTs' perceived significantly higher improvement in their *reflection on learning and actions* (their misconceptions and attitudes); improvement in *being critical about their learners' needs and characteristics* and improvement in their *interest in focusing on the mathematics content*, than improvement in their *mathematical competence* to engage in problem solving.

In support of these observations, the analysis further seemed to prove that the PSTs perceived equal improvement in *reflection on learning and actions* and *being critical about their learners' needs and characteristics* (p = 0.588229). The PSTs' similarly perceived improvement in *reflection on learning and actions,* in which the improvement was equal to their *interest in focusing on the mathematics content* (p = 0.828490). In addition, the PSTs' perceived improvement both in *being critical about their learners' needs and characteristics* and *interest*

in focusing on the mathematics content revealed the same level of improvement (p = 0.448655). These results have are visually displayed below, in Figure **5.8**.

Figure 5.8: Perceived transformation or improvement in beliefs

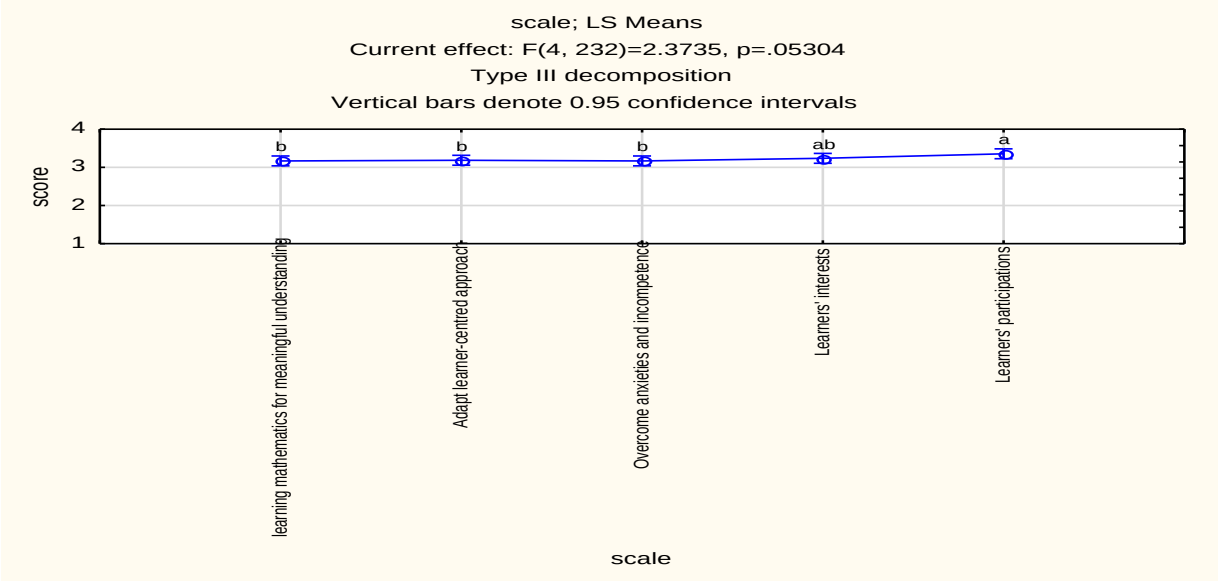


The visual display presented above (Figure **5.8**) also seems to confirm all three preceding proofs and confirm that the PSTs perceived *reflection on learning and actions*, *being critical about their learners' needs and characteristics* and *interests in focusing on the mathematics content* have improved equally highly over their perceived improvement in their *mathematical* competence. Therefore, in connection with the research question "what/which change(s)/improvement do the PSTs' perceive in their beliefs about mathematics and teaching and learning of mathematics?" it could be said that the PSTs perceived that their *reflection on learning and actions*; *being critical about their learners' needs and characteristics;* and *interest in focusing on the mathematics content* improved equally highly during their interaction with the ETE's teaching expertise.

Respondents' (PSTs) perceived affordances of the changes in PSTs' beliefs about the subject matter of mathematics and the teaching and learning of mathematics

The graphical display in Figure 5.9, below, shows trends in the means of the learning outcomes compared under this theme. This visual representation emphasises the comparison between the viewpoints of the subjects.

Figure 5.9: Perceived affordances of the transformations or improvements in beliefs



The visual representation shows that the PSTs' perceived almost equal appreciation in all the teaching capabilities. The measures of the teaching capabilities could be said to have improved equally over any significant difference. Thus, the PSTs perceived better and equal improvement in their abilities to *create ample opportunities for active learners' participations; promote learning mathematics for meaningful understanding; overcome learners' anxieties and improve learners' competence in learning;* and *adapt a learner-centred approach*. This observation seemed to be confirmed by the inferential statistical computations. Overall, the computed ANOVA with p = 0.05304 (F (4, 232) = 2.3735) showed that there was no evidence of strong or significant differences between the means of the compared learning outcomes, at the 95% confidence interval. The PSTs thus perceived fairly equal improvement in all the learning outcomes, as observed above. Table **5.26** below shows the computed means of the learning outcomes being compared.

Table 5.26: Perceived affordances of the transformations or improvement in beliefs

Effect	Level of Factor	N	Score Mean	Score Std. Dev.	Score Std. Err	Score −95.00%	Score +95.00%
Total		295	3.223729	0.505116	0.029409	3.165850	3.281608
Scale	promote learning mathematics for meaningful understanding	59	3.169492	0.378406	0.049264	3.070878	3.268105
Scale	adapting learner-centred approach	59	3.186441	0.571585	0.074414	3.037485	3.335397
Scale	overcoming anxieties and incompetence	59	3.169492	0.492755	0.064151	3.041079	3.297904
Scale	Learners' interests	59	3.237288	0.503059	0.065493	3.106190	3.368386
Scale	Learners' participation	59	3.355932	0.549693	0.071564	3.212681	3.499183

Furthermore, rigorous analysis with the calculated LSDs at 95% confidence intervals also seemed to show that no statistically significant differences were observed between the following paired teaching capabilities, thus confirming the preceding evidence that PSTs' perceived capabilities in *adapting learner-centred approach; overcoming learners' anxieties and improving learners' competence in learning* and *focusing instructional decisions on learners' interests* were improved to the same degree as their capabilities in *promoting learning mathematics for meaningful understanding* ($p = 0.815304$, $p = 1.000000$, $p = 0.350544$, respectively).

PSTs perceived fairly equal improvement in both of their perceived capabilities in *focusing instructional decisions on learners' interests* and *overcoming learners' anxieties and improving learners' competence in learning* as in *adapting learner-centered approach* ($p = 0.483653$, $p = 0.815304$, respectively).

PSTs' perceived capabilities in *overcoming learners' anxieties and improving learners' competence in learning* improved to the same degree as their capabilities in *focusing instructional decisions on learners' interests* ($p = 0.350544$).

PSTs perceived fairly equal improvement in their perceived capabilities in *creating ample opportunities for active learner participation* as in *focusing instructional decisions on learners' interests* ($p = 0.102989$).

Further supporting/confirming all three proofs and confirmations above, the rigorous analysis with the calculated LSDs at 95% confidence intervals indicated that there were statistically significant differences between the relatively less improved teaching capabilities and more improved teaching capabilities perceived: PSTs' perceived capabilities in *creating ample opportunities for active learner participation* were significantly improved above their perceived capabilities in *promoting learning mathematics for meaningful understanding* ($p = 0.010723$, mean difference = 0.186441); their capabilities in *overcoming learners' anxieties and improve learners' competence in learning* ($p = 0.010723$, mean difference = 0.186441) and their capabilities in *adapting learner-centered approach* ($p = 0.020209$ and mean difference of 0.169492).

Interestingly, the outcomes presented above could give fairly good insight about possible answer(s) to the research question "what/which affordances do the PSTs perceive from the improvement they perceive in their beliefs about mathematics and teaching and learning of mathematics?" Drawing from the evidence, it could probably be justified to conclude that the PSTs perceived fairly equal improvement in all the desired teaching capabilities on which they assessed their PD: they perceived that they were able to *create ample opportunities for active learner participation; promoting learning mathematics for meaningful understanding; overcoming learners' anxieties and improving learners' competence in learning;* and *adapt learner-centred approach* during their interaction with the ETE's teaching expertise.

PSTs' perceived improvement in their understanding of mathematics CK and development of PCK

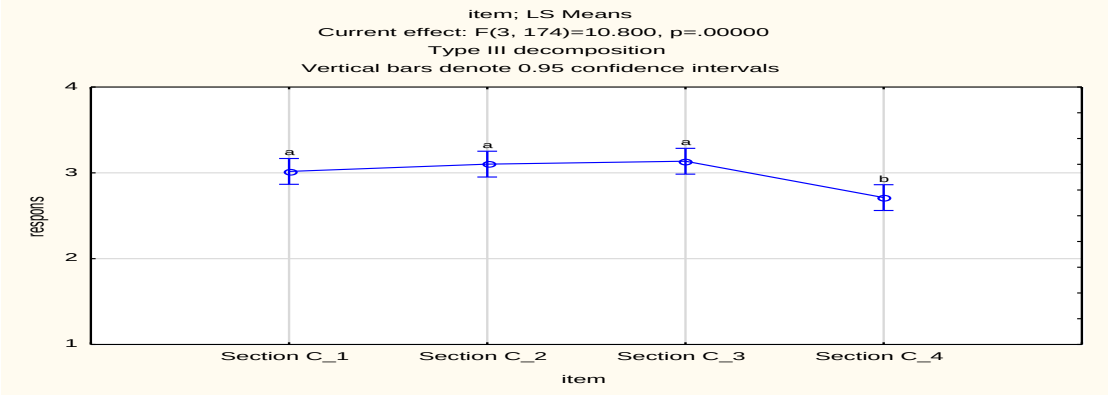
To succinctly present the PSTs' perceived achievements with regard to this theme, their responses were considered under the following sub-themes associated with improvement in their perceived understanding of the CK: *understanding of foundation mathematical concepts and procedures*; *understanding how learners learn number operations and relationships*; *solving problems using different strategies*; and *explaining why procedures work they way they do*. Similarly, their perceived developing PCK for Foundation Phase mathematics was considered under the following sub-themes: *make connections between ideas and strategies in solving*

problems in teaching and learning; and *accessing and assessing learners' thinking and understanding in teaching and learning.*

Perceived improvement in their understanding of Foundation Phase mathematics CK

In the preceding results of the frequencies of their responses, the PSTs expressed the levels of their perceived improvements in their understanding of the CK. Further analysis was done on those responses to establish, if any, strong evidence statistical significance of the PSTs' perceptions about the improvement in their understanding of the CK. The graphical display in Figure **5.10** shows the trends in the means of the learning outcomes being compared under the theme mentioned above. This visual representation emphasises the comparison between the different viewpoints of the subjects. The visual representation below shows that the PSTs' perceived greater improvement in *understanding foundation mathematical concepts and procedures; understanding how learners learn number operations and relationships*; and *solving problems using different strategies*, than in *explaining why procedures work they way they do*. Thus, the former three knowledge components had improved beyond the later knowledge component.

Figure 5.10: Perceived improvement in understanding Foundation Phase CK



Section **C_1** represents the PSTS' perceived *understanding of foundation mathematical concepts and procedures*. Section **C_2** represents the PSTS' perceived *understanding of how learners learn number operations and relationships.* Section **C_3** represents the PSTS' perceived *understanding of how to solve problems using different strategies*. Section **C_4** represents the PSTS' perceived *understanding of how to explain why procedures work they way they do*.

In support of the graphical evidence above, rigorous statistical computations of how the learning outcomes compared were done. The computed ANOVA with p = 0.00000 (F (3, 174) = 10.800) confirmed that there was evidence of strong significant statistical differences (at 95% confidence intervals) in improvement between some of the learning outcomes whose observed means are shown in Table **5.27,** below.

Table 5.27: Perceived improvement in understanding Foundation Phase CK

Effect	Level of Factor	N	Score Mean	Score Std. Dev.	Score Std. Err	Score −95.00%	Score +95.00%
Total		236	2.991525	0.604885	0.039375	2.913953	3.069098
Scale	Section **C_1**	59	3.016949	0.629491	0.081953	2.852903	3.180996
Scale	Section **C_2**	59	3.101695	0.578193	0.075274	2.951017	3.252373
Scale	Section **C_3**	59	3.135593	0.600506	0.078179	2.979100	3.292086
Scale	Section **C_4**	59	2.711864	0.526892	0.068596	2.574556	2.849173

In line with the evidence above, further analysis with the calculated LSDs at 95% confidence intervals also confirmed that significant differences in perceived improvement were observed in the following paired learning outcomes:

PSTs' *perceived improvement in understanding of foundation mathematical concepts and procedures* improved significantly over their perceived *understanding of how to explain why procedures work they way they do*, with p = 0.000318, and mean difference of 0.305085

PSTs' *perceived improvement in their understanding of how learners learn number operations and relationships* was significantly better than their perceived *understanding of how to explain why procedures work they way they do*: p = 0.000005 and mean difference of 0.389831.

PSTs' *perceived improvement in their understanding of how to solve problems using different strategies* improved significantly over the perceived *understanding of how to explain why procedures work they way they do*: p = 0.000001 and mean difference of 0.423729.

In further support of the earlier observations that the PSTs' perceived equally greater improvement in *understanding foundation mathematical concepts and procedures* and *understanding how learners learn number operations and relationships*, no evidence of strong statistically significant differences were observed in the following pair-wise comparisons:

PSTs' *perceived improvement in their understanding of foundation mathematical concepts and procedures* was as improved as their perceived *understanding of how learners learn number operations and relationships*, with p = 0.308967.

PSTs' *perceived improvement in their understanding of foundation mathematical concepts and procedures* and their *perceived understanding of how to solve problems using different strategies,* were at the same level of improvement, with p = 0.154933.

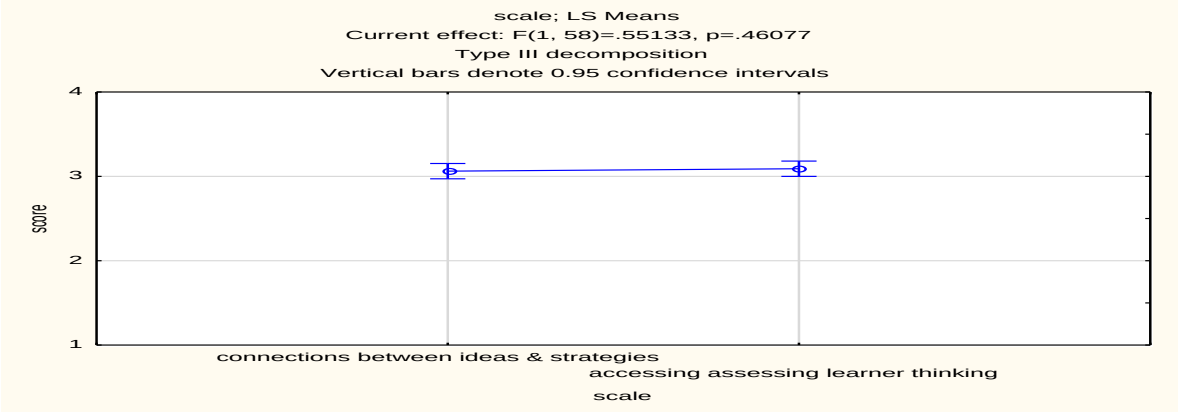
PSTs' *perceived improvement in their understanding of how learners learn number operations and relationships* was as improved as their *perceived understanding of how to solve problems using different strategies* = 0.683665.

Thus, all the three proofs and confirmations were supported by the later analysis and observation. and it could be concluded that the PSTs' perceived equally greater improvement in *understanding foundation mathematical concepts and procedures; understanding how learners learn number operations and relationships*; and *solving problems using different strategies*, than in *explaining why procedures work they way they do*.

Perceived improvement in the development of their PCK for Foundation Phase mathematics

Similar to ascertaining evidence of strong statistical significance in the improvement in their understanding of the CK, the frequencies of their responses expressing their perceived developing PCK for Foundation Phase mathematics were analysed further. The graphical display in Figure **5.11,** below, shows the trends in the means of the learning outcomes compared under the above theme. This visual representation is focused on comparison between the different viewpoints of the subjects. The representation shows that equal improvement in the indicators of their developing PCK for Foundation Phase mathematics was perceived by PSTs'. Thus, *understanding of how to make connections between ideas and strategies in solving problems* and *understanding of how to access and assess learners thinking and understanding in teaching and learning* were perceived to have improved equally by the PSTs.

Figure 5.11: Perceived improvement in the development of their PCK



In support of the graphical evidence in Figure **5.11**, rigorous statistical computations of how the learning achievements compared were done. The computed ANOVA with p = 0.46077 (F (1, 58) = 0.55133) showed that there was no evidence of strong significant statistical differences (at 95% confidence intervals) between the improvements in the two learning outcomes whose observed means are shown in Table **5.28,** below.

Table 5.28: Perceived improvement in developing PCK for Foundation Phase mathematics

Effect	Level of Factor	N	Score Mean	Score Std. Dev.	Score Std. Err	Score −95.00%	Score +95.00%
Total		118	3.076271	0.347043	0.031948	3.01300	3.139542
Scale	understanding how to make connections between ideas and strategies in solving problems	59	3.062147	0.368670	0.047997	2.96607	3.158223
Scale	understanding how to access and assess learners' thinking and understanding in teaching and learning	59	3.090395	0.326543	0.042512	3.00530	3.175493

The researcher was also interested in ascertaining which of the broader themes were most enhanced to triangulate the findings from the sub-themes above. Broadly speaking, there was evidence of strong statistical differences between the PSTs' perceived improvement in the totality of their understanding of the CK and the totality of the development of their PCK for Foundation Phase mathematics. This was revealed by the p-value (p = 0.07479; F (1, 58) = 3.2921) obtained from the ANOVA for the means of the learning outcomes analysed under this

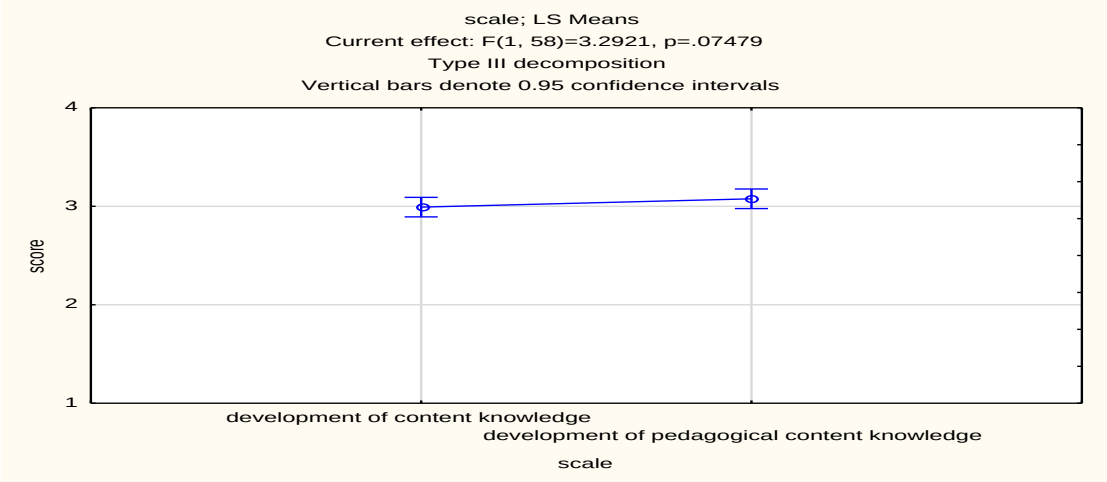
theme, which seemed to show that the observed mean measures of the PSTs' perceived improvement in understanding the mathematics CK and their perceived development of PCK for foundation mathematics were not significantly different at the 95% confidence interval.

The visual evidence in the graphical display in Figure **5.12** also supported the fact that both knowledge components were equally improved. Thus, it could mean that the PSTs perceived equal improvement in their CK and their PCK. Table **5.29** below shows the computed means of the learning outcomes under comparison.

Table 5.29: Perceived improvement in developing PCK for Foundation Phase mathematics

Effect	Level of Factor	N	Score Mean	Score Std. Dev.	Score Std. Err	Score −95.00%	Score +95.00%
Total		118	3.033898	0.381218	0.035094	2.96440	3.10340
Scale	Improvement in understanding of CK	59	2.991525	0.435410	0.056686	2.87806	3.10499
Scale	Development of PCK	59	3.076271	0.316110	0.041154	2.99389	3.15865

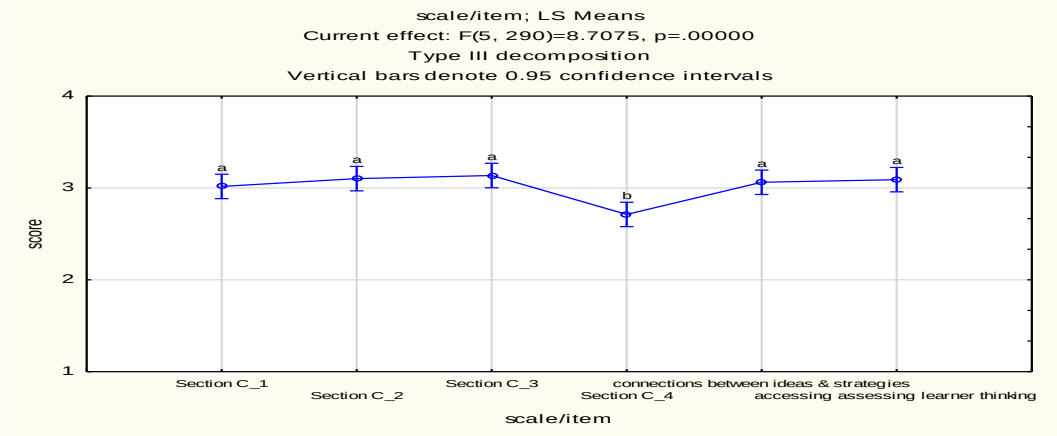
Figure 5.12: Perceived improvement in developing PCK for Foundation Phase mathematics



Additional evidence confirming the findings in the broader comparisons above (CK equally improved with PCK) was obtained from comparing the PSTs' perceived *understanding foundation mathematical concepts and procedures; understanding how learners learn number operations and relationships*; *solving problems using different strategies*; *explaining why procedures work they way they do; understanding of how to make connections between ideas and strategies in solving problems* and *understanding of how to access and assess learners*

thinking and understanding in teaching and learning. The apparent differences could only be observed between each of the four seemingly or relatively equally improved knowledge components (two of which are CK and the other two are PCK) and the seemingly or relatively less improved component of CK. This could be ascertained from the graphical display below, in Figure **5.13**.

Figure 5.13: Perceived improvement in CK and PCK for Foundation Phase mathematics



The conclusion could be drawn from Figure **5.13,** above, that the PSTs perceived relatively equal improvement in their *understanding of foundation mathematical concepts and procedures; understanding how learners learn number operations and relationships*; *solving problems using different strategies*; *understanding of how to make connections between ideas and strategies in solving problems* and *understanding of how to access and assess learners thinking and understanding in teaching and learning*. Hence it could be said that the improvements in their CK and development of PCK for foundation mathematics were at the same level.

In supporting the observations above, further confirmation was revealed by the p-value (p = 0.000000; F (5, 290) = 8.7075) obtained from the ANOVA for the means of the learning outcomes analysed here, which seemed to show that the PSTs' perceived *understanding of foundation mathematical concepts and procedures; understanding how learners learn number operations and relationships*; *solving problems using different strategies*; *understanding of how to make connections between ideas and strategies in solving problems* and *understanding of how to access and assess learners' thinking and understanding in teaching and learning* were significantly improved over their perceived understanding of how to *explain why procedures*

work they way they do, at a 95% confidence interval. This observation was further confirmed in the following pair-wise comparisons of the six (6) knowledge components whose means are given in Table **5.30** below.

Table 5.30: Perceived improvement in CK and PCK for Foundation Phase mathematics

Effect	Level of Factor	N	Score Mean	Score Std. Dev.	Score Std. Err	Score −95.00%	Score +95.00%
Total		354	3.01977	0.533945	0.028379	2.963961	3.075587
Scale	Section **C_1**	59	3.016949	0.629491	0.081953	2.852903	3.180996
Scale	Section **C_2**	59	3.101695	0.578193	0.075274	2.951017	3.252373
Scale	Section **C_3**	59	3.135593	0.600506	0.078179	2.979100	3.292086
Scale	Section **C_4**	59	2.711864	0.526892	0.068596	2.574556	2.849173
Scale	understanding of how to make connections between ideas and strategies in solving problems	59	3.062147	0.368670	0.047997	2.96607	3.158223
Scale	understanding of how to access and assess learners thinking and understanding in teaching and learning	59	3.090395	0.326543	0.042512	3.00530	3.175493

The further analysis with the calculated LSDs at 95% confidence intervals seemed to confirm the observations above showing that significant differences were observed between the each of the five (5) relatively equally improved components of the CK and PCK and relatively less improved component of CK as shown below:

PSTs' perceived improvement in their *understanding of foundation mathematical concepts and procedures; understanding of how learners learn number operations and relationships* and *understanding of how to solve problems using different strategies* has significantly improved over their understanding of how to *explain why procedures work they way they do* ($p = 0.000058$ and mean difference of 0.305085; $p = 0.000000$ and mean difference of 0.389831; and $p = 0.000000$ and mean difference of 0.423729, respectively).

PSTs' perceived improvement in their *understanding of how to make connections between ideas and strategies in solving problems* and *understanding of how to access and assess learners thinking and understanding in teaching and learning* had significantly improved over their

understanding of how to *explain why procedures work they way they do* (p = 0.000004 and mean difference of 0.350282, p = 0.000001 and mean difference of 0.378531, respectively).

The relatively equal levels of improvement observed between the five (5) components were also confirmed by the further analysis with the calculated LSDs at 95% confidence intervals, as shown below:

PSTs' perceived improvement in their *understanding of how learners learn number operations and relationships; understanding of how to solve problems using different strategies; understanding of how to make connections between ideas and strategies in solving problems* and *understanding of how to access and assess learners' thinking and understanding in teaching and learning* was shown to have as significantly improved as their *understanding of foundation mathematical concepts and procedures* (p = 0.258022, p = 0.113687 , p = 0.546031 , p = 0.326821, respectively).

PSTs' perceived improvement in their *understanding of how to solve problems using different strategies; understanding of how to make connections between ideas and strategies in solving problems* and *understanding of how to access and assess learners' thinking and understanding in teaching and learning* to have equally significantly improved as their *understanding of how learners learn number operations and relationships* (p = 0.650656, p = 0.597296, p = 0.879996, respectively).

PSTs' perceived improvement in both their *understanding of how to make connections between ideas and strategies in solving problems* and *understanding of how to access and assess learners thinking and understanding in teaching and learning* were confirmed as having equally significantly improved as their *understanding of how to solve problems using different strategies* (p = 0.326821, p = 0.546031 respectively).

PSTs' perceived improvement in their *understanding of how to make connections between ideas and strategies in solving problems* was confirmed to have equally significantly improved as their *understanding of how to access and assess learners' thinking and understanding in teaching and learning* (p = 0.705879).

All the evidence seemed to confirm that the PSTs' perceived improvement in understanding the mathematics CK and their perceived development of PCK for foundation mathematics were not statistically significantly different. Thus, in answering the research question of what/which change(s)/improvement the PSTs perceived in their understanding of CK and development of their PCK in Foundation Phase mathematics, it could be concluded that the PSTs perceived improvement in *understanding how learners learn number operations and relationships*; *solving problems using different strategies*; *understanding of how to make connections between ideas and strategies in solving problems* and *understanding of how to access and assess learners' thinking and understanding in teaching and learning* during their interactions with the ETE's teaching expertise.

PSTs' perceived affordances of the improvements in their understanding of CK and development of their PCK in mathematics

Table **5.31** shows the mean measures of the PSTs' perceived affordances or teaching capabilities regarding the improvement in their CK and PCK.

Table 5.31: Perceived affordances of the improvement in CK and PCK

Effect	Level of Factor	N	Score Mean	Score Std. Dev.	Score Std. Err	Score −95.00%	Score +95.00%
Total		236	3.126412	0.398094	0.025914	3.075360	3.177465
Scale	Can explain concepts and procedures to enhance learners understanding	59	3.046610	0.339480	0.044197	2.958141	3.135079
Scale	Can implement problem-centred teaching and learning approach	59	3.169492	0.388399	0.050565	3.068274	3.270709
Scale	Can facilitate learners' thinking and meaningful understanding of contents	59	3.080508	0.369764	0.048139	2.984147	3.176870
Scale	Can select appropriate teaching and learning activities and resources	59	3.209040	0.470991	0.061318	3.086299	3.331780

Further analysis was done on those responses to establish strong evidence, if any, of statistical significance of the PSTs' perceptions the teaching capabilities as perceived in their CK and PCK. The statistical computations showing how those affordances, compared to each other (i.e. the computed ANOVA with $p = 0.00214$, ($F(3, 174) = 5.0806$) revealed that there was evidence of

strong significant statistical differences (at 95% confidence intervals) between the teaching capabilities they perceived as presented Table **5.31**.

In support of this evidence, the calculated LSDs at 95% confidence intervals also confirmed statistically significant differences between the perceived affordances in the following paired teaching behaviours:

PSTs' perceived capabilities in both *implementing problem centered teaching and learning approach* and *selecting appropriate teaching and learning activities and resources* were significantly improved above their perceived capabilities in *explaining concepts and procedures to enhance learners' understanding* ($p = 0.010420$, mean difference = 0.22881; $p = 0.000772$, mean difference = 0.162429, respectively).

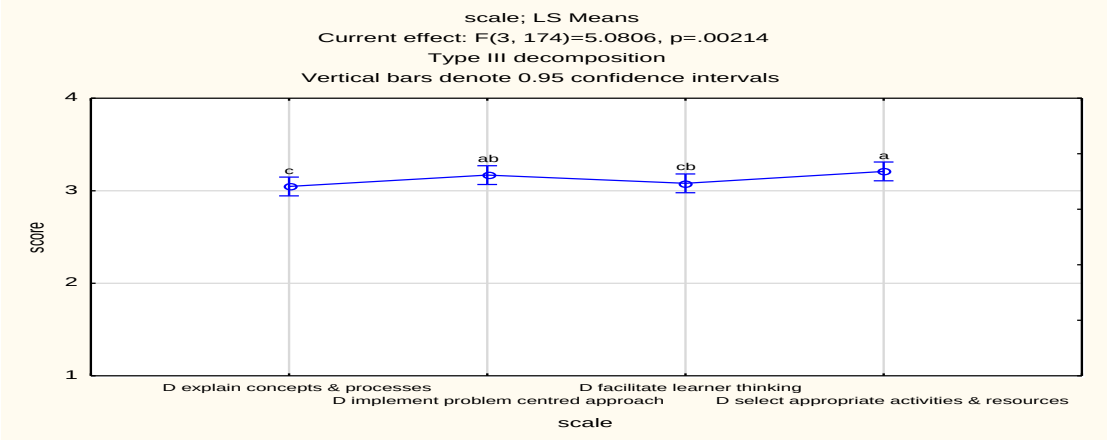
PSTs' perceived capabilities in *selecting appropriate teaching and learning activities and resources* have significantly improved over their capabilities in *facilitating learners' thinking and meaningful understanding of contents* ($p = 0.007429$ and mean difference of 0.128531).

Contrary to evidence presented above, the analysis also seemed to show that no statistically significant differences were observed between the PSTs' *perceived affordances of implementing a problem-centred teaching and learning approach* and their *perceived affordances of selecting appropriate teaching and learning activities and resources* (i.e. these were at the same level of improvement, with $p = 0.405726$). Similarly, the PSTs' perceived capabilities in *facilitating learners' thinking and meaningful understanding of contents* and their capability to *explain concepts and procedures to enhance learners' understanding,* were at the same level of improvement, with $p = 0.475939$. The PSTs' perceived capabilities in *facilitating learners' thinking and meaningful understanding of contents* likewise improved equally to their *perceived affordances of implementing a problem-centred teaching and learning approach,* with $p = 0.062428$.

The graphical display in Figure **5.14 (**below) also confirms all the evidence above. This visual representation emphasises the comparisons between the different viewpoints of the subjects. It shows that, although some differences are evident between some of the compared perceived teaching capabilities, such differences could not significantly differentiate between the levels of

perceived improvement. This is evidenced in the overlapping of some of the teaching capabilities.

Figure 5.14: Perceived affordances of the improvements in CK and PCK



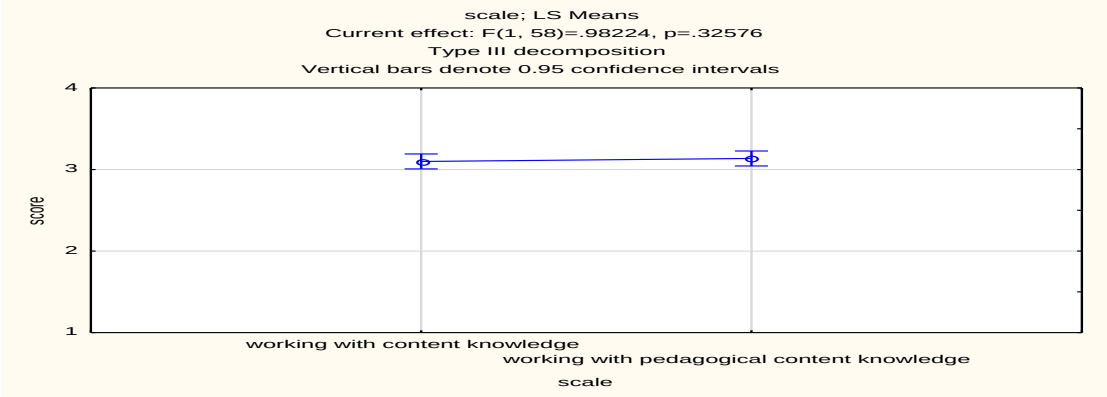
From all the evidence confirming one another, the perceived teaching capabilities compared here are seen to have overlapped. These interesting results could also contribute to the understanding or answering of the research question regarding what/which affordance(s) the PSTs perceived from their perceived improvement in their understanding of CK and development of PCK in Foundation Phase mathematics. Drawing from the evidence above, there probably is justification for concluding that the PSTs perceived fairly equal improvement in all the desired teaching capabilities on which they assessed their PD: they perceived improved capability in *selecting appropriate teaching and learning activities and resources; facilitating learners' thinking and meaningful understanding of contents; explaining concepts and procedures to enhance learners' understanding*; *implementing a problem-centred teaching and learning approach* due to their interaction with the ETE's teaching expertise.

This conclusion could also be supported by the overall analysis of the major themes themselves, which showed the computed ANOVA with p = 0.32576 (F (1, 58) = 0.98224), meaning that there was no strong evidence of any statistically significant differences between the PSTs' perceived affordances of their CK and PCK for Foundation Phase mathematics (at 95% or even 90% confidence intervals). This inference is also evident in Table **5.32** and Figure **5.15,** below.

Table 5.32: Perceived affordances of the improvements in CK and PCK

Effect	Level of Factor	N	Score Mean	Score Std. Dev.	Score Std. Err	Score -95.00%	Score +95.00 %
Total		118	3.117 433	0.351 236	0.032 334	3.05340	3.1814 69
Scale	Working with understanding of CK	59	3.099 274	0.327 331	0.042 615	3.01397	3.1845 77
Scale	Working with their developing PCK	59	3.135 593	0.375 558	0.048 894	3.03772	3.2334 64

Figure 5.15: Perceived affordances of the improvement in CK and PCK



The combined evidence, above, confirmed that affordances of their PCK perceived by PSTs' and the affordances of their CK had improved equally.

PSTs' perceptions about the most improved dimension(s) of their PD

In this analysis, the p-value was 0.00000 (F (5, 290) = 10.011) as derived from the ANOVA computations, indicating strong evidence of significant differences between the mean scores of the learning outcomes analysed under this theme, at the 95% confidence interval. Thus, at least one of those dimensions of the PSTs' PD had a higher or lower mean measure than the others, hence that particular learning outcome might have improved [or not] better than the other dimensions of the PSTs' PD. Table **5.33** below shows the computed means of the learning outcomes under comparison.

Table 5.33: Most improved component of PD

Effect	Level of Factor	N	Score Mean	Score Std. Dev.	Score Std. Err	Score −95.00%	Score +95.00%
Total		354	3.123050	0.369688	0.019649	3.084406	3.161693
Scale	*improvement in their beliefs (**Section A**)*	59	3.227401	0.332553	0.043295	3.140737	3.314065
Scale	*affordances of improvement in their beliefs or perceptions (**Section B**)*	59	3.208232	0.380120	0.049487	3.109137	3.307292
Scale	*improvement in understanding CK*	59	2.991525	0.435410	0.056686	2.878057	3.104994
Scale	*Development of PCK*	59	3.076271	0.316110	0.041154	2.993893	3.158650
Scale	*Affordances/working with CK*	59	3.099274	0.327331	0.042615	3.013971	3.184577
Scale	*Affordances/working with PCK*	59	3.135593	0.375558	0.048894	3.037722	3.233463

In support of the evidence above, further analysis with the calculated LSDs at 95% confidence intervals showed that significant differences were observed between the perceived improvements in the following paired learning outcomes:

PSTs' *perceived improvement in their beliefs about the subject matter of mathematics and teaching and learning of mathematics* improved significantly over their perceived improvement in understanding the CK of mathematics, with p = 0.000000, with a mean difference of 0.235876.

PSTs' *perceived improvement in their beliefs about subject matter of mathematics and teaching and learning of mathematics* was significantly better than their perceived capabilities in articulating their understanding of the CK in teaching: p = 0.001193 and mean difference of 0.128128.

PSTs' *perceived improvement in their beliefs about the subject matter of mathematics and teaching and learning of mathematics* improved significantly over the perceived development of their PCK for Foundation Phase mathematics: p = 0.000140 and mean difference of 0.151130.

PSTs' *perceived improvement in their beliefs about the subject matter of mathematics and teaching and learning of mathematics* improved significantly over their perceived capabilities in utilising their developing PCK: p = 0.019694 and mean difference of 0.091808.

PSTs' *perceived affordances of the improvement in their beliefs about subject matter of mathematics and teaching and learning of mathematics* **vs** *perceived improvements in understanding the CK of mathematics*, with p = 0.000000 and mean difference of 0.216707.

PSTs' *perceived affordances of the improvement in their beliefs about the subject matter of mathematics and teaching and learning of mathematics* vs *perceived affordances of the improvements in understanding the CK of mathematics*, with p = 0.005735 and mean difference of 0.108959;

PSTs' *perceived affordances of the improvement in their beliefs about the subject matter of mathematics and teaching and learning of mathematics* vs *perceived improvement in the development of their PCK for mathematics*, with p = 0.000851 and mean difference of 0.1311961;

PSTs' *perceived improvement in the development of their PCK for mathematics* vs *perceived improvement in understanding the CK of mathematics*, with p = 0.031222 with mean difference of 0.084746, at 95% confidence intervals;

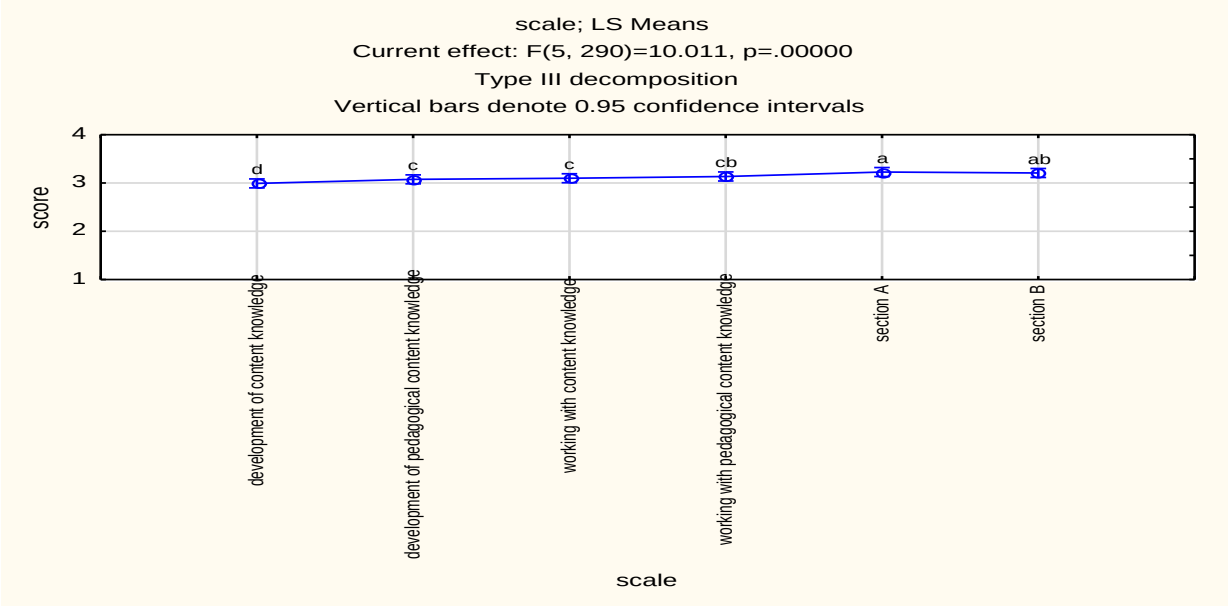
PSTs' *perceived affordances of the improvements in understanding the CK of mathematics* vs *perceived improvement in understanding the CK of mathematics*, with p = 0.006290 and mean difference of 0.107748;

PSTs' *perceived affordances of the improvements in the development of their PCK for mathematics* vs *perceived improvements in understanding the CK of mathematics*, with p = 0.000278 and mean difference of 0.144068.

In line with the evidence above, further analysis with the calculated LSDs at 95% confidence intervals also showed that there was no significant difference (with p = 0.624754) between the PSTs' *perceived improvement in their beliefs about subject matter of mathematics and teaching and learning of mathematics* and their *perceived affordances* of these particular improvements. This could be possible, because the extent of their improvement could be commensurate with or determine their capabilities in executing tasks demanding such improvement. Hence, both the perceived changes and the affordances of the changes were at an equal level. The above examples of proofs and confirmation are also supported in Figure **5.16,** which illustrated

confirmation that the PSTs perceived greater improvement in the transformation of their beliefs and their affordances than improvements in CK and PCK and their affordances.

Figure 5.16: Most improved component of PD



In addition to all the evidence which shows that the PSTs' perceived beliefs have greatly improved over CK and PCK, the analysis further confirmed that no significant differences were observed between the PSTs' perceived improvement and affordances of their mathematics CK and their PCK for mathematics as shown here:

PSTs' *perceived affordances of the improvement in their beliefs about the subject matter of mathematics and teaching and learning of mathematics* were as improved as their *perceived affordances of their developing PCK for mathematics*, with p = 0.064539.

PSTs' *perceived improvement in the development of their PCK for mathematics* and their *perceived affordances of the improvement in understanding the CK of mathematics*, were at the same level of improvement, with p = 0.557274.

PSTs' *perceived improvement in the development of their PCK for mathematics* was as improved as their *perceived affordances of the improvement in the development of their PCK for mathematics*, with p = 0.130779.

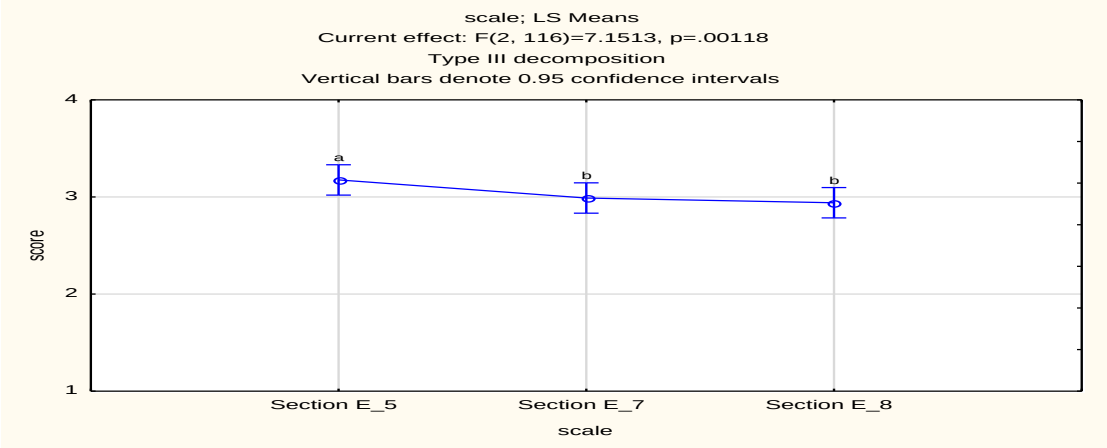
PSTs' *perceived affordances of the improvement in understanding the CK of mathematics* and their *perceived affordances of the improvement in the development of their PCK for mathematics*, were at the same level of improvement, with p = 0.354308.

Though there seemed to be fairly equal improvement in most of the learning outcomes compared above, it was clear that the most improved dimension of the PSTs' PD was the *perceived improvement in their beliefs about the subject matter of mathematics and teaching and learning of mathematics*.

Hence, to answer the research question "which of the three dimensions of their professional development (i.e. beliefs, content knowledge and pedagogical content knowledge) is most or least enhanced?" it could be said that the PSTs perceived fair improvement in all the indicators of change, however, *perceived improvement in their beliefs about the subject matter of mathematics and teaching and learning of mathematics* was significantly improved over the other two components of their PD.

To triangulate the findings about learning outcome(s) that was or were most improved, the PSTs responses to the questions eliciting their views about the attribute(s) of the teaching expertise which impacted most on improving their beliefs about the subject matter of mathematics and the teaching and learning of it, improving their understanding of the mathematics CK and developing their PCK for Foundation Phase mathematics were analysed. The pattern of their responses is shown in Figure **5.17**. This visual representation suggests that the PSTs' perceived improvement in their beliefs about the subject matter of mathematics and the teaching and learning of it have significantly above the perceived improvement in their understanding of the mathematics CK and development of their PCK for Foundation Phase mathematics.

Figure 5.17: Most improved component of PD



In the Figure 5.17, Section **E_5** represents improvements in the PSTS' beliefs about the subject matter of mathematics and the teaching and learning of it, with a Chronbach alpha score of 0.840174; **E_7** represents improvement in their understanding of the mathematics CK, with a Chronbach alpha score of 0.918481; and **E_8** represents development of their PCK for Foundation Phase mathematics, with a Chronbach alpha score of 0.933864. The graphical display in the figure suggests that E_5 was higher than E_7 and E_8. This trend in the visual representation emphasised that the PSTs perceived greater improvement in their beliefs about the subject matter of mathematics and the teaching and learning of it than the other two knowledge components of their PD.

In addition to the graphical evidence above, the rigorous analysis yielded a p-value of 0.00118 (F (2, 116) = 7.1513) from the ANOVA computations, indicating that there is strong evidence of significant differences between the mean scores of E-5, E_7 and E_8, at the 95% confidence interval. Thus, at least one of those dimensions of the PSTs' PD has a higher or lower mean measure than the others, hence, that particular learning outcome might have (or not have) improved more than the other dimensions of the PSTs' PD. Table **5.34,** below, shows the computed means of the learning outcomes under comparison.

Table 5.34: Most improved component of PD

Effect	Level of Factor	N	Score Mean	Score Std. Dev.	Score Std. Err	Score −95.00%	Score +95.00%
Total		177	3.035311	0.610767	0.045908	2.94471	3.125912
Scale	Section E_5	59	3.175847	0.463145	0.060296	3.05515	3.296544
Scale	Section E_7	59	2.989407	0.648809	0.084468	2.82033	3.158487
Scale	Section E_8	59	2.940678	0.682034	0.088793	2.76294	3.118417

At the 95% confidence interval, the PSTs' perceived improvement in their beliefs about the subject matter of mathematics and the teaching and learning of it improved significantly above the perceived improvement in their understanding of the mathematics CK ($p = 0.005324$, with mean difference of 0.186441). The analysis further revealed that perceived improvement in their beliefs about the subject matter of mathematics and the teaching and learning of it improved significantly above the perceived development of their PCK for Foundation Phase mathematics ($p = 0.000498$, mean difference 0.235169). However, no significant differences were observed between the PSTs' perceived improvements in their understanding of the mathematics CK and perceived development of their PCK for Foundation Phase mathematics ($p = 0.459374$). Thus, both knowledge components of their PD have improved equally. Drawing from the results obtained here, a fairly satisfactory answer to the researcher question "which of the three dimensions of their PD (i.e. beliefs, CK and PCK) is most or least influenced by the attributes of the teaching expertise of the expert teacher educator? could be PSTs' *perceived improvement in their beliefs about the subject matter of mathematics and the teaching and learning of it.*

Perceptions about the attribute(s) of teaching expertise with the most impact on the PSTs' beliefs about the subject matter of mathematics and teaching and learning mathematics

Table **5.35,** below, shows the mean measures of the PSTs' perceived associations between the attributes of teaching expertise they experienced in learning to teach Foundation Phase mathematics and the improvement they perceived in their beliefs about mathematics and the teaching and learning of mathematics. Further analysis of those responses revealed that there were strong evidence of statistical significant differences between the perceived attribute(s) of teaching expertise which had the most impact on the PSTs' beliefs. The computed ANOVA produced a p value of 0.00000 ($F(7, 406) = 20.587$), indicating that some of the attributes of teaching expertise were perceived by the PSTs to have had a greater impact on their beliefs about

mathematics and the teaching and learning of mathematics, than others did (at 95% confidence intervals)

Table 5.35: The attribute(s) of teaching expertise with the impact on the PSTs' beliefs

Effect	Level of Factor	N	Score Mean	Score Std. Dev.	Score Std. Err	Score −95.00%	Score +95.00%
Total		472	3.175847	0.729140	0.033561	3.109899	3.241796
Scale	*Clarity in lesson presentations/teaching* ***(E_1_1)***	59	3.169492	0.620137	0.080735	3.007883	3.331100
Scale	*Enthusiasm in teaching* ***(E_1_2)***	59	3.372881	0.692280	0.090127	3.192472	3.553291
Scale	*Articulation of subject knowledge expertise in teaching* ***(E_1_3)***	59	3.423729	0.563346	0.073341	3.276920	3.570537
Scale	*Preparation for and organisation of teaching* ***(E_1_4)***	59	3.457627	0.702754	0.091491	3.274488	3.640766
Scale	*Motivating/stimulating students' interest and engagement with learning experiences* ***(E_1_5)***	59	3.186441	0.681645	0.088743	3.008803	3.364078
Scale	*Understanding of students' learning needs and creating productive learning climate* ***(E_1_6)***	59	3.050847	0.729282	0.094944	2.860795	3.240899
Scale	*Humour in teaching* ***(E_1_7)***	59	2.491525	0.795957	0.103625	2.284098	2.698953
Scale	*Positive relationships with students and approachability* ***(E_1_8)***	59	3.254237	0.575153	0.074879	3.104352	3.404123

To be specific, the calculated LSDs at 95% confidence intervals also confirmed evidence of statistical significant differences between the impact of the attributes of teaching expertise on the PSTs' beliefs in the following paired attributes of teaching expertise:

PSTs perceived that the ETE's *enthusiasm in teaching; articulation of subject knowledge expertise in teaching;* and *preparation for and organisation of teaching* had impacted strongly on their beliefs than her *clarity in lesson presentation/teaching* (with p = 0.035523, mean difference = 0.203390; p = 0.008692, mean difference = 0.254237; and p = 0.002976 and mean difference of 0.288136, respectively).

PSTs perceived that the ETE's *clarity in lesson presentation/teaching* had much more impact on their beliefs than her *humour in teaching* (p = 0.00000 and mean difference of 0.677966).

PSTs perceived that the ETE's *enthusiasm in teaching* had much more impact on their beliefs than her *humour in teaching* (p = 0.00000 and mean difference of 0.881356) and *understanding of students' learning needs and creating a productive learning climate* (p = 0.000916 and mean difference of 0.322034).

PSTs perceived that the ETE's *articulation of subject knowledge expertise in teaching* had a greater effect on changing their beliefs than her *motivating/stimulating students' interest and engagement with learning experiences* (p = 0.014272, mean difference = 0.237288); *humour in teaching* (p = 0.00000, mean difference = 0.932203); and *understanding of students' learning needs and creating productive learning climate* (p = 0.000128, mean difference = 0.372881).

PSTs perceived that the ETE's *preparation for and organisation of teaching* had more impact on their beliefs than her *motivating/stimulating students' interest and engagement with learning experiences* (p = 0.005154 and mean difference of 0.271186); *humour in teaching* (p = 0.00000 and mean difference of 0.966102); *understanding of students' learning needs and creating productive learning climate* (p = 0.000030, mean difference = 0.406780); and *positive relationships with students and approachability* (p = 0.035523, mean difference = 0.203390).

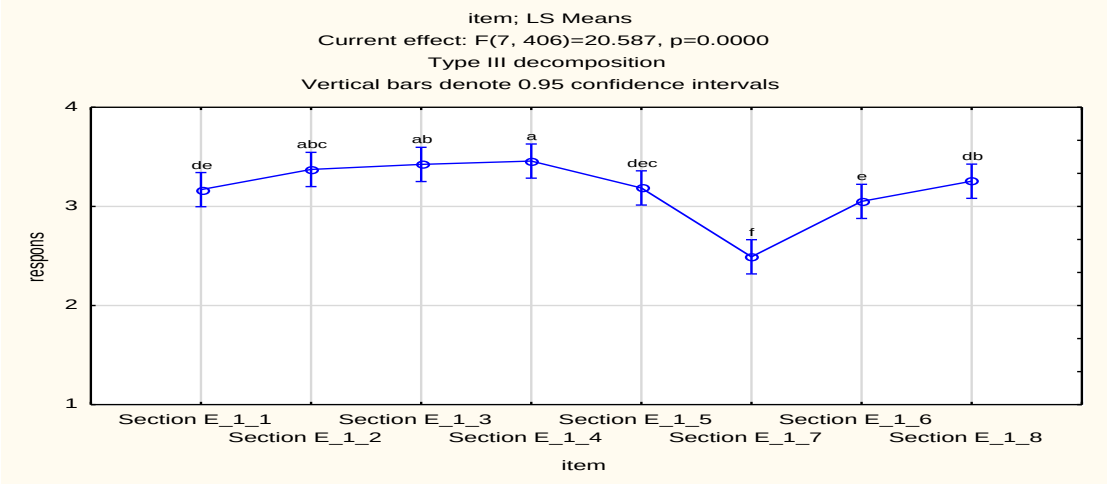
PSTs perceived that the ETE's *motivating/stimulating students' interest and engagement with learning experiences* had a greater influence on changing their beliefs than her *humour in teaching* (p = 0.00000, mean difference = 0.694915).

PSTs perceived that both the ETE's *understanding of students' learning needs and creating a productive learning climate* and *positive relationships with students and approachability* had a greater influence on changing their beliefs than her *humour in teaching* (p = 0.00000, mean difference = 0.559322 and p = 0.00000, mean difference = 0.762712, respectively).

PSTs perceived that both the ETE's *positive relationships with students and approachability* had a greater influence on changing their beliefs than her *understanding of students' learning needs and creating productive learning climate* (p = 0.035523, mean difference = 0.203390).

The pair-wise comparisons above involving the most/least impacting attribute(s) of the teaching expertise of the ETE regarding beliefs, seemed to show that the ETE's *preparation for and organisation of teaching; articulation of subject knowledge expertise in teaching; and enthusiasm in teaching* had the strongest impact on the PSTs' beliefs about mathematics and the teaching and learning of it. It further seemed to show that the ETE's *humour in teaching* had the least impact on the PSTs' beliefs about mathematics and the teaching and learning of it. This observation could also be inferred from the following graphical display (Figure **5.18)**.

Figure 5.18: The attribute(s) of teaching expertise with the strongest impact on the PSTs' beliefs



Perceptions about the attribute(s) of teaching expertise with the most impact on the PSTs' understanding of Foundation Phase mathematics CK

Table 5.36 shows the mean measures of the PSTs' perceived associations between the attributes of teaching expertise experienced in learning to teach Foundation Phase mathematics and the improvement they perceived in their understanding of the Foundation Phase mathematics CK.

Table 5.36: The attribute(s) of teaching expertise with the most impact on the PSTs' CK

Effect	Level of Factor	N	Score Mean	Score Std. Dev.	Score Std. Err	Score −95.00%	Score +95.00%
Total		472	2.989407	0.845805	0.038931	2.912906	3.065907
Scale	*Clarity in lesson presentation/teaching* ***(E_2_1)***	59	3.033898	0.787096	0.102471	2.828780	3.239017
Scale	*Enthusiasm in teaching* ***(E_2_2)***	59	3.101695	0.802902	0.104529	2.892457	3.310932
Scale	*Articulation of subject knowledge expertise in teaching* ***(E_2_3)***	59	3.305085	0.701089	0.091274	3.122380	3.487789
Scale	*Preparation for and organisation of teaching* ***(E_2_4)***	59	3.118644	0.852678	0.111009	2.896435	3.340853
Scale	*Motivating/stimulating students' interest and engagement with learning experiences* ***(E_2_5)***	59	3.084746	0.836415	0.108892	2.866775	3.302717
Scale	*Understanding of students' learning needs and creating a productive learning climate* ***(E_2_6)***	59	2.881356	0.852678	0.111009	2.659147	3.103565
Scale	*Humour in teaching* ***(E_2_7)***	59	2.389831	0.851306	0.110831	2.167979	2.611682
Scale	*Positive relationships with students and approachability* ***(E_2_8)***	59	3.000000	0.809427	0.105378	2.789062	3.210938

The computed ANOVA produced a p value of 0.00000 (F (7, 406) = 15.698), indicating that some of the attributes of teaching expertise were perceived by the PSTs to have impacted more strongly on their understanding of the Foundation Phase mathematics CK, than others did (at 95% confidence intervals)., The calculated LSDs at 95% confidence intervals also specifically confirmed evidence of strong statistically significant differences between the impact of the attributes of teaching expertise on the PSTs' understanding of the CK in the following paired attributes of teaching expertise:

PSTs perceived that the ETE's *articulation of subject knowledge expertise in teaching* had greatly improved their understanding of the Foundation Phase mathematics CK – more so than her *clarity in lesson presentation/teaching* (p = 0.005175, mean difference = 0.271186).

PSTs perceived that the ETE's *clarity in lesson presentation/teaching* had improved their understanding of the Foundation Phase mathematics CK more than her *humour in teaching* (p = 0.000000, mean difference = 0.644068) did.

PSTs perceived that the ETE's *enthusiasm in teaching* had improved their understanding of the Foundation Phase mathematics CK more than her *understanding of students' learning needs and creating productive learning climate* and *humour in teaching* (p = 0.022883, mean difference = 0.220339 and p =0.000000, mean difference = 0.711864, respectively) did.

PSTs perceived that the ETE's *articulation of subject knowledge expertise in teaching* had improved their understanding of the Foundation Phase mathematics CK more than her *enthusiasm in teaching* (p = 0.035610, mean difference = 0.203390); *motivating/stimulating students' interest and engagement with learning experiences* (p = 0.022833, mean difference = 0.220339)*; understanding of students' learning needs and creating productive learning climate* (p = 0.000014, mean difference = 0.423729)*; humour in teaching* (p = 0.000000, mean difference = 0.915254)*;* and *positive relationships with students and approachability* (p = 0.001681 mean difference = 0.305085) did.

PSTs perceived that the ETE's *preparation for and organisation of teaching* had improved their understanding of the Foundation Phase mathematics CK more than her *understanding of students' learning needs and creating productive learning climate* and *humour in teaching* (p = 0.014318, mean difference = 0.237288 and p =0.000000, mean difference = 0.728814, respectively) did.

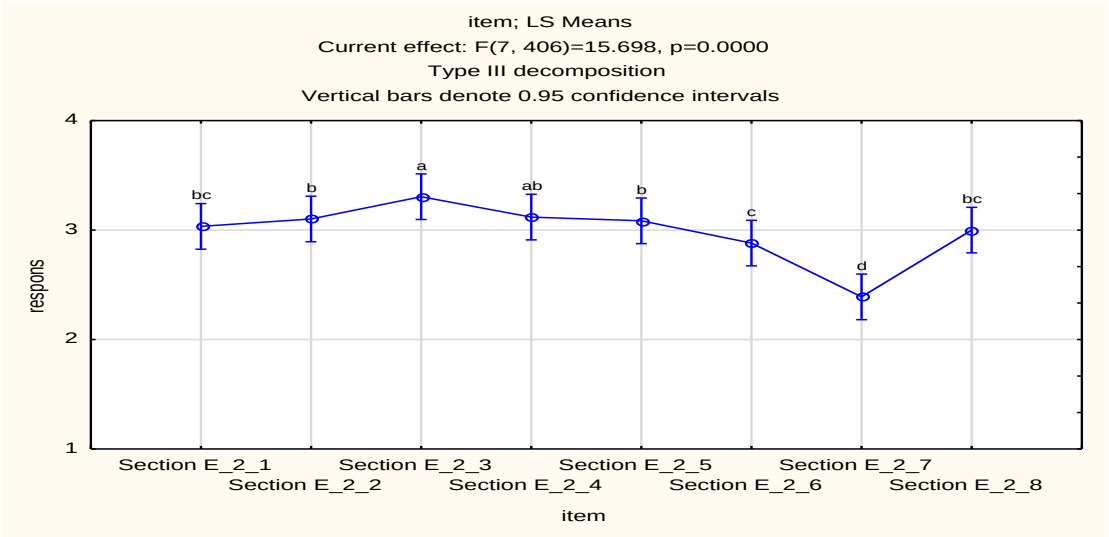
PSTs perceived that the ETE's *motivating/stimulating students' interest and engagement with learning experiences* had improved their understanding of the Foundation Phase mathematics CK more than her *understanding of students' learning needs and creating productive learning climate* and *humour in teaching* (p = 0.035610, mean difference = 0.203390 and p = 0.000000, mean difference = 0.694915, respectively) did.

PSTs perceived that both the ETE's *understanding of students' learning needs and creating productive learning climate* and *positive relationships with students and approachability* had improved their understanding of the Foundation Phase mathematics CK more than her and

humour in teaching (p = 0.000001, mean difference = 0.491525 and p =0.000000, mean difference = 0.610169, respectively) did.

The above pair-wise comparisons concerning the most/least impacting attribute(s) of the teaching expertise of the ETE, on CK, seem to show that *articulation of subject knowledge expertise in teaching; enthusiasm in teaching; motivating/stimulating students' interest and engagement with learning experiences; preparation for and organisation of teaching;* and *clarity in lesson presentations/teaching* had the strongest impact on the PSTs' understanding of the Foundation Phase mathematics CK. It further seems to show that the ETE's *humour in teaching* had the weakest impact on the PSTs' understanding of the Foundation Phase mathematics CK. This observation can also be inferred from the graphical display below (Figure **5.19**).

Figure 5.19: The attribute(s) of teaching expertise with the most impact on the PSTs' CK



Perceptions about the attribute(s) of teaching expertise that have the most impact on the development of the PSTs' PCK for Foundation Phase mathematics

Table **5.37,** below, shows the mean measures of the PSTs' perceived associations between the attributes of teaching expertise experienced in learning to teach Foundation Phase mathematics and the development of their PCK for Foundation Phase mathematics. Further analysis of those responses revealed that there was strong evidence of statistically significant differences between

the perceived attribute of teaching expertise which had the most impact of the on the PSTs' developing PCK for Foundation Phase mathematics. The computed ANOVA produced a p value of 0.00000 (F (7, 406) = 14.265), indicating that some of the attributes of teaching expertise were perceived by the PSTs to have had a stronger impact on their developing PCK for Foundation Phase mathematics than others did (at 95% confidence intervals).

Table 5.37: Attribute(s) of teaching expertise with the most impact on the PSTs' PCK

Effect	Level of Factor	N	Score Mean	Score Std. Dev.	Score Std. Err	Score −95.00%	Score +95.00%
Total		472	2.940678	0.850052	0.039127	2.863793	3.017563
Scale	*Clarity in lesson presentation/teaching* ***(E_3_1)***	59	3.000000	0.830455	0.108116	2.783582	3.216418
Scale	*Enthusiasm in teaching* ***(E_3_2)***	59	3.016949	0.798523	0.103959	2.808853	3.225045
Scale	*Articulation of subject knowledge expertise in teaching* ***(E_3_3)***	59	3.169492	0.812670	0.105801	2.957709	3.381274
Scale	*Preparation for and organisation of teaching* ***(E_3_4)***	59	3.000000	0.830455	0.108116	2.783582	3.216418
Scale	*Motivating/stimulating students' interest and engagement with learning experiences* ***(E_3_5)***	59	2.983051	0.840598	0.109436	2.763990	3.202112
Scale	*Understanding of students' learning needs and creating productive learning climate* ***(E_3_6)***	59	3.016949	0.840598	0.109436	2.797888	3.236010
Scale	*Humour in teaching* ***(E_3_7)***	59	2.355932	0.840357	0.104718	2.146316	2.565549
Scale	*Positive relationships with students and approachability* ***(E_3_8)***	59	2.983051	0.840598	0.109436	2.763990	3.202112

The calculated LSDs at 95% confidence intervals also confirmed evidence of statistically significant differences between the attributes of teaching expertise perceived to have the most impact on the PSTs' PCK in the following paired attributes of teaching expertise:

PSTs perceived that the ETE's *clarity in lesson presentation/teaching* had improved the development of their PCK for Foundation Phase mathematics more than her *humour in teaching* (p = 0.00000, mean difference = 0.644068) did.

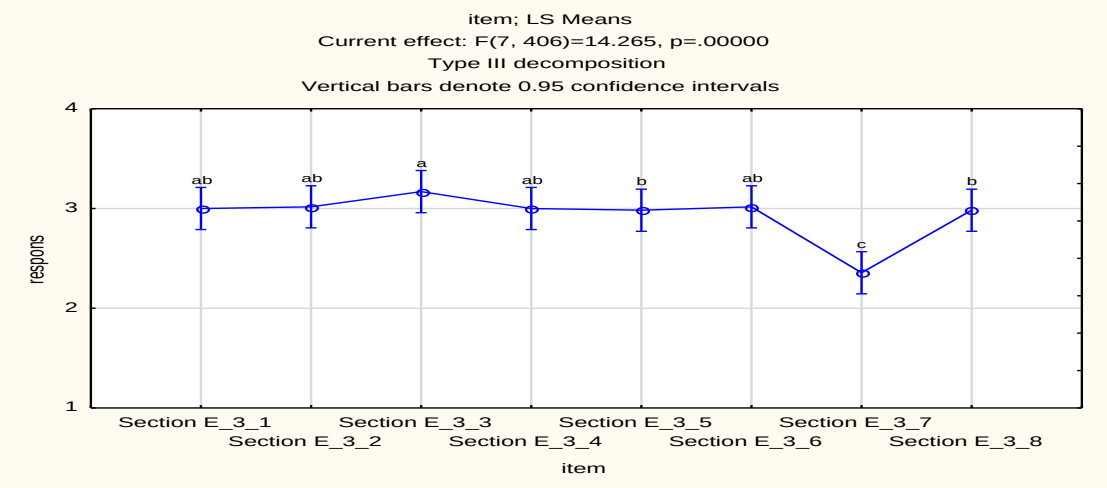
PSTs perceived that the ETE's *enthusiasm in teaching* had improved the development of their PCK for Foundation Phase mathematics more than her *humour in teaching* (p = 0.00000, mean difference = 0.661017) did.

PSTs perceived that the ETE's *articulation of subject knowledge expertise* in teaching had improved the development of their PCK for Foundation Phase mathematics more than her *motivating/stimulating students' interest and engagement with learning experiences; humour in teaching* and *positive relationships with students and approachability* (p = 0.041879, mean difference = 0.186441, p = 0.000000, mean difference = 0.813559, and p = 0.04179, mean difference = 0.186441, respectively) did.

PSTs perceived that the ETE's *preparation for and organisation of teaching; motivating/stimulating students' interest and engagement with learning experiences; understanding of students' learning needs and creating a productive learning climate;* and *positive relationships with students and approachability* had improved the development of the their PCK for Foundation Phase mathematics more than her *humour in teaching* (p = 0.00000, mean difference = 0.644068; p = 0.000000, mean difference = 0.627119, p = 0.000000, mean difference = 0.661017, p = 0.000000, mean difference = 0.627119, respectively) did.

The above pair-wise comparisons of the attribute(s) of teaching expertise of the ETE with the most/least impact on PCK, seemed to show that all the ETE's teaching expertise had a considerable impact on the development of the PSTs' PCK for Foundation Phase mathematics, excepting her *humour in* teaching, which had the least impact on the PSTs' developing PCK for Foundation Phase mathematics. This observation could also be inferred from Figure **5.20,** below. The graphical presentation below shows the PSTs' perceptions about the attribute(s) of the ETE's teaching expertise which impacted most on the development of their PCK for Foundation Phase mathematics.

Figure 5.20: The attribute(s) of teaching expertise with the most impact on the PSTs' PCK



5.4.1.5. Comparing improvement in learning outcomes (PD) from the two experiences

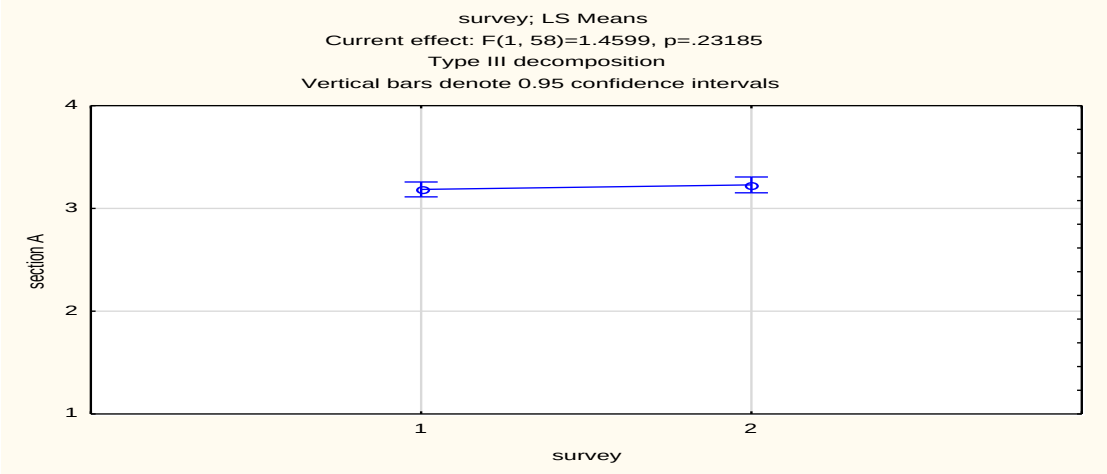
To find fairly accurate and justifiable answers to the question "which of the two experiences impacted more on the dimensions of their PD?", the researcher compared corresponding learning outcomes or achievements from the PSTs' learning experiences during their two-year training period and their learning experiences in interaction with the ETE's teaching expertise in the 3rd-year Foundation Phase mathematics module.

In this attempt to ascertain whether or not there were any significant differences between the learning achievements, the computed means of the corresponding overarching themes or learning achievements and the constituent sub-themes or learning achievements of the two learning experiences introduced above were compared. The comparisons are shown below.

Perceptions of the experience that impacted more on the PSTs' beliefs about the subject matter of mathematics and teaching and learning mathematics

The visual display in Figure **5.21** seems to show that two learning experiences improved the PSTs' perceived *beliefs about the subject matter of mathematics and teaching and learning of mathematics* equally significantly. This observation was justified by the computed p-value (p = 0.23185) at 95% confidence intervals.

Figure 5.21: Comparison of PSTs' perceived improvements in their beliefs



In Figure **5.21** above and in all subsequent graphs in this section, 1 represents the two-year training period and 2 represents the 3rd-year interaction with the ETE's teaching expertise. Further comparison of the sub-themes or constituent learning achievements of the broader theme were also compared, as shown below.

Comparison of improvements in reflection on learning and actions

Figure 5.22: Comparison of improvements in reflection on learning and actions

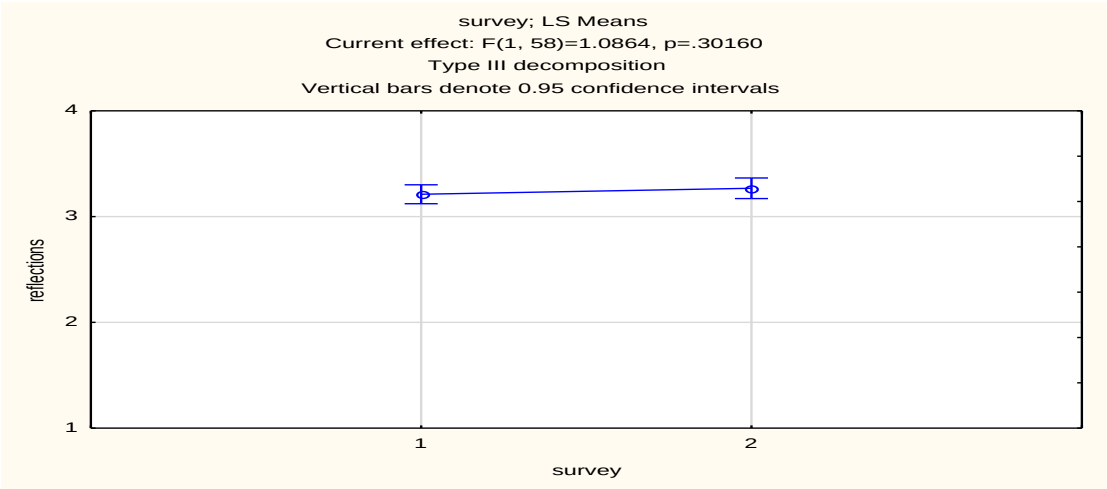
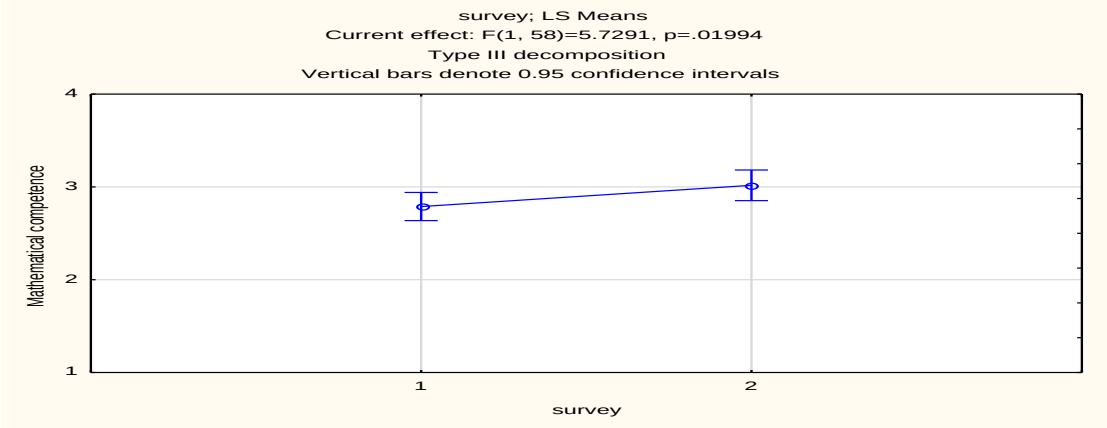


Figure **5.22** seems to show that the two learning experiences have improved the PSTs' perceived *reflection on learning and actions* (i.e. about mathematics, teaching young children, and how they learn) equally significantly. This observation was confirmed by the computed p-value (p = 0.30160) at 95% confidence intervals.

Comparison of improvements in overcoming feelings of mathematical incompetence

The graphical display below (Figure **5.23**) shows that interaction with the ETE's teaching expertise improved the PSTs' perceived *feelings of incompetence to engage in teaching and learning mathematical problem-solving* activities significantly more than the two-year training. This observation was confirmed by the computed p-value (p = 0.01994) at 95% confidence intervals.

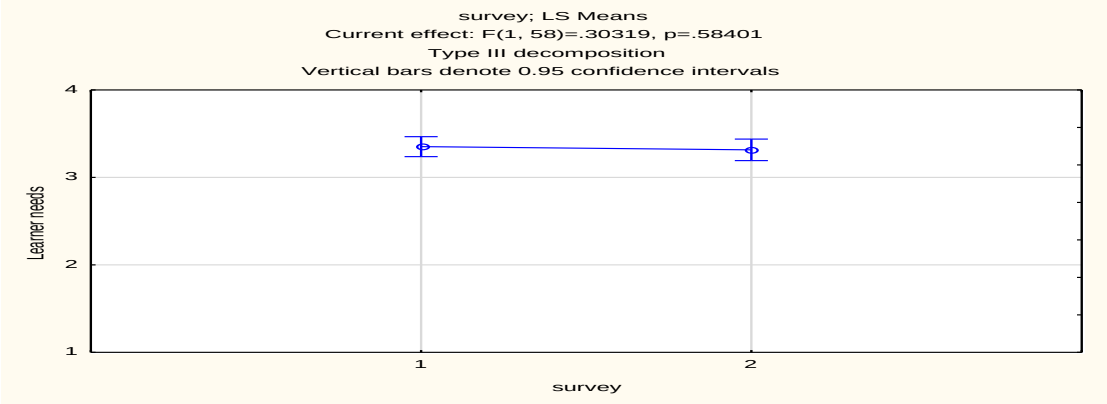
Figure 5.23: Comparison of improvements in overcoming feelings of mathematical incompetence



Comparison of improvements in being critical about learner needs

The graphical display in Figure **5.24** shows that the two learning experiences have equally significantly improved the PSTs' perception of *being critical about learners' needs and characteristics in mathematical instructions* This observation was confirmed by the computed p-value (p = 0.54801) at 95% confidence intervals.

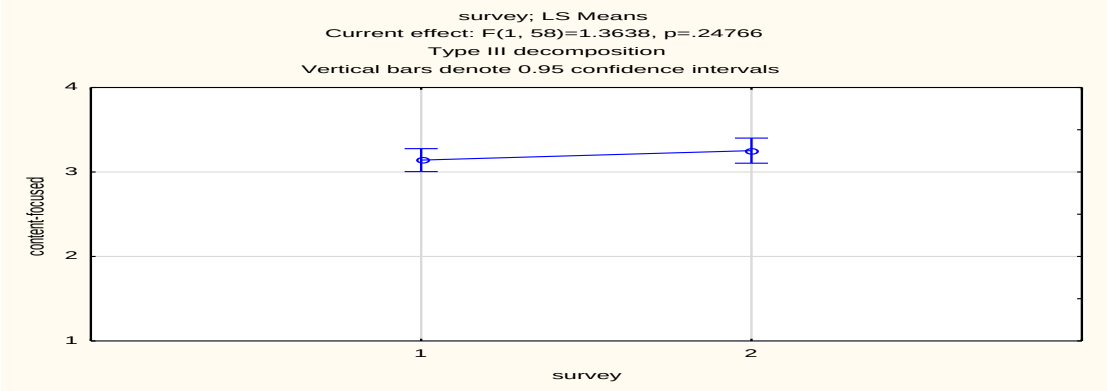
Figure 5.24: Comparison of improvement in being critical about learner needs



Comparison of improvement in being interest in focusing on the mathematics content

The graphical display below (Figure **5.25**) shows that the two learning experiences had equally significantly improved the PSTs' perception of *willingness or interest in focusing on the content of the mathematics in mathematical instructions*. This observation was supported by the computed p-value (p = 0.24766) at 95% confidence intervals.

Figure 5.25: Comparison of improvements in being interested in focusing on the mathematics content

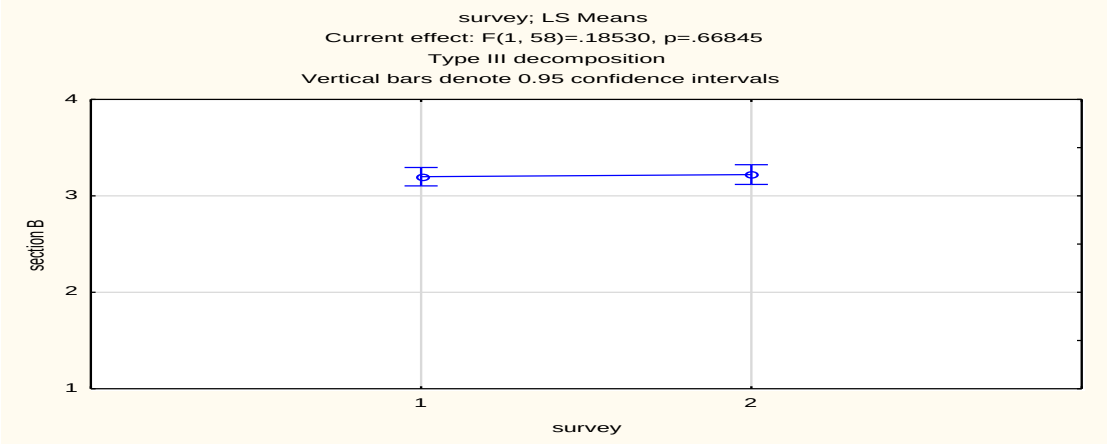


Perceptions on the experience that impacted more on the affordances of PSTs' beliefs about the subject matter of mathematics and teaching and learning mathematics

The visual display in Figure **5.26,** below, shows that the two learning experiences had equally significantly improved the PSTs' perceptions about the affordances of *beliefs/perception about subject matter of mathematics and teaching and learning of mathematics*. This observation was

also justified by the computed p-value (p = 0.66845) at 95% confidence intervals. Further comparison of the sub-themes or constituent learning achievements of the broader theme above was also undertaken, as shown below:

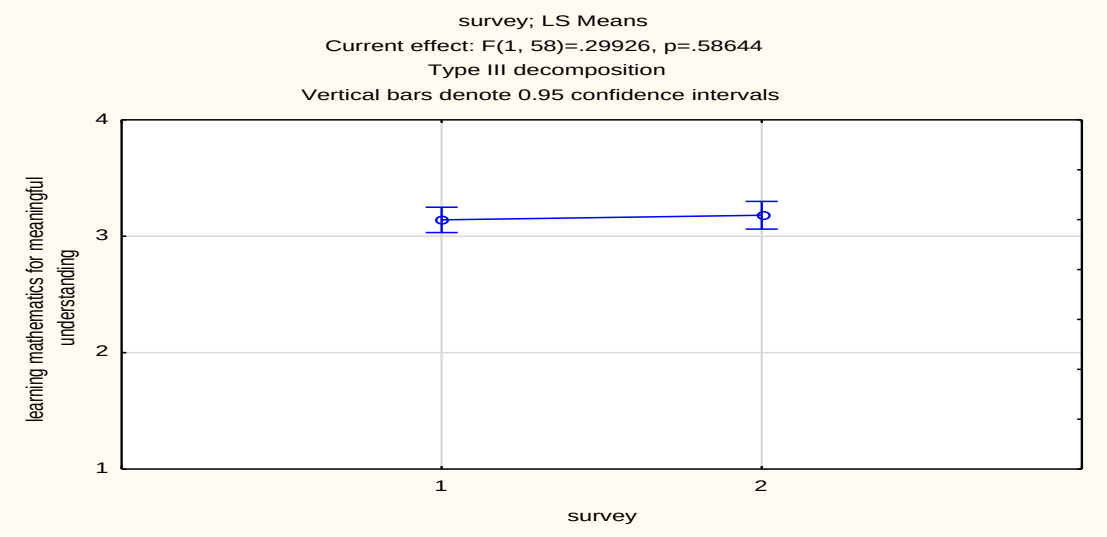
Figure 5.26: Comparison of PSTs' perceived teaching capabilities in their improved beliefs



Comparison of perceived capabilities in promoting learning mathematics for meaningful understanding

Figure **5.27** below seems to show that the two learning experiences had equally significantly improved the PSTs' perception of *capabilities in promoting learning mathematics for meaningful understanding*. This observation was supported by the computed p-value (p = 0.58644) at 95% confidence intervals.

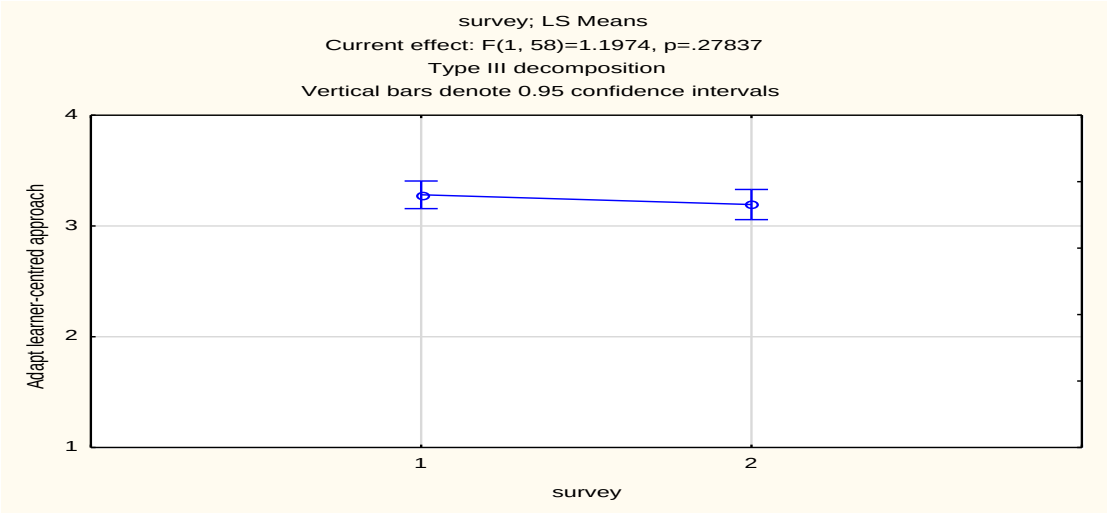
Figure 5.27: Comparison of perceived capabilities in promoting learning mathematics for meaningful understanding



Comparison of perceived capabilities in adapting a learner-centred approach

Figure **5.28,** below, shows that the two learning experiences had equally significantly improved the PSTs' perceived *capabilities in adapting a learner-centred approach in teaching and learning*. This observation was supported by the computed p-value (p = 0.27837) at 95% confidence intervals.

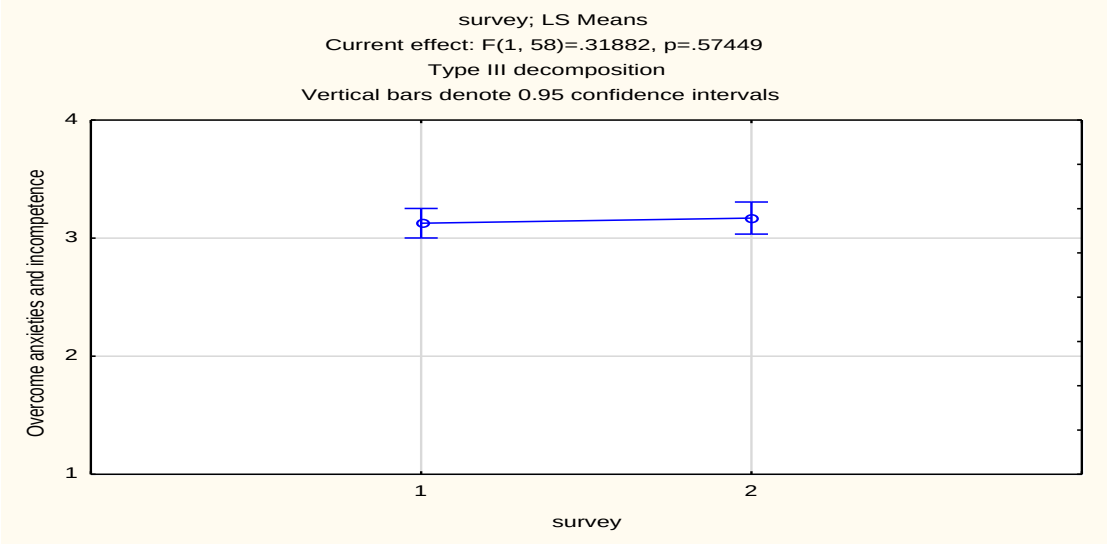
Figure 5.28: Comparison of perceived capabilities in adapting a learner-centred approach



Comparison of perceived capabilities in assisting learners to overcome their anxieties and incompetence in learning

The graphical display below (Figure **5.29**) seems to show that the two learning experiences had equally significantly improved the PSTs' perception of *capabilities in assisting learners to overcome their anxieties and incompetence in learning*. This observation was supported by the computed p-value (p = 0.57449) at 95% confidence intervals.

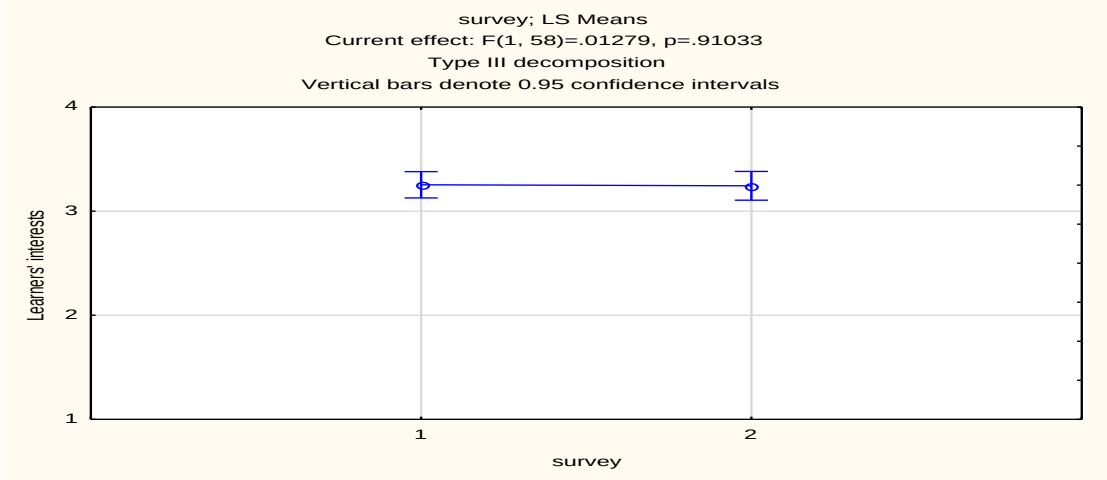
Figure 5.29: Comparison of perceived capabilities in assisting learners to overcome their anxieties and incompetence in learning



Comparison of perceived capabilities in focusing instructional decisions on the learners needs and interests

The graphical display in Figure **5.30** shows that the two learning experiences had equally significantly improved the PSTs' perception of *capabilities in focusing instructional decisions on the learners' needs and interests*. This observation was supported by the computed p-value (p = 0.91033) at 95% confidence intervals.

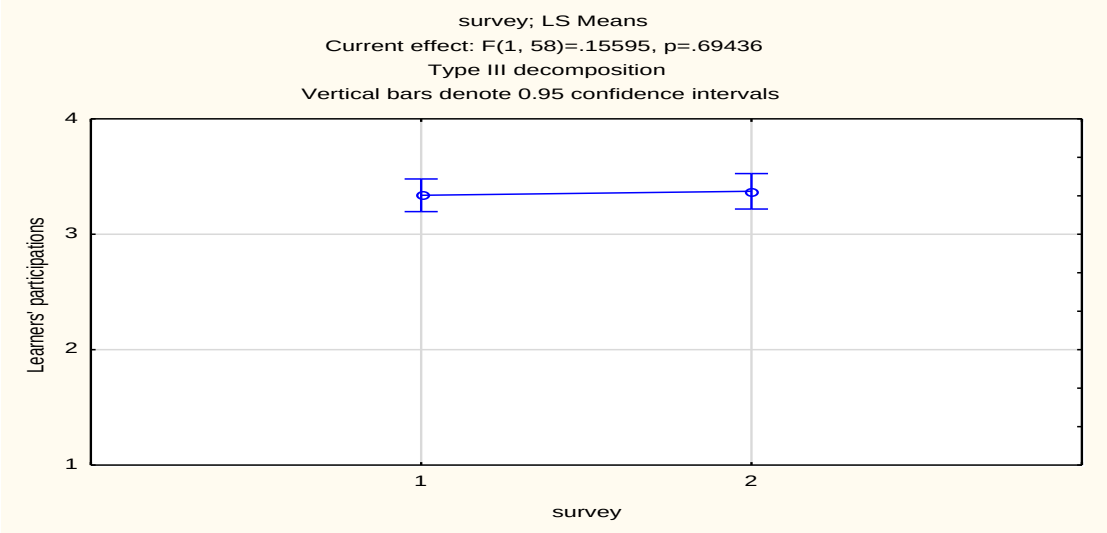
Figure 5.30: Comparison of perceived capabilities in focusing instructional decisions on the learners needs and interests



Comparison of perceived capabilities in creating ample opportunities for active learner participation

The graphical display below, in Figure **5.31**, shows that the two learning experiences had equally significantly improved the PSTs' perception of *capabilities in creating ample opportunities for active learner participation*. This observation was supported by the computed p-value (p = 0.69436) at 95% confidence intervals.

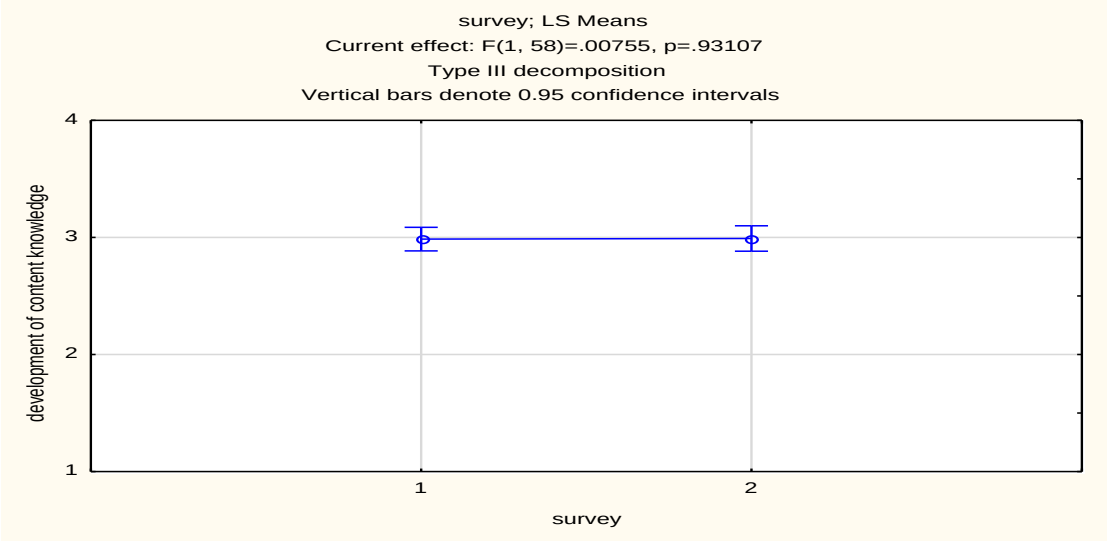
Figure 5.31: Comparison of perceived capabilities in creating ample opportunities for active learner participation



Perceptions about the experience that impacted more on the PSTs' understanding of Foundation Phase mathematics CK

Figure **5.32,** below, shows that the two learning experiences had equally significantly improved the PSTs' perception of *understanding of the mathematics CK* they were going to teach. This observation was supported by the computed p-value (p = 0.93107) at 95% confidence intervals.

Figure 5.32: Comparison of improvements in understanding mathematics CK

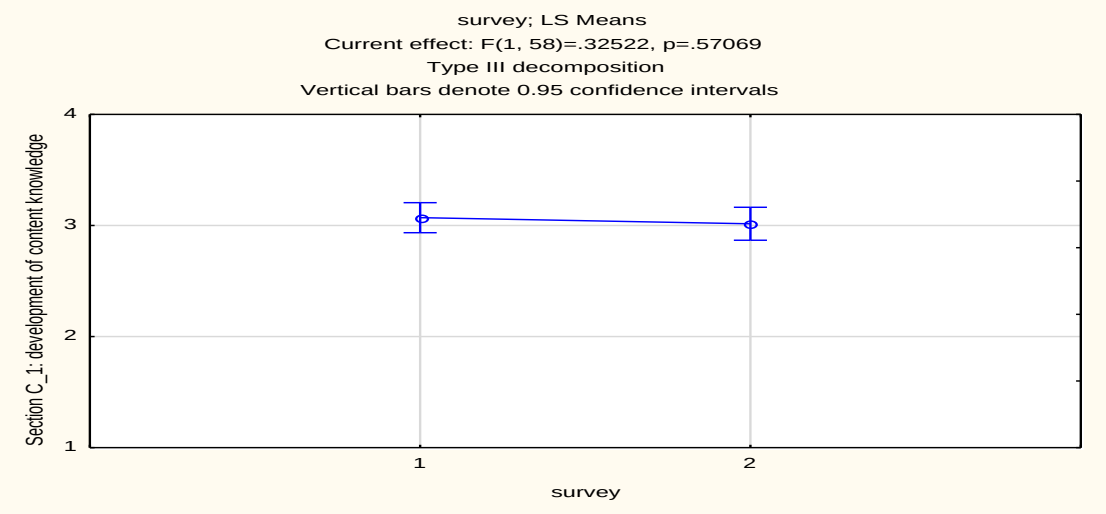


Further comparison of the sub-themes or constituent learning achievements of the broader theme above was also undertaken, as shown below:

Comparison of improvement in understanding Foundation Phase mathematics concepts and procedures

Figure **5.33,** below, shows that the two learning experiences had equally significantly improved the PSTs' perception of *understanding of Foundation Phase mathematics concepts and procedures*. This observation was supported by a computed p-value (p = 0.57069) at 95% confidence intervals.

Figure 5.33: Comparison of improvements in understanding Foundation Phase mathematics concepts and procedures



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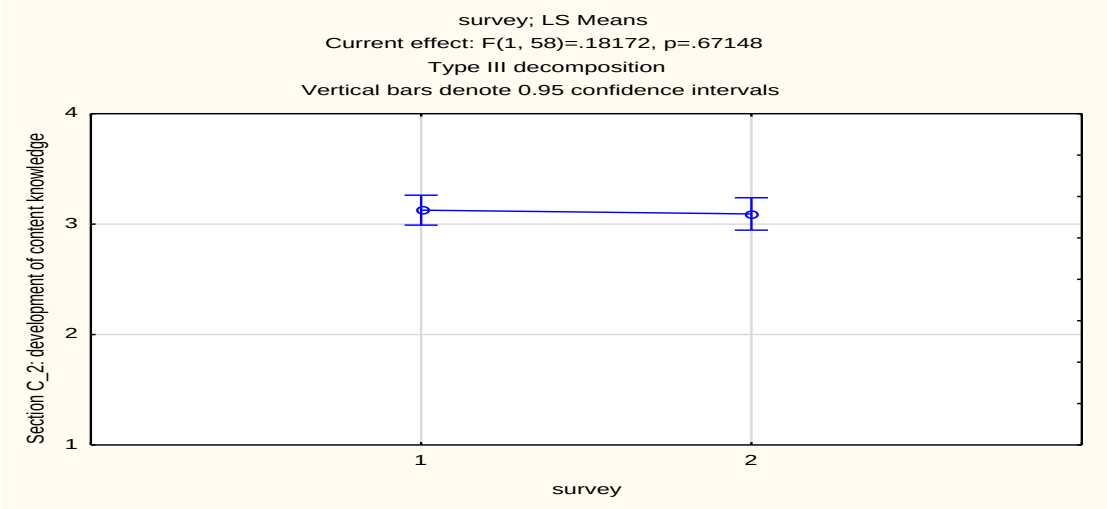
Comparison of improvements in understanding how learners learn number operations and relationships

Figure **5.34,** below, shows that the two learning experiences had equally significantly improved the PSTs' perception of *understanding how learners learn number operations and relationships.* This observation was supported by the computed p-value (p = 0.67148) at 95% confidence intervals.

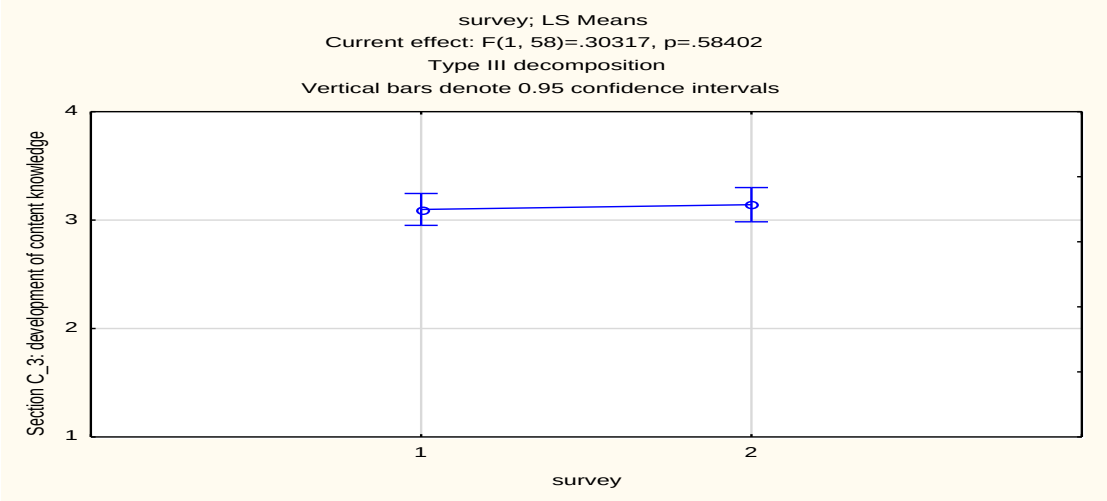
Figure 5.34: Comparison of improvements in understanding how learners learn number operations and relationships



Comparison of improvements in understanding how to solve problems using different strategies

The graphical display in Figure **5.35** shows that the two learning experiences had equally significantly improved the PSTs' perception of *understanding of how to solve problems using different strategies.* This observation was supported by the computed p-value (p = 0.58402) at 95% confidence intervals.

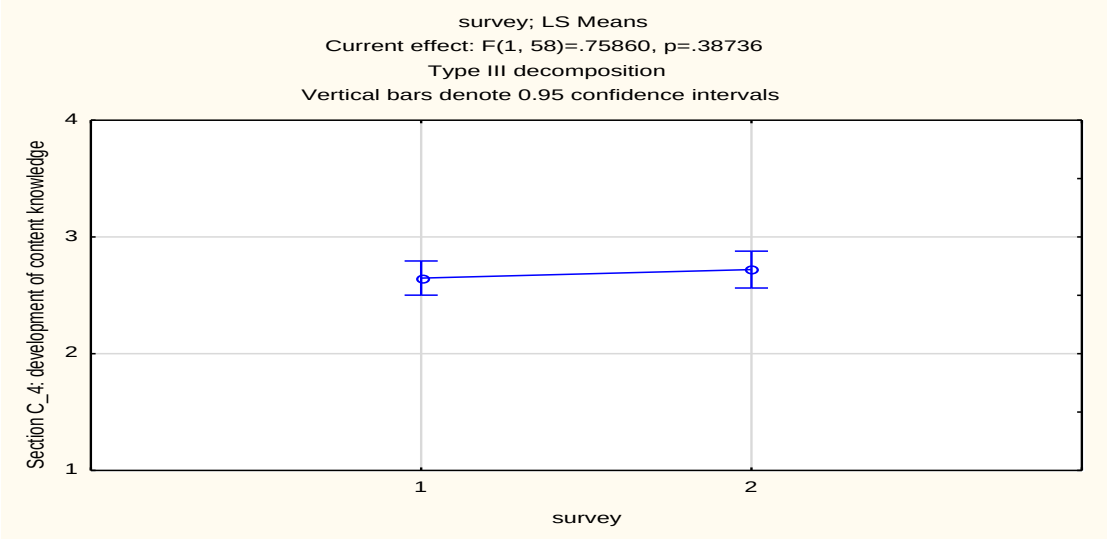
Figure 5.35: Comparison of improvements in understanding how to solve problems using different strategies



Comparison of improvements in understanding how to explain why procedures work they way they do

Figure **5.36,** below, shows that the two learning experiences had equally significantly improved the PSTs' perception of *understanding of how to explain why procedures work the way they do.* This observation was supported by the computed p-value (p = 0.38736) at 95% confidence intervals.

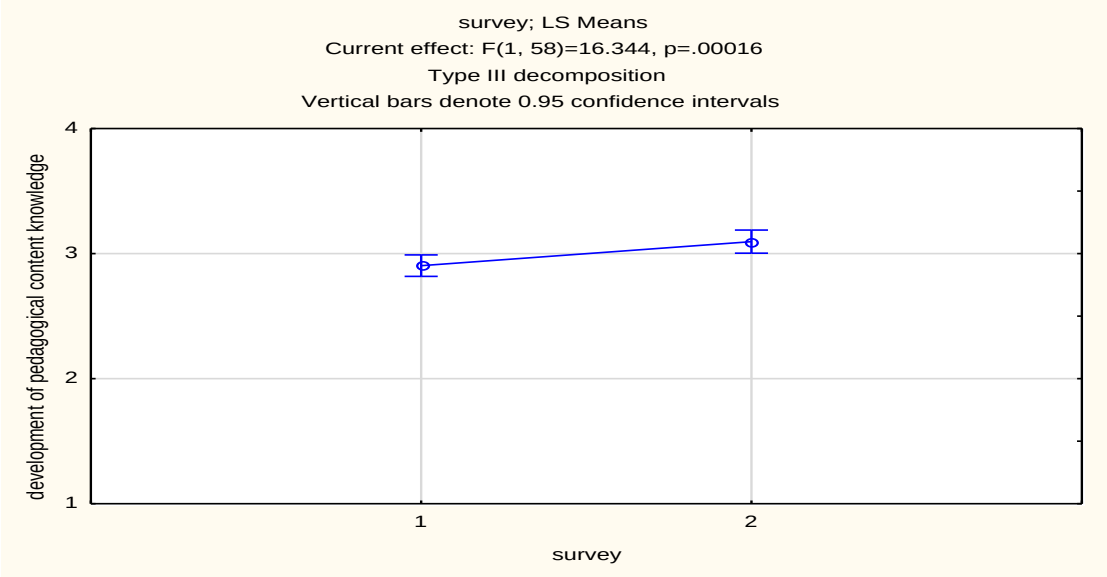
Figure 5.36: Comparison of improvements in understanding how to explain why procedures work they way they do



Perceptions about the experience impacting more on the development of the PSTs' PCK for Foundation Phase mathematics

The graphical display in Figure **5.37** shows that interaction with the ETE's teaching expertise had improved the PSTs' developing PCK for Foundation Phase mathematics more significantly than the two-year training did. This observation was confirmed by the computed p-value ($p = 0.00016$) at 95% confidence intervals.

Figure 5.37: Comparison of improvements in developing PCK

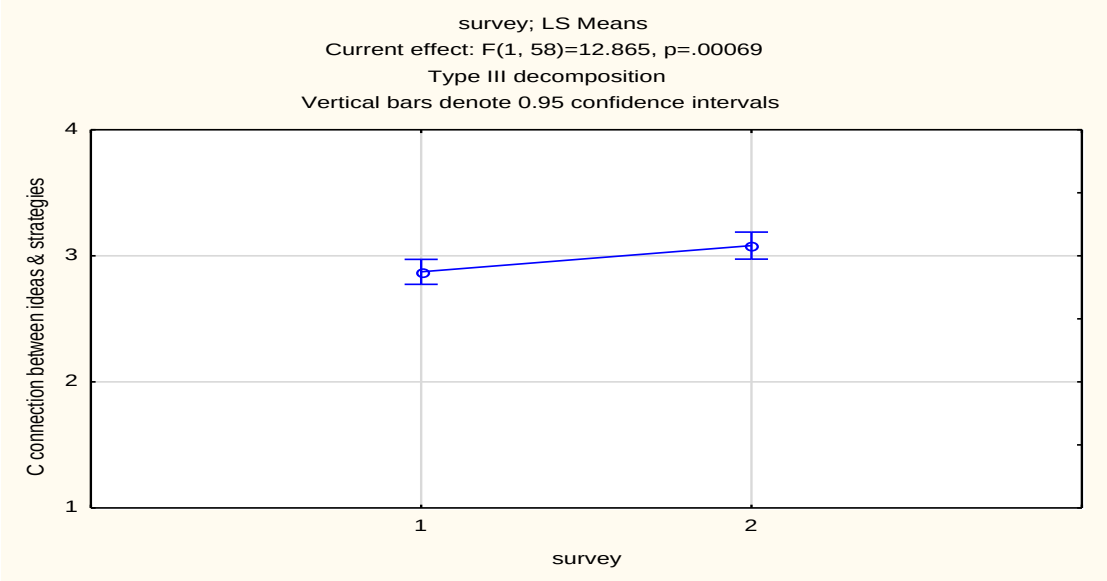


Further comparison of the sub-themes or constituent learning achievements of the broader theme above was also undertaken, as shown below:

Comparison of improvements in understanding how to assist learners to make connections between ideas and strategies in solving problems

Figure **5.38,** below, shows that interaction with the ETE's teaching expertise had improved the PSTs' perception of *understanding how to assist learners to make connections between ideas and strategies in solving problems* more significantly than the two-year training period did. This observation was confirmed by the computed p-value (p = 0.00069) at 95% confidence intervals.

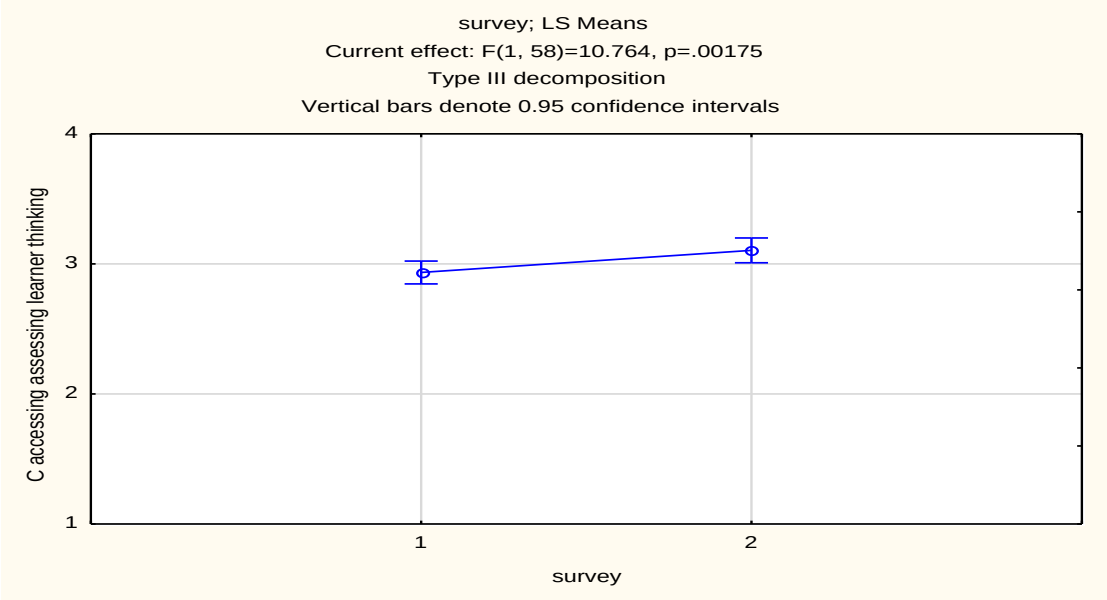
Figure 5.38: Comparison of improvements in understanding how to assist learners to make connections between ideas and strategies in solving problems



Comparison of improvements in understanding how to access and assess learners' thinking and understanding

The graphical display in Figure **5.39** shows that interaction with the ETE's teaching expertise had improved the PSTs' perception of *understanding how to access and assess learners' thinking and understanding* more significantly than the two-year training did. This observation was confirmed by the computed p-value (p = 0.00175) at 95% confidence intervals.

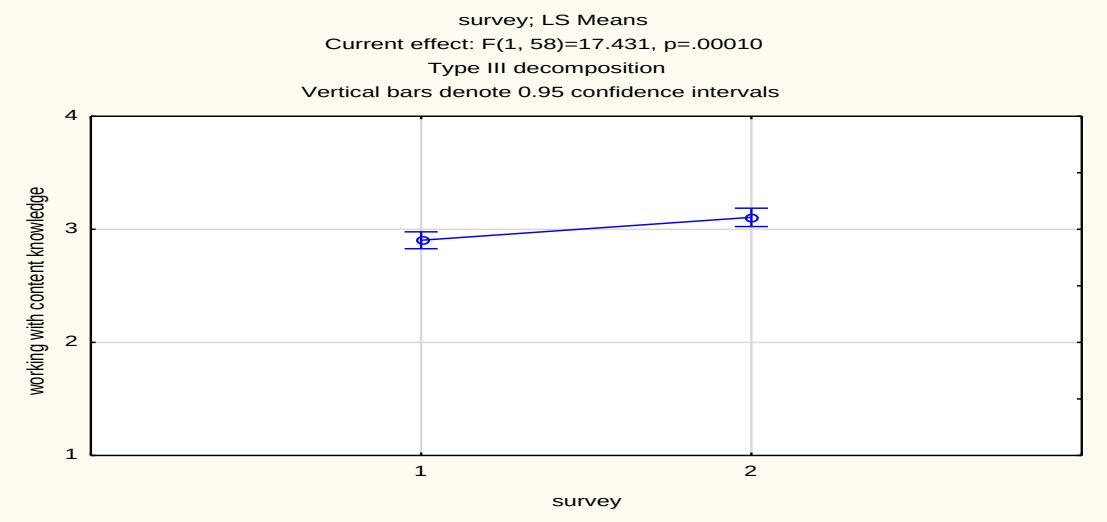
Figure 5.39: Comparison of improvements in understanding how to access and assess learners' thinking and understanding



Perceptions about the experience that impacted more on the affordances of the PSTs' CK for Foundation Phase mathematics

Figure **5.40,** below, shows that interaction with the ETE's teaching expertise had improved the PSTs' perception of teaching capabilities in their *understanding of the mathematics CK for Foundation Phase mathematics* more significantly than the two-year training period did. This observation was confirmed by the computed p-value (p = 0.00010) at 95% confidence intervals. Further comparison of the sub-themes or constituent learning achievements of the broader theme above were also compared, as shown below:

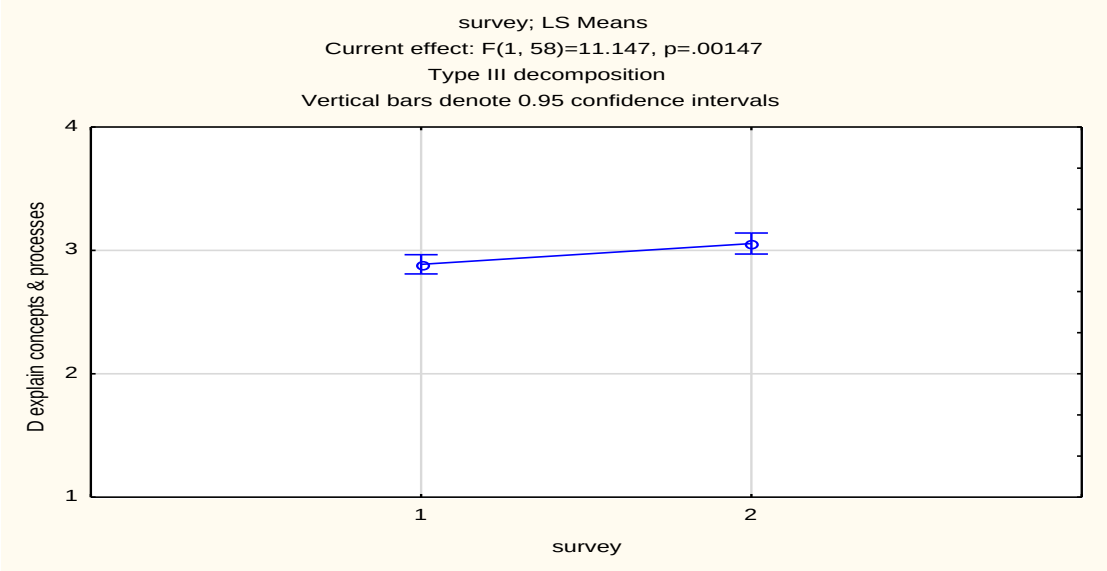
Figure 5.40: Comparison of PSTs' perceived teaching capabilities in their improved CK



Comparison of perceived capabilities in explaining concepts and procedures to enhance learners' understanding

Figure **5.41** below shows that interaction with the ETE's teaching expertise had improved the PSTs' teaching capabilities and their belief that they *can explain concepts and procedures to enhance learners understanding* more significantly than the two-year training period did. This observation was confirmed by the computed p-value (p = 0.00147) at 95% confidence intervals.

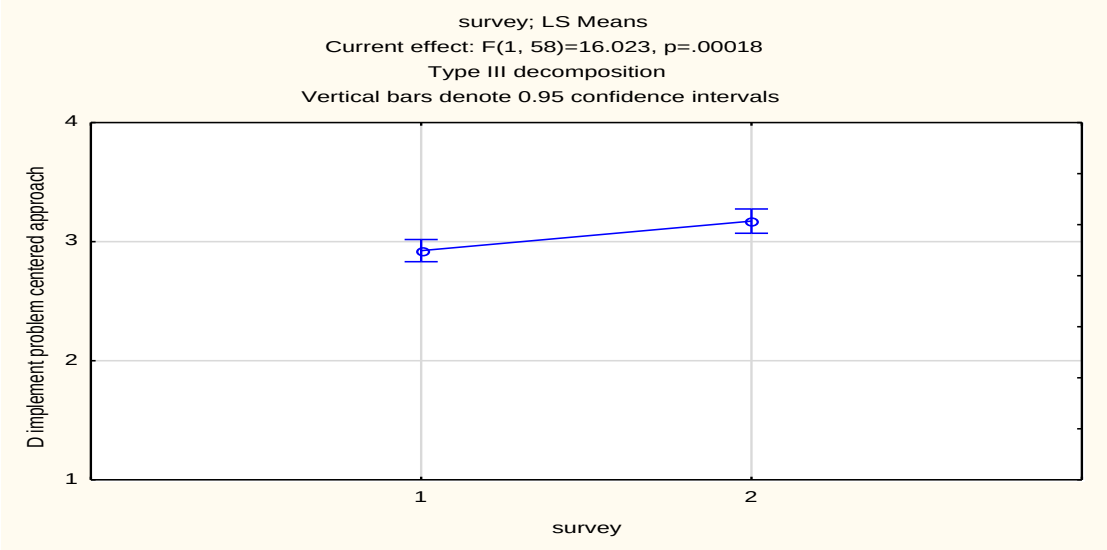
Figure 5.41: Comparison of perceived capabilities in explaining concepts and procedures to enhance learners understanding



Comparison of perceived capabilities in implementing a problem-centred teaching and learning approach

Figure **5.42,** below, shows that interaction with the ETE's teaching expertise had improved the PSTs' teaching capabilities and their belief that they *can implement a problem-centred teaching and learning approach* significantly more than the two-year training period did. This observation was confirmed by the computed p-value (p = 0.00018) at 95% confidence intervals.

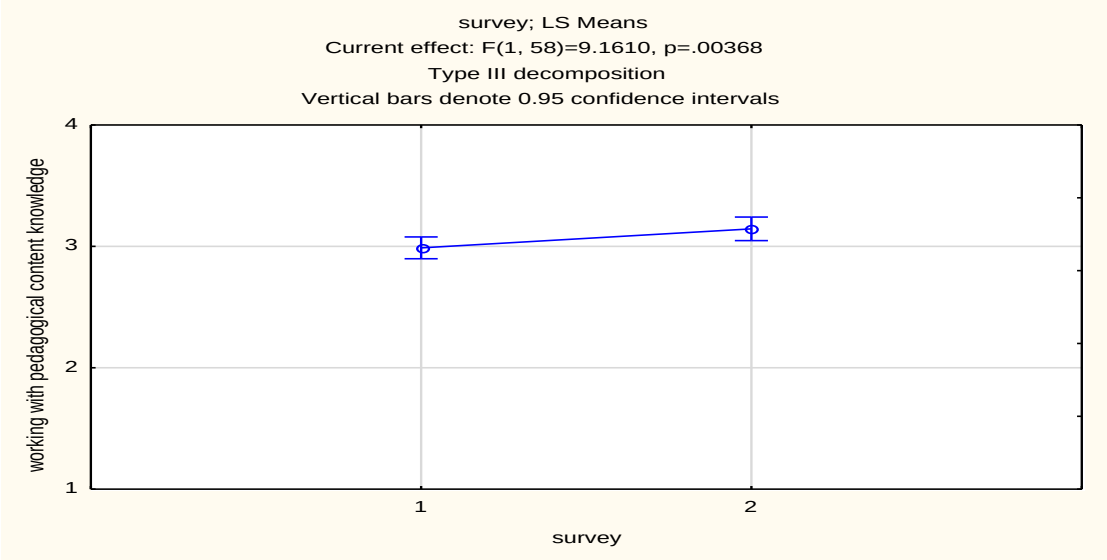
Figure 5.42: Comparison of perceived capabilities in implementing a problem-centred teaching and learning approach



Perceptions about the experience impacting more on the affordances of the PSTs' PCK for Foundation Phase mathematics

Figure **5.43,** below, shows that interaction with the ETE's teaching expertise had improved the *affordances of the PSTs' developing PCK for Foundation Phase mathematics* significantly more than the two-year training period did. This observation was confirmed by the computed p-value ($p = 0.00368$) at 95% confidence intervals. Further comparison of the sub-themes or constituent learning achievements of the broader theme, above, was also undertaken, as shown below:

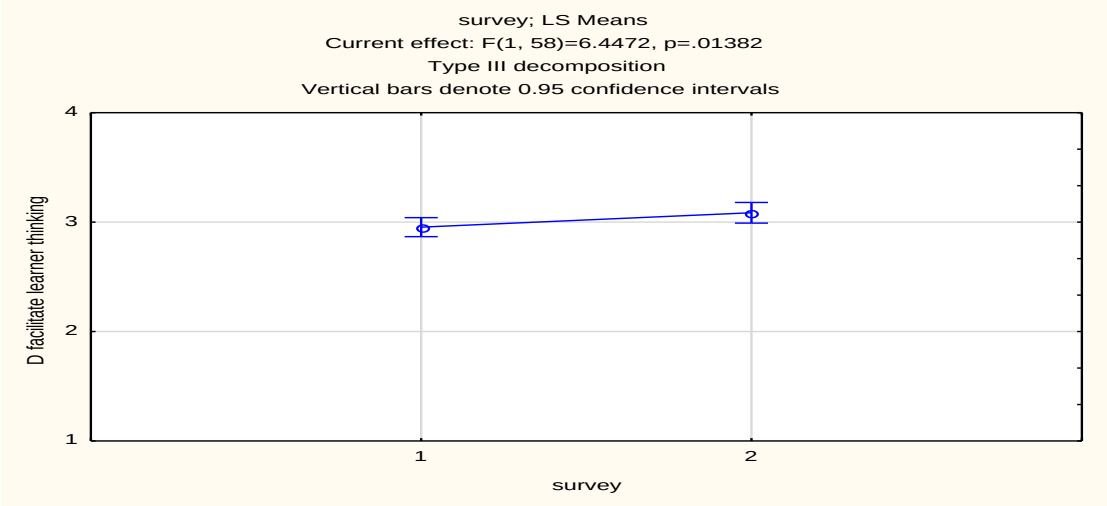
Figure 5.43: Comparison of PSTs' perceptions of teaching capability in their developing PCK



Comparison of perceived teaching capabilities in facilitating thinking and meaningful understanding of contents

Figure **5.44,** below, shows that interaction with the ETE's teaching expertise had improved the PSTs' teaching capabilities and their belief that they *can facilitate thinking and meaningful understanding of contents* significantly more than the two-year training period did. This observation was confirmed by the computed p-value (p = 0.01382) at 95% confidence intervals.

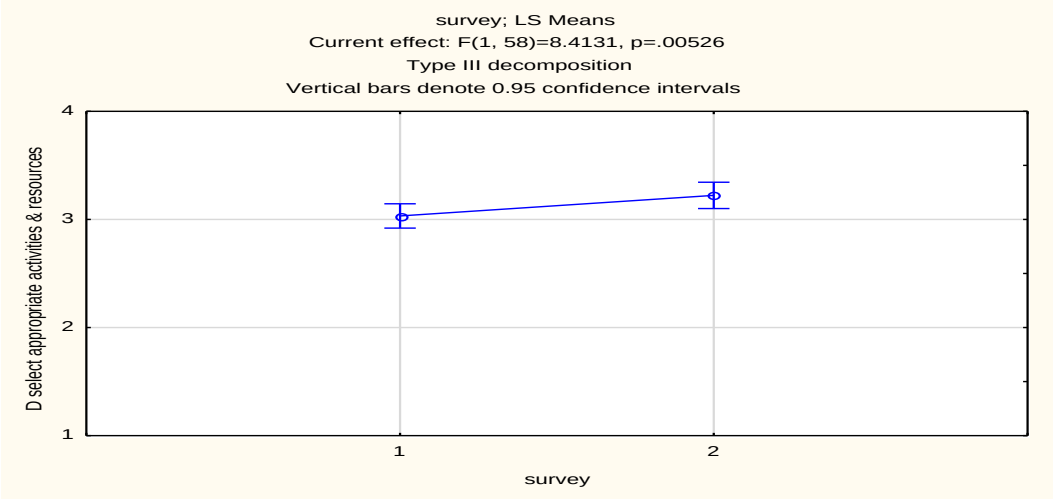
Figure 5.44: Comparison of perceived teaching capabilities in facilitating thinking and meaningful understanding of contents



Comparison of perceived teaching capabilities in selecting appropriate teaching and learning activities and resources

The graphical display in Figure **5.45** shows that interaction with the ETE's teaching expertise had improved the PSTs' teaching capabilities and their belief that they *can select appropriate teaching and learning activities and resources* significantly more than the two-year training period did. This observation was confirmed by the computed p-value (p = 0.00526) at 95% confidence intervals.

Figure 5.45: Comparison of perceived teaching capabilities in selecting appropriate teaching and learning activities and resources



5.4.2. Summary of findings (Phase B)

Overall, the emerging message from the preceding results seems to be that, during their interaction with the ETE's teaching expertise, significantly more improvement in the PSTs' perception of *transformation of beliefs about the subject matter of mathematics and the teaching and learning of it* occurred than in the perception of *improvement in their understanding of the mathematics CK and development of PCK for mathematics*. Similarly, the results seemed to show that the PSTs' perception of *affordances of the transformation of their beliefs about mathematics and the teaching and learning of mathematics* had improved more than the *affordances of the improvement in their CK and development of their PCK*. The observations reported here provide a fair answer to the research question: Which of the dimensions of their PD is most or least influenced from the two experiences? That is to say that the PSTs' perceived *transformation of their beliefs about mathematics and the teaching and learning of it* as component of their PD influenced most, while the PSTs' perceived *improvements in their CK and development of their PCK* as improved fairly equally, though not as much as the improvement in their perceived beliefs.

Other factual conclusions drawn from the results were that, among the equally important indicators of the PSTS' perceived *transformation of their beliefs about the subject matter of*

mathematics and the teaching and learning of it, their perceived *reflection on learning and actions, being critical about their learners' needs and characteristics* and *interests in focusing on the mathematics content* had improved equally highly over their perceived improvement in their *mathematical* competence. PSTs also perceived improvement in aspects such as *understanding foundation mathematical concepts and procedures; understanding how learners learn number operations and relationships*; *solving problems using different strategies; understanding of how to make connections between ideas and strategies in solving problems* and *understanding of how to access and assess learners thinking and understanding in teaching and learning,* in their CK and PCK.

Other supporting findings of PSTs' perceived transformation in their beliefs about the subject matter of mathematics and the teaching and learning of it involved the following: *create ample opportunities for active learner participation; promote learning mathematics for meaningful understanding (facilitate learners' meaningful understanding); overcome learners' anxieties and improve learners' competence in learning (overcoming their feelings of incompetency to engage young learners in solving mathematical problems);* and *adapt learner-centred approach*; *reflecting on and correcting their misconceptions about the subject matter of mathematics; reflecting on and correcting their misconceptions about teaching young children mathematics; use manipulatives to overcome learners' anxieties; take instructional decisions to suite learners' interest/needs.*

Supporting findings of PSTs' perceived improvement and affordances of their CK and development of PCK were related to *how to explain, or ability to explain, solution methods or strategies to learners in problem solving; assess learners' understanding of mathematical ideas and procedures; access learners' thinking about concepts, procedures, etc; help learners to connect their mathematical ideas in problem solving; assist learners to solve problems requiring multiple ideas and strategies; explain similarities and differences among different representations, solutions, or methods; explain why mathematical procedures work; critically reflect on the effectiveness of teaching methodology; provide a problem-solving learning context; assist learners to solve problems using ideas and strategies known or unknown to them; explain the similarities and differences among children's representations, solutions,*

All the attributes of the ETE's teaching expertise were perceived to have improved the PSTs' PD in general; however, it was found that the ETE's *preparation for and organisation of teaching; articulation of subject knowledge expertise in teaching;* and *enthusiasm in teaching* had the greatest influence or impact in transforming or improving the PSTs' *beliefs, perceptions, misconceptions, and attitudes towards the subject matter of mathematics and the teaching and learning of it*. Similarly, the ETE's *articulation of subject knowledge expertise in teaching; enthusiasm in teaching; motivating/stimulating students' interest and engagement with learning experiences; preparation for and organisation of teaching;* and *clarity in lesson presentation/teaching* had the greatest influence or impact on the PSTs' *understanding of the Foundation Phase mathematics CK*. All the attributes of teaching expertise had greatly influenced or impacted on the *development of* PSTs' *PCK for Foundation Phase mathematics,* **excepting** *humour in teaching*. Interestingly, the ETE's *humour in teaching* was perceived to have the least impact on any of the three components of the PSTs' PD.

5.4.3. Interview Results (Phase B)

This section presents the results from the interviews with the same English-speaking group of PSTs who volunteered to participate in this study, five (5) of whom were accessible. Unlike the previous interview, this interview focused on eliciting detailed explanations or interpretations of the PSTs' PD with **special reference** to their experiences in learning to teach Foundation Phase Mathematics from the **teaching expertise** they experienced in the 3rd-year mathematics module. Their responses in the interview were expected to provide additional in-depth understanding of the research problem, as well as wider and detailed answers to the following questions:

i. What change(s)/improvement do the PSTs' perceive in their beliefs about mathematics and teaching and learning of mathematics?
ii. What affordance(s) do the PSTs perceive from the improvement they perceive in their beliefs about mathematics and teaching and learning of mathematics?
iii. What change(s)/improvement do the PSTs' perceive in their understanding of the mathematics CK and development of their PCK for Foundation Phase mathematics?

iv. What affordance(s) do the PSTs perceive from the improvement they perceive in their understanding of the mathematics CK and development of their PCK for Foundation Phase mathematics?

v. Which of the three dimensions of their professional development (i.e. beliefs, content knowledge and pedagogical content knowledge) is most or least enhanced?

vi. Which of the dimensions of the teaching expertise they experienced influenced the PSTs' PD most or least?

vii. Which of the two experiences impacted most/least on the dimensions of their PD?

The analysis of the interview responses generated themes similar to those used in analysing the data from the survey. These analytical themes were generated through the method of constant comparisons (as described in Chapter 4) of the interviewees' responses to the interview questions. The analytical themes included the respondents'

- perceived changes/improvement in their beliefs about the subject matter of mathematics and teaching and learning of mathematics
- perceived teaching capabilities (abilities to facilitate learning effectiveness) resulting from the changes/improvement in their beliefs
- perceived improvement in understanding of mathematics CK
- perceived teaching capabilities (abilities to facilitate learning effectiveness) resulting from the improvement in understanding of CK
- perceived developing PCK
- perceived teaching capabilities (abilities to facilitate learning effectiveness) resulting from the developing PCK
- perceived most improved dimension of the PSTs' PD
- perceived teaching expertise which impacted most on perceived changes/improvement in
    - beliefs about the subject matter of mathematics and teaching and learning of mathematics
    - understanding of mathematics CK;
    - development of PCK

The themes indicated above are in line with the inquiry questions guiding this investigation as well as the two major themes: ***perceived changes/improvement in PSTs' PD*** and ***perceived affordances of the changes/improvement in PSTs' PD***.

Perceived changes/improvement in PSTs' PD comprises perceived changes/improvement in PSTs' beliefs about the subject matter of mathematics and teaching and learning of mathematics; PSTs' perceived improvement in their understanding of the mathematics CK; and PSTs' perceived development in their PCK. ***Perceived affordances of the changes/improvement in PSTs' PD*** also comprises perceived affordance(s) of the changes/improvement in PSTs' beliefs about the subject matter of mathematics and teaching and learning of mathematics; PSTs' perceived affordances of the improvement in their understanding of the mathematics CK; and PSTs' perceived affordances of their developing PCK. This categorisation aligns the interview themes with the themes used in analysing the results of the survey. The following sections present the findings from the interviews in accordance with these themes.

5.4.3.1. Descriptions of the PSTs' pre-existing views, misconceptions, attitudes

Upon commencing the third-year Foundation Phase mathematics module, some of the PSTs shared some entry behaviours or characteristics held in common. These are presented verbatim in the narratives:

> PST 1 said, "... so the misconception is that it is easy to teach children mathematics and it is not at all, ..."

> PST 4 said, "I didn't enjoy learning mathematics as a child; so I was very [concerned] about how to teach it to young children because of my own attitudes towards it."

In supporting her colleague's feelings above, PST 3 said, " … my previous like grade 10 I almost threw math away and I was very negative towards math." In addition, PST 2, who found herself in a similar situation, said, "… in the first and second year I had a lot of self doubt, I thought I couldn't teach math, I didn't like math, I didn't want to do math, I didn't see any point in learning math …"

> PST 4 said, "I had the misconceptions that only clever people have to do or teach mathematics."

While sharing similar perceptions about the subject matter of mathematics with her colleague above, PST 5 said, "mathematics seemed a bit hazy for me, …"

> PST 4 said, "I had negative expectations or connotations against algebra, in high school I didn't do well with it … I was very sceptical about how to teach something like early algebra."

PST 2 expressed similar anxiety, saying that, "… before this interactions I couldn't stand on my feet, and I couldn't draw links between strategies"

> PST 4 said, "... initially I was very sceptical about believing and practising the problem-centred approach in teaching and learning of mathematics."

PST 2 also shared the same scepticism or pessimism with her colleague, saying that, "I had a vague idea about how to conduct problem solving strategies in teaching and learning of mathematics, I have never actually done one, I knew from my school experiences that in problem solving the teacher gives the learner a method to solve the problem."

In the interaction reported above, the PSTs expressed their coincidental views, beliefs, attitudes, and misconceptions about mathematics and the teaching and learning of it. This clearly showed the state of their minds or thinking prior to their interaction with the teaching expertise of the ETE in the 3rd-year Foundation Phase mathematics course. In what follows the PSTs described the views about mathematics which they have been convinced to subscribe to help them overcome their misconceptions and attitudes they described above.

5.4.3.2. Descriptions of changing beliefs, attitudes, and misconceptions

The PSTs seemed to have adjusted their beliefs about teaching and learning of mathematics associated with their views of the problem-centred approach to teaching and learning. This became evident in their passionate claims quoted below:

> PST 1 said, '…you have to keep asking questions to get children thinking and they can get how to sort out the problem you have given them in their own ways"
>
> PST 2 said, "I have had concrete examples or experiences of the problem-centered approach in our lectures, it helped me visualise a problem-centred approach in a mathematics class, …"

While supporting the views above, PST 1 said: "The problem-centred approach is my belief in how to teach mathematics and how to learn mathematics because the difference in giving the children a problem and telling them this is the problem you have to do it this way, and then given them a problem and tell now you figure it out, helping them through questioning them, ask then show me what you did there, why did you do it this way and stuff like that, I that is how I believe it ..."

PST 5 buttressed her colleagues' views about mathematics and teaching and learning of it, saying, "… I understand the connections between mathematical ideas, understand the connections between high school mathematics and elementary school mathematics. Teaching and learning mathematics should include more practical experience because that way you see it actually working best with our understanding and learners' understanding."

The views in PST 3's belief were buttressed when she said that "Math is about problem-solving, different ways of how to solve a problem, different ways of thinking, broadening your understanding, creative thinking"

Their belief in the problem-centered approach seemed to have developed their views that the subject matter of mathematics is connected with the learners' own thinking and expression of their minds relative to real life situations or their physical environment. The excerpts below supported the descriptions of their beliefs:

> PST 4 said, "I view mathematics as a hands-on practical approach …"

In sharing similar belief with her colleague above, PST 5 stressed saying, "… but now I believe I am seeing it [mathematics] in practice". In addition, PST 2 supported the two views above with her observation that " …my view now about mathematics is no longer the straightforward one way seeing and doing things but a kind of mind-map with all these different links …" She stressed that "… I believe that every child can do mathematics, no child should be left behind, … mathematics is not that abstract thing it is something that you can use in everyday life and mathematics is all around us and we just need to look for it, convince children that mathematics can be fun, …, poor strugglers should be attended to and integrated in the mathematics lesson to benefit them."

> PST 4 said, "I believe teaching and learning should focus on getting children to be thinking about problems and what to do about the problem"

PST 2 perceived similar achievement and said, "… but in third year when I learnt about the problem centred approach to teaching and learning and math, I felt my perceptions have better improved. I am slowly restoring my interest and confidence I feel enthusiastic about math now, encourage my students to ask questions and develop interest in math, relate math to their lives"

> PST 4 said, "… learners should be able use their hands on the skills and minds and words to describe what they are doing and to make sense of what they are doing"

While supporting PST 4's beliefs above, PST 2 concluded by saying that "… if the problem-centered approach is done correctly children were able to learn quickly."

5.4.3.3. Perceived improvement in beliefs about mathematics and the teaching and learning of it

The PSTs perceived that their beliefs, misconceptions, and attitudes improved and that they had been re-oriented to explore to gain wider and deeper mathematical content and teaching knowledge. Such changes in attitudes and beliefs could be emphasising that mathematical knowledge is not static but dynamic and could be acquired through exploration. These common shared views are evidenced in the quotations:

> PST 4 said, "I have learnt to teach children in a different way - different from what I experienced when I was a child - and understanding how children learn mathematics. "

In supporting her colleague's views above, PST 2 was convinced of the improvement she perceived in herself, saying that "I have learnt how to pose a problem and I understand how let learners discuss it …". In addition, PST 5 said, "I am careful not to just give contents to children and work it for them on the board, …". PST 3 perceived similar changes and said that "I feel I should not limit myself about math and become comfortable and confident to share knowledge with children". While expressing her own perceived changes in support of her colleagues, PST 1 said "I am more passionate about teaching mathematics to the young ones, and more passionate about teaching and learning mathematics as a problem-centred approach, I am more passionate about letting the children decide for themselves, to me this is how to teach mathematics to children ..."

> PST 4 said, "I have been able to change my own misconceptions and I want to transfer this change to children that not only clever people do mathematics."

PST 2 observed similar changes in herself and buttressed the changes in her misconceptions, saying, "I believe that children would respond to learning so much better if they are given the opportunities to figure out their own strategies, and play around with math." In addition, PST 3 expressed perceiving similar changes, saying that "It is very important that I don't limit the children's thinking (about processes, ideas, concepts, strategies, solutions) to my possible misconceptions …"

> PST 4 said, "… I have learnt to try or experiment something new that can improve teaching and learning of mathematics …"

In sharing similar changes in belief with PST 4, above, PST 2 said "I have learnt that there's actually a certain degree of creativity in math and I am only seeing it now in the problem-centered approach, I also understand that there are so many different ways to solve one problem, I can see that children have different levels of thinking about problems, so that really changed my idea about mathematics –the views I had about mathematics – from the problem-centred approach" From her side, PST 3 said, "I learnt that I should have a purpose behind everything that I teach."

> PST 4 said, "… my negative mind-set is has been changed very much to develop a positive view about mathematics and the T/L of it."

In expressing similar perceived improvement, PST 2 said that "..I see changes in my attitudes towards mathematics, and developed enthusiasm about mathematics". She added, further saying that "I have learnt how to come to their [children's] level, assess their situation, and how to talk to them". PST 5 also added when she perceived similar changes and said that "I have learnt to let my negative attitude towards mathematics go, my wrong perceptions, misconceptions misunderstanding of the CK and begin learning proper understanding of mathematics from the lecturer.". While supporting her colleagues' views above, PST 3 stressed the changes she perceived by saying, "I feel I should relearn the things that I don't understand and almost take myself as I was a child and reconstruct my conceptions or misconceptions … I have learnt to keep positive attitude towards math and focus on the content, keep an open mind that there's not just one way of doing a math activity, solving a problem, or learning."

> PST 4 said, "I have developed my confidence in teaching Foundation Phase mathematics."

PST 2 shared similar achievements, saying, "… but now there's more flow and more consistency in my thinking". She added, with emphasis, that "…my thinking has been enhanced a lot more, I will accommodate children working at their own pace and their own levels. I can think quickly on my feet". PST 3 expressed similar achievements when she said that "[the] problem-centered

approach to learning mathematics we learnt from the lecturer is totally new to us, it has been a challenge, and it has challenged my perceptions of math".

While expressing the perceived changes or improvement in their beliefs, misconceptions and attitudes towards mathematics and the teaching and learning of it, it became evident that the interviewees were emphasising the following achievements/improvements which could answer the research question "What change(s)/improvement do the PSTs' perceive in their beliefs about mathematics and teaching and learning of mathematics?"

- Understanding that learners need be allowed to work at their own pace and level of thinking;
- Improvement in their own consistency in thinking, self-confidence in teaching;
- Understanding the connections between mathematical ideas;
- Understanding that learners need to relate learning of content to their own everyday experiences;
- Understanding that learners own different solution methods and thinking needs to be encouraged;
- Understanding that they need to encourage learners to think and question what they are learning or experiencing to enhance their understanding;
- Understanding that they need to encourage learners to actively participate in showing their skills and thoughts in the content of what they are learning;
- Understanding that they need to understand learners' thinking in order to assist them to improve their thinking and learning;
- They learnt to pose relevant but challenging problems to improve learners' understanding and thinking;
- They learnt to engage learners in discussions of their own ideas;
- They learnt to give learners maximum opportunities to figure out their own strategies in learning or solving problems;
- They developed an interest/willingness in exploring new ways of teaching and learning;
- They learnt that they need to create ways of making mathematics interesting/fun and challenging for learners;

- They learnt that they need to adapt teaching to learners' levels of thinking and understanding;
- Improvement in their understanding of how to assess learners' needs and abilities to improve their thinking and understanding
- They developed interest in mathematics and focus on the main or basic content and problem.

5.4.3.4. Perceived affordances of the improvements in beliefs about mathematics and the teaching and learning of it

The PSTs perceived that, with the above improvement/changes perceived in their beliefs, attitudes and misconceptions, they were able to encourage and create opportunities for young learners to explore mathematics and take greater responsibility for their own knowledge and understanding of the mathematics they are learning, thus overcoming, addressing, or improving children's anxieties about mathematics and showing that everyone is able to do mathematics. The excerpts below support their shared views:

> PST 4 said, "… I can listen to what children are doing, ask them questions before criticising them or their work, ask what they are doing and why and how, give them the [opportunity] to express their understanding, accept what children are doing …".

In expressing her perceived teaching behaviour to support her colleague above, PST 5 said, "I can give them a problem which has the mathematics content in it; children work through the problem themselves; they come out with their own strategies, then I will funnel their solution strategies by sequencing them from the poorest to the best strategies". While supporting her colleague, PST 1 said,

> "I can give children relevant content problems that they will be interested in, not problems they can't relate to, it has to be interesting to little kids, they can relate to it and they will want to learn more. Show children that math can be fun and interesting, it is not just boring a +b = c."

PST 4 said: "I can plan lessons at a level that children can understand."

In sharing similar teaching capabilities with her colleague above, PST 2 said "I can give them a problem they can relate to, let them use their own strategies …" PST 5 also reported similar teaching capabilities when she said that "I will concentrate on teaching basic concepts and their roots, help them develop on those concepts so that children will see the connections between them"

> PST 4 said, "I can prepare, organise and plan mathematical instructions to make it interesting for children to enjoy learning mathematics."

This perceived teaching behaviour was also shared by PST 2 in her claim when she said, "I can encourage children to explore mathematics to build their skills and develop their interest in it". While expressing similar perceived teaching capacity, PST 5 said, "I can create a positive mathematical environment for my learners, make mathematics the favourite subject for my learners, want to make learners passionate about mathematics."

> PST 4 said, "I can identify children's negative feelings towards mathematics, encourage them to develop positive views about mathematics, to encourage and show them that they were able to learn and do better in mathematics."

PST 5 shared similar perceived affordability in teaching capabilities, saying that "This approach gives me the confidence I need to teach and I can also restore confidence in my students".

> PST 4 said, "… in Foundation Phase mathematics especially, I can involve children in practical learning experiences, use concrete learning materials and real life situations and they should be able to describe what they doing in or with the mathematics".

PST 2 shared similar perceived affordability in teaching young learners when she said, "I can give children the opportunities to flex their mathematical ideas, instead of parrot learning."

The affordances of the improvement they perceived testify to what they have learnt from the teaching expertise of the lecturer in Foundation Phase mathematics about how a lesson can be taught to optimise learners' mathematical achievements through the problem-centered approach. In summary, the interactive views presented above, highlight that the PSTs have perceived

possible teaching capabilities when their entry beliefs, attitudes and misconceptions about mathematics and teaching and learning of mathematics were challenged. They seemed to perceive that they were able to engage learners in learning the mathematics content from practical problems; use manipulatives to enhance teaching and learning; assist learners to make connections between concepts and procedures; create opportunities for learners to express their own understanding. These affordances could answer the research question of "What affordance(s) do the PSTs perceive from the improvement they perceive in their beliefs about mathematics and teaching and learning of mathematics?"

5.4.3.5. Perceived improvement in understanding of mathematics CK

The improvement perceived by interviewees is presented verbatim in the following quotes:

> PST 4 said, "I see that improvements in my understanding combined of the content with the practical hands-on experiences which enhance better understanding"

PST 5 achieved similar improvement in understanding of the content, saying that "I understand where everything link together, and how to link the approach with the content area, link the problem-centered approach with the, with say division"

> PST 4 said, "I understand the contents from different example and situations or experiences, opportunities to engage with the content at different levels."

Similar to PST 4's understanding above, PST 2 described her understanding of the CK saying that "I understand the contents and the links between them …". PST 5 equally perceived similar improvement in her understanding of the content, saying that "I understand the background knowledge of the concepts and how they link together, I understand the different strategies that I can use …"

The PSTs seemed to have improved in understanding of the mathematics CK they were learning to teach. They seemed to share the following understanding of the CK, which could provide a fair answer the research question "What change(s)/improvement do the PSTs' perceive in their understanding of CK?" – they perceived that they understood how content blends with practical problems or experiences; how concepts link with procedures; the content from different

examples and situations or the multiple embodiments of concepts and procedures; the connections between concepts or ideas.

5.4.3.6. Perceived affordances of the improvement in understanding of mathematics CK

The affordances of improvement perceived by interviewees are presented verbatim in the following quotes:

> PST 4 said, "I can create more opportunities and experiences which have the mathematics contents in them, to help my learners understand the practical learning experiences that show the content".

In line with the views of PST 4 above, PST 2 perceived that she was able to "… help them (learners) to develop [a] correct or solid foundation in their understanding so that they can take further when they grow older". While sharing perceived teaching capabilities similar to her colleagues above, PST 5 said, "I can present learning problems that can generate better understanding of the content I am teaching."

> PST 4 said: "I can understand and interpret what they (learners) are thinking and learning."

While supporting her colleague, above, PST 2 perceived that she could "… go through their (children's) minds, what should be happening, what tools they are using and I can link them together to create a powerful lesson". Similarly, PST 5 shared the teaching capabilities of her colleagues, saying that "I can use my understanding to improve learners' misconceptions about certain concepts".

> PST 4 said, "I can be clear in what I understand and what I expect my learners to understand."

In expressing her own perceived teaching capacities in line with PST 4's capabilities above, PST 2 said, "I can facilitate my lesson to be structured and it must flow, connectivity between ideas and processes or procedures in the learning experiences, lessons must build on each other". Similarly to her colleagues' perceived teaching capabilities, PST 5 also said, "I integrate my understanding of the content with the problem-centred teaching and learning approach to enable

me [to] get the learners engaged with the learning experiences to understand the problem and the content they are learning."

PST 4 said, "I can adapt my understanding to suit the levels of my students."

Similarly, PST 2 perceived that she was able to "… start with the simple contents, start with their beginning knowledge, ask what goes on in the kids' minds, and then just improve that knowledge".

The interactive' views above about the perceived affordances of the improvement in their understanding of the mathematics CK could be highlighting the following achievements, which could provide the answer to the research question of "What affordance(s) do the PSTs perceive from the improvement they perceive in their understanding of CK?" The PSTs perceived that they were able to adapt lessons to meet the needs and levels of their students' thinking and understanding; facilitate mathematical lessons to follow structurally to help learners to make connections between their ideas or understanding easily; use learners' understanding and thinking to create effective mathematical instruction and correct their misconceptions; engage learners in learning problems that can generate better understanding of the content.

5.4.3.7. Perceived improvement in the development of their PCK for Foundation Phase mathematics

Concerning perceived improvement in the development of their PCK, the interviewees are quoted verbatim in the following:

PST 4 said, "I understand that teaching and learning math should be hands-on and practical, allow learners to internally create and analyse what they are doing to make sense of the mathematics."

PST 2 shared similar perceived improvement in developing her PCK, saying that "I understand learner's thinking about the content, their understanding of what and how about the contents". In line with her colleague's view, above, PST 5 perceived that she could "analyse how a student does his/her work to see what works and what does not work, create the right learning environment". In a similar manner, PST 3 perceived that she understood how to "… relate to the process that the students are going through".

> PST 4 said, "I understand [that I] need to know the levels where my students are, take into account the diversities in their levels, make efforts to meet my learners' learning needs."

In line with PST 4's perceived improvement, above, PST 2 shared the same experience, saying that "I have learnt to know my learners very well and how well their literacy works …".

The PSTs' views seemed to highlight the following improvements in the development of their PCK: they understand that they need to cater for the diverse needs of learners' thinking and understanding to facilitate effective teaching and learning of mathematics; they also understand the need to create opportunities for learners to construct their own understanding of the content they are learning. These conclusions can be said to provide a reasonable answer to the research question of "What change(s)/improvement do the PSTs' perceive in the development of their PCK in Foundation Phase mathematics?"

5.4.3.8. Perceived affordances of the development of their PCK for Foundation Phase mathematics

Affordances the interviewees perceived as resulting from the development of their PCK for Foundation Phase mathematics include the following, again quoted in their own words:

> PST 4 said, "I create opportunities for learners to engage in mathematics; no learner should feel excluded …"

PST 2 shared similar teaching capability, saying that "I can adapt strategies which can work for their meaningful understanding of the content they are learning". In line with her colleagues' perceived teaching capabilities, PST 5 said, "… with my good basic knowledge and simple materials I can create a good mathematics learning environment". She also added "… I can create opportunities for learners to experience their own cognitive conflicts to develop the connections between their conceptions leading to better understanding of the content they are learning". While expressing her perceived teaching capability, PST 3 said, "I can assist children to solve a problem in many different ways explore the relations between the various strategies used, what are the similarities, what are the differences, what does it tell us …".

> PST 4 said, "I can create a positive problem-centered learning environment [in which] every learner is able to learn something from their experience."

While sharing her perceived affordances of her PCK, PST 2 said, "I can encourage questioning learners' thought about the content to assess their what and how about the contents". She was also convinced that she could "… pose problems to learners to get them engaged with the problems, observe them while they are working, ask questions that really get them thinking, facilitate and guide them to develop the relevant skills to build upon their understanding of the content". In the same manner, PST 5 perceived that she was capable of "…choosing the problem suited to their abilities, engage them with problems at their ability levels so that they can grasp the content they are learning". Like her peers above, PST 3 expressed her perceived teaching capabilities by saying that "I can provide children with the problem, encourage them to solve it the way they feel comfortable solving it themselves".

> PST 4 said, "I can meet them [my learners] at the point of their needs in mathematics, encourage learners to ask me questions and answer my questions …"

While articulating similar perceived teaching capabilities, PST 2 said, "I can understand their learning needs and perhaps what might be hindering them, understand where their problems in the content lies, pick up the underlying problems and help them overcome it." PST 5 expressed her perceived teaching capabilities similarly in "I will be interested in knowing my students' ability levels to guide my instructional decisions". In articulating her perceived teaching capabilities in line with her colleagues above, PST 3 said, "I can adapt the way that I teach to suit the different students' learning needs, so that I make them as productive as possible."

> PST 4 said, "I can scaffold their learning, one level to another or from one point of knowledge to a higher point of knowledge …."

In line with PST 4's teaching capabilities above,

PST 2 said, "I can assist learners to understand concepts deeply and how they all link, connect, build on each other, there should be a logical sense in the understanding, emphasis on the similarities and differences in others, drawing links between the contents and contexts for better understanding".

Like her colleagues, PST 5 expressed her perceived teaching capabilities in saying that "I can support my learners to improve their understanding by questioning them and they questioning me …". PST 3 shared the same perceived teaching behaviours as her peers, saying that "I can make learning fun, engage children to ask questions".

> PST 4 said, "I can use or adapt practical hands-on experience to the needs of my learners."

While sharing her teaching capacities like PST 4 above, PST 2 said, "I can adapt the contents to the problem-centred teaching and learning approach, give students problems to explore their understanding and skills, discuss their solution problems." In line with her colleagues' perceived teaching capabilities, PST 5 also said, "I will focus on the learner and what they are learning,… give my learners problems which will challenge them, get the learners to generate their own understanding."

> PST 4 said, "I can communicate with my learners very well to understand their learning needs and improve their achievements."

PST 2 shared similar teaching capacity with PST 4, above, saying that "I speak to learners in a way that makes sense …". She added, "I can facilitate classroom discussions, guide learners in the process, ask the right questions about their thinking and actions, their solutions and strategies." Like her colleagues, PST 5 said that she could "… engage my students in learner on smaller scale to give me a more zoomed-in perspective about what is going on with my learners in such small-scale interactions and engagements". She also added "I can engage them with problems and allow them solve [the problems] themselves using their own understanding then engage them in discussions to organise their strategies in the order that progresses from the poorest to the best". Like her colleagues, PST 3 articulated her perceived teaching capabilities as: "I can discuss the similarities between the different strategies that the different children came up with,…, discuss systematically, start with the least sophisticated strategies used, and build upon that with the more sophisticated strategies used, and look at the similarities and differences between them"

The emphasis and the contexts of their perceptions and descriptions above seem to show that they had developed PCK in learning to teach which may be similar to those of effective Foundation Phase mathematics classroom teachers. Equally important, the PSTs seemed to have developed their PCK based on or oriented towards their understanding of the problem-centered teaching and learning approach. The interrelationship of the views about the perceived affordances of the development of their PCK for Foundation Phase mathematics suggests that they PSTs' shared the following perceived teaching capabilities, which could answer the research question of "What affordance(s) do the PSTs perceive from the improvement they perceive in the development of their PCK in Foundation Phase mathematics?" They perceived that they were able to:

- adapt mathematical instructions to cater for the diverse needs of the learners
- choose the problems which would suit their learners' abilities
- adapt strategies to improve meaningful understanding of the content they are learning
- create opportunities for learners to experience their own cognitive conflicts to develop to better understanding of the content they are learning
- engage learners in interactive studies or learning or discussions to enhance their thinking and understanding
- adopt the problem-centered approach in mathematical instruction in which learners express their own understanding of the problem
- engage in discussion with learners about their strategies to find solutions to improve their understanding
- assist learners to recognise connections between content and context for better understanding
- assist learners to develop logical understanding of the content, and explore similarities and differences in their reasoning and solutions
- assess students' learning needs and provide the necessary scaffolding experiences to take them from one level to another
- encourage questioning of learners' thinking about the content to assess their understanding of the 'what and how' of the contents

5.4.3.9. Comparison of improvement in PD in the two learning experiences

The interviewees responded to the question inquiring about the learning experiences in which they perceived greater improvement in all the aspects of their PD. Their responses showed that they perceived more marked improvement in the all the dimensions of their PD when they were learning to teach from the teaching expertise of the lecturer who facilitated the 3rd-year Foundation Phase mathematics module, than from their two-year training course. Evidence to support this claim is shown in the following excerpts from the interview sessions with the PSTs.

5.4.3.10. Improvement in beliefs about mathematics and the teaching and learning of it

In responding to the question inquiring about the course from which they perceived greater improvement in all the aspects of their PD, interviewees said the following:

PST 1 said, "My 3rd year... "

PST 2 said, "... in the first and second year I had a lot of self-doubt, I thought I couldn't teach math – I didn't like math, I didn't want to do math, I didn't see any point in learning math, but in [the] third year when I learnt about the problem-centred approach to teaching and learning and math, I felt my perceptions have better improved. I am slowly restoring my interest and confidence … I feel enthusiastic about math now, encourage my students to ask questions and develop interest in math, relate math to their lives…"

PST 3 said, "In the previous years we didn't have this lecturer in the modules we studied, we had different lecturers. Also this 3rd-year math module is more focused on grade-specific and it is getting down to the core problems and misconceptions that we had with math. It is definitely alarming to imagine the changes that I need and the knowledge gap that need to be filled in myself before I can become the effective teacher that I need to be to teach. So I will say it's this 3rd-year module that has the greatest impact on my beliefs."

PST 4 said, "… it's definitely my 3rd year, I really feel I am more confident and have gained more experiences compared to my 1st - & 2nd - year experiences".

PST 5 said, "… my learning experiences in the 3rd year has improved my beliefs, misconceptions, and attitudes better than the 1st and 2nd year."

5.4.3.11. Improvement in understanding of mathematics CK

Improvement in understanding of mathematics CK was reported as follows:

PST 2 said, "our school content knowledge grew in the 3rd year …"

PST 3 said, "the third year right now is better"

PST 4 said, "third year is better than first and second year: I don't think my first and second provided me with so much understanding of the CK [as] my 3rd year…"

PST 5 said, "third year's improvements in my understanding of the CK is better than the improvements in 1st and 2nd year"

5.4.3.12. Development of PCK for teaching Foundation Phase mathematics

The interviewees reported their development of PCK for teaching Foundation Phase mathematics as in the following direct quotations:

PST 1 said, "My views haven't changed much, just to say we've gained more pedagogical knowledge in this 3rd year."

PST 2 said, "... not only did our school CK grow but we also got the other aspect which was how to teach how to use the content in our classroom, in the first and second we had much of one of the knowledge, but we didn't have the other half, third year brought them together."

PST 3 said, "it is definitely the third year, more than the first and second year experiences, here we were also more narrow focused on the problem-centred approach to teaching and learning"

PST 4 said, "…third year is better than first and second year, my PCK in the third year has restored my confidence in T/L; understanding my content a bit better than last year, knowing and understanding what learners need to know or learn played a greater role in developing my PCK"

PST 5 said, "I think it's a lot better than the PCK i developed in my second year. I have learnt how to conduct my lesson to make it productive, to improve on my ability to integrate more content lessons in the problem-centered approach."

All the interviewees seemed to emphasise that they perceived that their PD in the third year, while they were learning to teach from the ETE, had improved over the changes they perceived in their PD in the first and second years of their training. They further emphasised that they perceived more and better improvement in their beliefs about mathematics and the teaching and learning of it; understanding of the mathematics CK; and developing PCK during their interaction with the teaching expertise of the lecturer for third-year Foundation Phase mathematics module.

5.4.3.13. Attributes of teaching expertise which greatly impacted on PSTs' PD

The interviewees' responses to the question that sought their views about the attribute(s) of the teaching expertise which they associated with the changes they perceived in the dimensions of their PD showed that most of them associated more than one attribute with the perceived changes/improvement. This is evidenced in the following quotations:

5.4.3.14. Transformation of beliefs about mathematics and teaching and learning of mathematics

PST 1 said, "I would say *enthusiasm in teaching* and *positive relationships with students and approachability*"

> PST 2 said, "*Positive relationships with students and approachability* was one of those that made big big impact; *enthusiasm in teaching* and *articulation of subject knowledge expertise* also impacted largely"

PST 2 supported views expressed above, saying that the lecturer's positive relationship with them "… really really helped me to change and improved my attitudes phenomenally …". This was confirmed in PST 3's observation that "our relationship with her is so positive that we don't hold back from asking". In further supporting her colleagues, PST 3 claimed that "[s]he tries to integrate us all into the class". In addition, PST 2's views further accord with PST 4's claims that ".. her knowledge is far greater and far higher … in the ideal world what she has and what she teaches us would be perfect ... but she is able to adapt it [to] suit our level … her enthusiasm makes me feel enthusiastic about math … ". In supporting her colleagues, PST 5 pointed out that "she's open, she allows you ask her extra questions on things you are struggling with, she doesn't get upset and she will accept you a hundred times if you approach her with your learning problems". While supporting her colleagues quoted above, PST 1 said, "She makes it interesting such that we want to learn ... you can see the passion that she has for it [math] and it makes you question why does she have that passion and to find out why, ... I want to find out more about I want to find out about how she got to where she is and how that passion was created ... and just to see lecturers who are so enthusiastic about their subjects … and the effects that it can have on future teachers"

> PST 3 said, "It is definitely her *articulation of subject knowledge expertise* and *preparation for and organisation of teaching."*

While buttressing her own views, PST3 said that "she's very organised in the way that she teaches us, it's well structured, lesson presentation is in order and one built in another". In addition, PST 2 confirmed PST 3's point with her claim that "[h] Her articulations is so well that it's completely pointless to look for further understanding elsewhere". Furthermore, PST 3's views were supported by PST 4's claims that "… she's well prepared and well organised for most times … she's always over prepared [rather] than under prepared". PST 2 agreed, saying that "… she's really really prepared, she provides enough learning materials, we may not need to

search for extra materials …" PST 5 confirmed these claims with her viewpoint that it "allowed me to fully grasp the content".

> PST 4 said, "I think it's her *motivating/stimulating students' interest and engagement with learning experiences."*

PST 4's observations that "she's practically engaging us in the learning experiences, and providing us with meaningful learning experiences" confirms her own views above. Furthermore, PST 2 agrees with PST 4 in her observations that:

> "… she speaks a lot about her own experiences which really help us visualise what we're going into which motivate us. So she would talk about a kid who struggled, but the way she describes it makes really feel for that little kid and that motivate us because we wanna work harder, we wanna keep pushing so we can provide the best we can for the kid… And she has this way of describing like you can change kids' situations and as we go out we can change the whole of the South African Education. I will be very much excited to learn more from her in my fourth year Foundation Phase mathematics module due to these motivations of hers."

> PST 5 said, "... her *enthusiasm in teaching* improved my beliefs about the subject matter of mathematics and the teaching and learning of it most."

In supporting her own viewpoint, PST 5 claimed that "it modelled the right teaching attitudes for us". PST 5's viewpoint (above) was confirmed by PST 2's observation that "you can see she really loves the mathematics and she takes pride in it … and that kind of rubs off on you to be enthusiastic". She further added that "… because she's enthusiastic about what she 's teaching us it makes us interested to learn more from her …it got us consumed by the lesson"". While supporting PST 5, PST 3 indicated that "She sort of makes you believe that it is possible to do math or learn math. She doesn't discourage or take you any further back". In addition, PST 2 agreed with her colleagues, saying that "it kind of rubs off in way that make you want know as much as you can …you wanna take pride in your work".

5.4.3.15. Improvement in understanding of the foundation phase mathematics CK

PST 1 said, "I think her *clarity in lesson presentation/teaching* and *preparation for and organisation of teaching* are the very big, I think clarity is very important."

She supported her claim by saying, "... she starts saying this is what you know and this is where I'm gonna take you, it is transparent you knew what is gonna happen, how it's gonna happen when it's gonna happen, we knew exactly what to expect in the lesson, .. we could immediately go into our little boxes in our brains and say that okay this is the box we're going to attach this to … which allows you to accept the information that she is giving us, to add to our already existing knowledge and just adapt it … "

PST 2 said, "I would say her *articulation of subject knowledge expertise*; *preparation for and organisation of teaching*; *clarity in lesson presentation/teaching*; *understanding of students' learning needs and creating productive learning climate* are the big ones for me."

PST 2 supported her own views (above), saying that "she understands it and comes down to your level, get the message well across to you …" . She also buttressed her viewpoints, saying that "if it's not clear it gets very very confusing, so luckily for us our lecturer is that way". Furthermore, PST 2's convictions (above) were confirmed in PST4's views that "she creates the productive learning climate in our lecture rooms ... she's able to meet us at the point of our needs in mathematics". While buttressing the above claims, PST 5 observed that "she creates huge learning experiences from using simple learning materials, e.g. a piece of newsprint or something like that …". She also added that "her clarity models different strategies and gives us practical examples about how to go about teaching similar content areas".

PST 3 said: "... her *articulation of subject knowledge expertise* I feel that is most importantly related to my understanding of the CK ..."

In supporting her own conviction above, PST 3 claimed that "this is very important to me, she is very knowledgeable, well informed …". While supporting a fellow student's view, PST 2 confirmed that "[it] was vital in improving our CK". PST 1 likewise confirmed her colleagues' views, saying "Her knowledge of her subject itself is amazing, … if you go to her and ask her

she will tell you the answer straight away and tell you but have thought that you could do it this way… the other day she brought musical instruments into our classroom and she taught us math using musical instruments … this is how she sees the whole thing, ... she doesn't keep it in the box … I promise you if you give her animal names she will be able to use it to teach you math with the animal names."

> PST 4 said, "I think her *Understanding of students' learning needs and creating productive learning climate."*

PST 4 added to own views, saying that the lecturer "creates the productive learning climate in our lecture rooms ... she's able to meet us at the point of our needs in mathematics". In addition, PST 2 confirms PST 4's view, saying that "… it's actually weird how fast she can pick up who's at what level, who's capable of what, who's under working there, who's struggling on what". Also, PST 5 agreed with her colleagues' views above with her claim that "she makes us excited to work on problems which develop my understanding of the problem".

> PST 5 said, "I think her *articulation of subject knowledge expertise*; *preparation for and organisation of teaching*; and *understanding of students' learning needs and creating productive learning climate."*

PST 3 buttressed her colleagues viewpoints with her observation that "she's always got a goal in mind and she keeps that in focus, you will not be seen around doing nothing, we [are] always productive …"., PST 2 Furthermore supported the above viewpoint by her observation that "she's very, very prepared for absolutely everything; I don't think anyone asked her a question that she has been able to answer".

5.4.3.16. Development of PCK for Foundation Phase mathematics

> PST 1 said, "I think her *clarity in lesson presentation/teaching* and *positive relationships with students and approachability* greatly enhanced my PCK."

> PST 2 said, "I would say *motivating/stimulating students' interest and engagement with learning experiences*; *clarity in lesson presentation/teaching; humour in teaching;* and *understanding of students' learning needs and creating a productive learning climate"*.

PST 2, in supporting the above viewpoints, claimed that "her lessons follow very structured thing and it flows … it follows this clear logical line … so it's really not hard to understand her lesson … ". She indicated further that "she is so clear that we don't have to guess or doubt what we have to know or do". PST 4, on other hand, only partially agrees with PST 2's views quoted above, saying that "… she's very humorous, but it doesn't appeal to all of us …". PST 5, on the contrary, was totally convinced that "her humour creates relaxed classroom environment where we can laugh things off … she uses it [to] disperse tension when mistakes happen during lectures, no one feels the mistake is a bad thing … ". PST 3 supported PST 5 with her observation that "it creates the general positive atmosphere for us to begin learning in, … it's a brilliant environment to be in. It's better than someone who's gloomy or uninterested, yeah!!"". While supporting the arguments, above PST 5 claimed that "her clarity in teaching modelled the correct way to employ [the] problem-centred approach in teaching young learners". In support of the views above, PST 5 confirmed that " [her motivation/stimulation] gave us the opportunities to figure out what our misconceptions were ".

> PST 3 said, "... my PCK was greatly influenced by her *articulation of subject knowledge expertise".*

On her part, PST 5 buttressed PST 3's viewpoint with her claim that "she presents across well to us and make our misconceptions pop up; she picks them up and makes us aware of it …". PST 5 added that "it allowed me to organise my thoughts well around what she was presenting to me".

> PST 4 said, "I think her *understanding of students' learning needs and creating productive learning climate* greatly enhanced my PCK."

PST 5 agreed with PST 4's viewpoint above with her point that "... she's able to create the right learning … she's able analyse what works, what doesn't work and tries to understand it on our level, …".

> PST 5 said, "I would say my lecturer's *preparation for and organisation of teaching*; and *understanding of students' learning needs and creating productive learning climate* improved my PCK the most."

In supporting PST 5's views, PST 3 said that "it's [her preparation and organisation] been a very good example of how it should [be] done especially in the Foundation Phase, because with the children being so busy and they need to be kept busy you need to be organised and prepared for the unexpected, so … yeah she's been a very good example of that." In agreement with her colleague above, PST 4 claimed that "… in fact she has a lot on the plate all the time because she's always involved , … sometimes I think if she brings all her stuff in her lecturing with us it will even be a great experience". She further added that "the lecturer created a productive climate in the classroom, and she's well prepared and organised for the lessons, it brought out her enthusiasm about the lesson [and] motivated me". Also, PST 2 supported the views of her friends above with her point that "she came really really down to our level, we learnt more about what the learner might struggle with".

Drawing from the interaction between the views of the PSTs quoted above, it seemed that they perceived the ETE's *understanding of students' learning needs and creating productive learning climate* and her *articulation of subject knowledge expertise* as the teaching expertise with the most impact on their PD. These attributes of the ETE's teaching expertise were the most frequently mentioned in interactions above. The two attributes identified here as the teaching expertise with the most impact could answer the research question regarding "Which of the dimensions of the teaching expertise they experienced influenced the PSTs' PD most or least?" The attributes with the least impact were *Positive relationships with students and approachability* and *humour in teaching.* These were the least mentioned attributes relating to the PSTs' PD.

5.4.3.17. Dimension of the PSTs' PD most impact upon during their interactions with the teaching expertise of the 3rd year Foundation Phase mathematics lecturer:

The interviewees were asked about the dimension of their PD that they thought had been greatly enhanced by the attributes of the teaching expertise with which they had interacted, in other words, their views about the aspect of their PD which experienced the strongest impact from the teaching expertise encountered in the third-year Foundation Phase mathematics module. Their responses showed that they perceived the greatest impact to be on their beliefs about the subject matter of mathematics and the teaching and learning of it and PCK, rather than CK. The excerpts below confirm their claims:

PST 1 said, “I think my CK … is where the biggest change came, I think you can’t take each of them in isolation, I think they’re all connected.”

PST 4 said, I think it influenced my beliefs about the subject matter of mathematics and the teaching and learning of it the most, then my PCK … because I think if you were able to change someone’s beliefs from the inside, the PCK and the CK could be changed automatically.”

PST 2 said, “I feel the biggest change in my beliefs.”

PST 5 said, “I think CK can be learnt from textbooks, but the beliefs about the subject matter of mathematics and the teaching and learning of it and PCK cannot be learnt better from the textbook; I need someone [an expert teacher] [to] talk about them, discuss them with me and to ignite that passion for change, adaption, or adaption in me, i need her [expert teacher educator] model the desired beliefs, attitudes, conceptions, teaching behaviour, teaching knowledge for me, I learnt more from her modelling of these to improve my beliefs about the subject matter of mathematics and the teaching and learning of it and PCK.”

PST 3 said, “I think firstly PCK, then beliefs about the subject matter of mathematics and the teaching and learning of it…”

The context and emphasis on their perceived improvements in the dimensions of their PD could not be doubted because their reasons for their passionate claims were well articulated to reflect what could be happening in the real situations of learning to teach where PSTs are actively learning from an ETE. It could, therefore, be accepted that the perceived improvement in their beliefs about the subject matter of mathematics and the teaching and learning of it and PCK answer the research question about which of the three dimensions of their PD (i.e. beliefs, CK and PCK) had been most or least influenced by the attributes of the teaching expertise of the expert teacher educator.

5.4.4. Summary of findings (Phase B)

From the preceding presentation of the PSTs' responses to the interview questions, the following conclusions could be drawn with reference to the research questions introduced above and repeated here:

- What change(s)/improvement do the PSTs' perceive in their beliefs about mathematics and teaching and learning of mathematics?

  The PSTs perceived improvement in:

  - Understanding that learners need be allowed to work at their own pace and level of thinking;
  - Their own consistency in thinking, self-confidence in teaching;
  - Understanding the connections between mathematical ideas;
  - Understanding that learners need to relate learning of content to their own everyday experiences;
  - Understanding that learners own different solution methods and thinking need to be encouraged;
  - Understanding that they need to encourage learners to think and question what they are learning or experiencing to enhance their understanding;
  - Understanding that they need to encourage learners to actively participate in showing their skills and thoughts in the content they are learning;
  - Understanding that they need to understand learners' thinking in order to assist them to improve their thinking and learning;
  - Learning to pose relevant but challenging problems to improve learners' understanding and thinking;
  - Learning to engage learners in discussion of their own ideas;
  - Learning to give learners maximum opportunity to figure out their own strategies for learning or problem solving;
  - Developing interest in/willingness to explore new ways of teaching and learning;
  - Learning that they need to create ways of making mathematics interesting/fun and challenging for learners;

- Learning that they need to adapt teaching to learners' levels of thinking and understanding;
- Understanding how to assess learners' needs and abilities to improve their thinking and understanding;
- developing an interest in mathematics and focusing on the main or basic content and problem.

❖ What affordance(s) do the PSTs perceive from the improvement they perceive in their beliefs about mathematics and teaching and learning of mathematics?

The PSTs perceived that they were able to:

- engage learners in learning the mathematics content from practical problems;
- use manipulatives to enhance teaching and learning;
- assist learners to make connections between concepts and procedures;
- create opportunities for learners to express their understanding.

❖ What change(s)/improvement do the PSTs' perceive in their understanding of CK and development of their PCK in Foundation Phase mathematics?

The PSTs perceived that they understood …

- how contents blend with practical problems or experiences;
- how concepts link with procedures to the content from different examples and situations or the multiple embodiments of concepts and procedures;
- the connections between concepts or ideas;
- that they need to cater for the diverse needs of learners thinking and understanding to facilitate effective teaching and learning of mathematics;
- the need to create opportunities for learners to construct their own understanding of the content they are learning.

- What affordance(s) do the PSTs perceive from the improvement they perceive in their understanding of CK and development of their PCK in Foundation Phase mathematics?

  The PSTs perceived that they were able to:

  - adapt lessons to meet the needs and levels of their students' thinking and understanding;
  - facilitate mathematical lessons to follow structurally to help learners to recognise connections between their ideas or understanding easily;
  - use learners' understanding and thinking to create effective mathematical instruction and correct their misconceptions;
  - engage learners with learning problems that can generate better understanding of the content;
  - adapt mathematical instructions to cater for the diverse needs of the learners;
  - choose the problems that will suit their learners' abilities;
  - adopt strategies that can improve meaningful understanding of the content they are learning;
  - create opportunities for learners to experience their own cognitive conflicts to develop better understanding of the content they are learning;
  - engage learners in interactive studies or learning, or discussions to enhance their thinking and understanding;
  - adopt the problem-centred approach in mathematical instruction by which learners express their own understanding of the problem;
  - engage in discussion with learners' solution strategies with learners to improve their understanding;
  - assist learners to recognise connections between content and context for better understanding;
  - assist learners to develop logical understanding of the content, and explore the similarities and differences in their reasoning and solutions;
  - assess students' learning needs and provide them with the necessary scaffolding experiences to take them from one level to another;

- encourage questioning learners' thinking about the content to assess their understanding of the 'what and how' of contents.

❖ Which of the dimensions of the teaching expertise experienced influenced the PSTs' PD most or least?

- *enthusiasm in teaching; motivating/stimulating students' interest and engagement with learning experiences; articulation of subject knowledge expertise; positive relationships with students and approachability* and *preparation for an organisation of teaching* had the most powerful influence or impact on transforming or improving the PSTs' *beliefs, perceptions misconceptions, and attitudes towards the subject matter of mathematics and the teaching and learning of it*.
- *articulation of subject knowledge expertise*; *preparation for an organisation of teaching*; *clarity in lesson presentation/teaching*; *understanding of students' learning needs and creating a productive learning climate* had the most powerful influence or impact on the PSTs' *understanding of the Foundation Phase mathematics CK.*
- *motivating/stimulating students' interest and engagement with learning experiences*; *clarity in lesson presentation/teaching; humour in teaching; articulation of subject knowledge expertise;* and *understanding of students' learning needs and creating a productive learning climate* had powerfully influenced or impacted the *development of* PSTs' *PCK for Foundation Phase mathematics.*
- *Positive relationships with students and approachability* and *humour in teaching* had the least powerful impact on all the components of PD mentioned above.

❖ Which of the three dimensions of their PD (i.e. beliefs, CK and PCK) was most or least influenced by the attributes of the teaching expertise of the expert teacher educator?

The PSTs perceived that their *beliefs about the subject matter of mathematics and the teaching and learning of it* and *the development of their PCK Foundation Phase mathematics* were most improved.

- Which of the two experiences impacted most/least on the dimensions of their PD?

  The PSTs perceived more and better improvement in their beliefs about mathematics and the teaching and learning of it, understanding of the mathematics CK, and developing PCK during their interaction with the teaching expertise of the *3rd-year Foundation Phase mathematics lecturer* and *3rd-year Foundation Phase mathematics lecturer,* than in the *first and second years of their training.*

5.4.5. Quantitative and Qualitative findings merged (Phase B)

In the tables that follow, the survey and interview findings about the PST's perceptions about their PD (perceived improvements) and their potential successes (perceived affordances of the improvement) in their future classrooms are compared in accordance with the themes and the research questions that guided this study.

Table 5.38: Merged findings about the PSTs' perceived transformation in their beliefs (Phase B)

Research question	**Findings from survey results**	**Findings from interview results**	**Similarities/differences in findings – confirmations, supplementary insight, additional information, detailed interpretations**
What transformations do the PSTs' perceive in their beliefs about mathematics and teaching and learning of mathematics?	It was found that the PSTs perceived remarkable improvement in ... *overcoming their feelings of incompetency to engage young learners in solving mathematical problems* *reflecting and correcting their misconceptions about the subject matter of mathematics and how to teach mathematics to young children* *being critical about their learners' needs and characteristics* *their interests in focusing on the mathematics content in teaching and learning of mathematics*	The interviewees perceived the following improvement in their beliefs about mathematics and the teaching and learning of it: Understanding that learners need be allowed to work at their own pace and level of thinking Improvement in their own consistency in thinking, self-confidence in teaching. Understanding that mathematical ideas are connected Understanding that learners need to relate learning of content to their everyday experiences Understanding that learners own different solution methods and thinking needs to be encouraged Understanding that they need to encourage learners to think and question what they are learning or experiencing to enhance their understanding Understanding that they need to encourage learners to actively participate in showing their skills and thoughts in the content they are learning. Understanding that they need to understand learners' thinking in order to assist them to improve on their thinking and learning. They have learnt to pose relevant but challenging problems to improve learners' understanding and thinking. They have learnt that they need to engage	The interviewees' claims that they perceived improvements in their understanding that learners need be allowed to work at their own pace and level of thinking, confirmed the survey findings that the PSTs perceived improvement in *being critical about their learners' needs and characteristics*, as well as *reflecting on and correcting their misconceptions about the subject matter of mathematics and how to teach young children mathematics.* The interviewees' confidence in having perceived improvement in their own consistency in thinking and self-confidence in teaching supported the survey findings that the PSTs perceived improvement in *overcoming their feelings of incompetency to engage young learners in solving mathematical problems.* The interviewees' certainty that they perceived improvement in their understanding that they need to encourage learners to think and question what they are learning or experiencing to enhance their understanding complement the survey findings that the PSTs perceived improvement in their *being critical about their learners' needs and characteristics*, as well as *focusing on the mathematics content in teaching and learning of mathematics.*

		learners in discussions about their own ideas. They have learnt to give learners maximum opportunities to figure out their own strategies in learning or solving problems. They have developed interest in exploring new ways of teaching and learning. They have learnt that they need to create ways of making mathematics interesting/fun and challenging for learners. They have learnt that they need to adapt teaching to learners' levels of thinking and understanding. They understand how to assess learners needs and abilities to improve their thinking and understanding. They have developed interest in mathematics and focus on the basic content and problem.	The interviewees' conviction that they perceived improvement in their understanding of the need to understand learners' thinking, pose relevant but challenging problems, create ways of making mathematics interesting and challenging for learners, and adapting teaching to learners' levels of thinking confirm the survey findings that the PSTs perceived improvement in *being critical about their learners' needs and characteristics*, as well as *focusing on the mathematics content in teaching and learning of mathematics.* The interviewees' claims that they perceived improvements in their understanding of the need to engage learners in discussions, give learners maximum opportunities, and encourage learners to actively participate in showing their skills and thinking confirm the survey findings that the PSTs perceived improvement in *focusing on the mathematics content in teaching and learning of mathematics*, as well as *reflecting and correcting their misconceptions about the subject matter of mathematics and how to teach young children mathematics.* The interviewees' confidence that they perceived improvement in their understanding that mathematical ideas are connected could confirm the survey findings that the PSTs perceived improvement in their *interest in focusing on the mathematics content in teaching and learning of mathematics*, as well as *reflecting and correcting their misconceptions about the*

			subject matter of mathematics and how to teach young children mathematics. The interviewees' confidence that they perceived improvement in their understanding that learners need to relate learning of content to their everyday experiences could complement the survey findings that the PSTs perceived improvement in their *being critical about their learners' needs and characteristics*, as well as *reflecting and correcting their misconceptions about the subject matter of mathematics and how to teach young children mathematics.* The interviewees' claims that they perceived improvement in their understanding that learners own different solution methods and thinking needs to be encouraged support the survey findings that the PSTs perceived improvement in *overcoming their feelings of incompetency to engage young learners in solving mathematical problems*, as well as *reflecting and correcting misconceptions about the subject matter of mathematics and how to teach young children mathematics.*

Table 5.39: Merged findings about the PSTs' perceived affordances of the improvement in their beliefs (Phase B)

Research question	Findings from survey results	Findings from interview results	Similarities in findings – confirmations, supplementary insight, additional information, detailed interpretations
What affordances do the PSTs perceive from the improvement perceived in their beliefs about mathematics and teaching and learning of mathematics?	The findings reveal that the PSTs perceived they were able to … *use manipulatives to overcome learners' anxieties.* *take instructional decisions to suit learners' interest/needs* *create ample opportunities for active learner participation* *promote learning mathematics for meaningful understanding* *overcome learners' anxieties and improve learners' competence in learning* *adapt to learner-centred instruction approach*	The interviewees perceived they were able to: engage learners in learning the mathematics content through practical problems use manipulatives to enhance teaching and learning assist learners to make connections between concepts and procedures create opportunities for learners to express their understanding .	The interviewees' confidence in their ability to engage learners in learning the mathematics content from practical problems could confirm the survey findings that the PSTs believed they could *promote learning mathematics for meaningful understanding* as well as *use manipulatives to overcome learners' anxieties*. The interviewees' conviction that they were able to use manipulatives to enhance teaching and learning could support the survey's findings that the PSTs believed that they can *use manipulatives to overcome learners' anxieties, adopt the learner-centred approach* as well as *promote learning mathematics for meaningful understanding* The interviewees' perceptions that they were able to assist learners to make connections between concepts and procedures could complement the survey's findings that the PSTs believed that they can *create ample opportunities for active learner participation, take instructional decisions to suit learners' interest/needs*, as well as *promote learning mathematics for meaningful understanding.* The interviewees' certainty that they were able to create opportunities for learners to express their understanding is consistent with the survey findings that the PSTs believed that they can *adopt a learner-centred approach, overcome learners' anxieties and improve learners' competence in learning, create ample opportunities for active learner participation, use manipulatives to overcome learners' anxieties, take instructional decisions to suit learners' interest/needs*, as well as *overcome learners' anxieties and improve learners' competence in learning.*

Table 5.40: Merged findings of the PSTs' perceived improvement in their CK and PCK (Phase B)

Research question	**Findings from survey results**	**Findings from interview results**	**Similarities/differences in findings – confirmation, supplementary insight, additional information, detailed interpretations**
What improvements do the PSTs' perceive in their understanding of mathematics CK and development of their PCK for Foundation Phase mathematics?	The findings show that the PSTs perceived appreciable improvement in their understanding of ... *mathematical concepts and procedures – how to explain procedures, how to explain similarities and differences among different representations, solutions, or methods* *how learners learn number operations and relationship.* *solving problems using different strategies – how to explain solution methods in solving problem; how to assist learners to solve problems requiring multiple ideas and strategies* *how to make connections between ideas and strategies in solving problems – how to help learners to link their mathematical ideas in solving problems* *- how to access learners' thinking about concepts, procedures; how to assess learners' understanding of mathematical ideas and procedures*	The interviewees perceived improvement in their understanding of … how content blends with practical problems or experiences how concepts link with procedures the content from different examples and situations (i.e. the multiple embodiments of concepts and procedures) the connections between concepts or ideas the need to cater for the diverse needs of learners' thinking and understanding to facilitate effective teaching and learning of mathematics the need to create opportunities for learners to construct their own understanding of the content they are learning	The interviewees' claims that they perceived improvement in their understanding of how contents blend with practical problems or experiences, confirmed the survey findings that the PSTs perceived improvement in their *understanding of how to make connections between ideas and strategies in solving problems*, as well as in *how to help learners to link their mathematical ideas in problem solving.* The interviewees' conviction that they perceived improvement in their understanding of the need to cater for the diverse needs of learners in thinking and understanding to facilitate effective teaching and learning of mathematics could complement the survey findings that the PSTs perceived improvement in their *understanding of how learners learn number operations and relationships*, as well as in, *how to assess learners' understanding of mathematical ideas and procedures; how to access learners' thinking about concepts and procedures.* The interviewees' confidence that they perceived improvement in understanding the need to create opportunities for learners to construct their own understanding of the content they are learning, could be consistent with the survey findings that the PSTs perceived improvement in their *understanding of how to make connections between ideas and strategies*

			in solving problems; how to help learners to link their mathematical ideas in solving problems; how to assess learners' understanding of mathematical ideas and procedures; and *how to access learners' thinking about concepts, procedures.* The interviewees' certainty that they perceived improvement in their understanding of the content from different examples and situations could support the survey findings that the PSTs perceived improvement in their *understanding of mathematical concepts and procedures; how to make connections between ideas and strategies in solving problems; how to help learners to connect their mathematical ideas in problem solving; how to explain procedures;* and *how to explain similarities and differences among different representations, solutions, or methods.* The interviewees' conviction that they perceived improvement in their understanding of how concepts link with procedures could confirm the survey findings that the PSTs perceived improvement in their *understanding of solving problems using different strategies*; *how to explain solution methods in problem solving; how to assist learners to solve problems requiring multiple ideas and strategies; how to make connections between ideas and strategies in solving problems; how to help learners to connect their mathematical ideas in problem solving;* as well as *how to explain similarities and differences among different representations, solutions, or methods.*

Table 5.41: Merged findings of the PSTs' perceived affordances of the improvement in their CK and PCK (Phase B)

Research question	**Findings from survey results**	**Findings from interview results**	**Similarities/differences in findings – confirmation, supplementary insight, additional information, detailed interpretations**
What affordances do the PSTs perceive from the improvement in their understanding of the mathematics CK and development of their PCK for Foundation Phase mathematics?	The findings reveal that the PSTs perceived that with the improvement in their understanding of the mathematics CK and development of PCK for Foundation Phase mathematics, they were able to ... *select appropriate teaching and learning activities and resources* and *critically reflect on the effectiveness of their teaching methodology* *facilitate learners thinking and meaningful understanding of contents– assist learners to solve problems requiring multiple ideas and strategies* *explain concepts and procedures to enhance learners' understanding – explain the similarities and differences among children's representations, solutions; assist learners in finding answers using different strategies; explain why mathematical procedures work the way they do; explain solution methods or strategies to learners* *implement a problem-centred teaching and learning approach: provide a problem-solving learning context; assist learners to solve problems using ideas and strategies*	The PSTs perceived that they were able to ... adapt lessons to meet the needs and levels of learners' thinking and understanding facilitate mathematics lessons to follow structurally to help learners and easily make connections between their ideas or understanding use learners' understanding and thinking to create effective mathematical instruction and correct their misconceptions engage learners in learning problems that can generate better understanding of the content choose the problems which will suit their learners' abilities. adopt strategies which can improve meaningful understanding of the content they are learning. create opportunities for learners to experience their own cognitive conflicts to develop better	The interviewees' conviction that they were able to adapt lessons to meet the needs and levels of learners' thinking and understanding complemented the survey findings that the PSTs believe they can *select appropriate teaching and learning activities and resources, as well as critically reflect on the effectiveness of their teaching methodology*. In the same way, the interviewees' belief that they were able to adapt lessons to meet the needs and levels of learners' thinking and understanding could support the survey findings that the PSTs believe they can *facilitate learners thinking and meaningful understanding of contents,* as well as *assist learners to solve problems requiring multiple ideas and strategies.* In addition, the same claims above by the interviewees could confirm the survey findings that the PSTs believed they can *explain concepts and procedures to enhance learners understanding; explain the similarities and differences among children's representations and solutions; assist learners in finding answers using different strategies;* as well as *explain why mathematical procedures work the way they do.* The survey findings that the PSTs believe they were able to *implement a problem-*

	known or unknown to them	understanding of the content they are learning engage learners in interactive studies or discussions to enhance their thinking and understanding adopt the problem-centred approach in mathematical instruction whereby learners express their own understanding of the problem engage in discussion of learners' solution strategies with learners to improve their understanding assist learners to recognise connections between content and context for better understanding assist learners to develop logical understanding of the content and explore the similarities and differences in their reasoning and solutions assess students' learning needs and provide the necessary scaffolding experiences to take them from one level to another encourage questioning learners' thinking about the content to assess their understanding of the 'what and how' of the content	*centred teaching and learning approach; provide a problem-solving learning context; assist learners to solve problems using ideas and strategies known or unknown to them* could be confirmed by the interviewees' beliefs they can choose the problems which will suite their learners' abilities; adapt strategies which can improve meaningful understanding of the content they are learning; create opportunities for learners to experience their own cognitive conflicts to develop to better understanding of the content they are learning; engage learners in interactive studies to enhance their thinking and understanding; as well as adapt the problem-centred approach in mathematical instruction where learners express their own understanding of the problem The survey findings that the PSTs believe they can *facilitating learners thinking and meaningful understanding of contents, assist learners in solving problems requiring multiple ideas and strategies* could be could be explained by the interviewees' claims that they can engage in discussions of learners' solution strategies with learners to improve their understanding; assist learners to recognise connections between content and context for better understanding; assist learners to develop logical understanding of the content; explore the similarities and differences in their reasoning and solutions; assess students' learning needs and provide them with the necessary scaffolding experiences to take them from one level to another, as well as encourage questioning learners' thinking about the content to assess their understanding of the 'what and how' of the contents.

			Both survey findings that the PSTs believe they were able to *select appropriate teaching and learning activities and resources; critically reflect on the effectiveness of teaching methodology* and *facilitate learners thinking and meaningful understanding of contents; assist learners to solve problems requiring multiple ideas and strategies* are supported by the interviewees' convictions that they can facilitate mathematical lessons to follow structurally to help learners to find connections between their ideas or understanding with ease. The interviewees' claims that they were able to use learners' understanding and thinking to create effective mathematical instruction and correct their misconceptions confirmed the survey findings that the PSTs believe they can *facilitate learners' thinking and meaningful understanding of contents; assist learners to solve problems requiring multiple ideas and strategies* as well as *implementing problem-centred instructional approach*. The findings from the interviews that the PSTs believe they can engage learners in learning problems that can generate better understanding of the content and adapt mathematical instructions to cater for the diverse needs of the learners support the survey's findings that the PSTs' believed they can *select appropriate teaching and learning activities and resources; critically reflect on the effectiveness of teaching methodology* as well as *implement a problem-centred instructional approach*.

Table 5.42: Merged findings of the most or least enhanced dimension(s) of PD (Phase B)

Research question	**Findings from survey results**	**Findings from interview results**	**Similarities/differences in findings – confirmation, supplementary insight, additional information, detailed interpretations**
Which of the three dimensions of the PSTs' PD (i.e. beliefs, CK, PCK) is/are most or least enhanced?	It was found that the PSTs perceived most improvement in their *beliefs about subject matter of mathematics and teaching and learning of mathematics.* It was also found that the PSTs perceived remarkable improvement in their: *a.* *developing PCK for Foundation Phase mathematics* and their affordances b. teaching capabilities, from their *understanding of the mathematics CK for Foundation Phase*	Drawing from the interactions between the views of the PSTs, it seemed that they perceived the most improvement in their *beliefs about subject matter of mathematics and teaching and learning of mathematics* and *development of their PCK* for Foundation Phase mathematics.	The interviewees' claim that their *beliefs about subject matter of mathematics and teaching and learning of mathematics* were most impacted upon by the ETE's teaching expertise confirmed similar findings in the survey. Similarly, the survey findings that the PSTs perceived significant improvement in their *developing PCK for Foundation Phase mathematics*, teaching capabilities from their *understanding of the mathematics CK for Foundation Phase mathematics*, confirmed similar claims by the interviewees.

Table 5.43: Merged findings about the attribute(s) of teaching expertise that most or least impacted their PD (Phase B)

Research question	**Findings from survey results**	**Findings from interview results**	**Similarities/differences in findings – confirmation, supplementary insight, additional information, detailed interpretations**
Which of the attribute(s) of the teaching expertise impacted most or least the PSTs' PD?	All the attributes of the ETE's teaching expertise were perceived to have improved the PSTs' PD in general, however, it was found that the ETE's *preparation for and organisations of teaching; articulation of subject knowledge expertise in teaching; and enthusiasm in teaching* had the greatest impact in transforming the PSTs' *beliefs, perceptions misconceptions, and attitudes towards the subject matter of mathematics and the teaching and learning of it*. *articulation of subject knowledge expertise in teaching; enthusiasm in teaching; motivating/stimulating students' interest and engagement with learning experiences; preparation for and organisations of teaching;* and *clarity in lesson presentations/teaching* had the greatest impacts on the PSTs' *understanding of the Foundation Phase mathematics CK* all the attributes of teaching expertise have greatly impacted on the *development of* PSTs' *PCK for Foundation Phase mathematics*, except *humour in teaching*. *Humour in teaching* was perceived to have the least impact on all three components of the PSTs' PD.	Drawing from the interactions between the views of the PSTs it seemed that they perceived the ETE's: *enthusiasm in teaching; motivating/stimulating students' interest and engagement with learning experiences; articulation of subject knowledge expertise; positive relationships with students and approachability* and *preparation for and organisations of teaching* had the greatest impact in transforming the PSTs' *beliefs, perceptions misconceptions, and attitudes towards the subject matter of mathematics and the teaching and learning of it*. *articulation of subject knowledge expertise*; *preparation for and organisation of teaching*; *clarity in lesson presentation/teaching*; *understanding of students' learning needs and creating a productive learning climate* had the greatest impact on the PSTs' *understanding of the Foundation Phase mathematics CK* *motivating/stimulating students' interest and engagement with learning experiences*; *clarity in lesson*	The interviewees' perception that the ETE's *enthusiasm in teaching; articulation of subject knowledge expertise; and preparation for and organisation of teaching* had the greatest impact in transforming their beliefs, *perceptions misconceptions, and attitudes towards the subject matter of mathematics and the teaching and learning of it* were confirmed by the survey findings that the above attributes had a similar impact on their beliefs/perception. Both the interviews and the survey findings confirmed that the PSTs perceived that the ETE's *articulation of subject knowledge expertise; preparation for and organisation of teaching*; and *clarity in lesson presentation/teaching* had the greatest influence or impact on their *understanding of the Foundation Phase mathematics CK* The survey findings that the PSTs perceived that all the ETE's attributes of teaching expertise **except** *humour in teaching* had greatly impacted the *development of* their *PCK for Foundation Phase mathematics* confirmed the similar emphasis by the interviewees

		presentation/ teaching; humour in teaching; articulation of subject knowledge expertise; and *understanding of students' learning needs and creating a productive learning climate* had greatly impacted the *development of* PSTs' *PCK in Foundation Phase mathematics* *Positive relationships with students and approachability* and *humour in teaching* had the least impacts on all the components of PD above. Overall, drawing from the interactions between the views of the PSTs above, it seemed that they perceived the ETE's her *articulation of subject knowledge expertise* and *preparation for and organisations of teaching* to be the most impacting teaching expertise on their PD. These attributes of the ETE's teaching expertise appeared to be the most frequently mentioned in interactions of the views.	However, the impact of *humour in teaching* was not left out of the some of the interviewees' statements. The rare or least mentioned impacts of *positive relationships with students and approachability* and *humour in teaching* in both findings could confirm that those aspects had the least impact on the components of PD. Similarly, the frequent mention of *preparation for and organisation of teaching* and *articulation of subject knowledge expertise in teaching* in both findings could confirm that those three had the most powerful impact on all the components of PD above.

Table 5.44: Merged findings to ascertain which learning phase had more/less impact (Phase A/B)

Research question	**Findings from survey results**	**Findings from interview results**	**Similarities/differences in findings – confirmation, supplementary insight, additional information, detailed interpretations**
Which of the two learning experiences (i.e. the two years or the third year) impacted more/less on the dimensions of the PSTs' PD?	The PSTs perceived that both learning experiences equally improved all the indicators they perceived in their: *beliefs/perception of subject matter of mathematics and teaching and learning of mathematics,* ***excepting*** improvement in *overcoming their feelings of incompetence to engage in teaching and learning mathematical problem-solving activities*. affordances of the perceived *beliefs/perceptions about the subject matter of mathematics and teaching and learning of mathematics* *understanding of the mathematics CK* they will be teaching Contrary to the above, the PSTs perceived that their interaction with the ETE's teaching expertise significantly improved all the indicators they perceived in their: *developing PCK for Foundation Phase mathematics* teaching capabilities from their *understanding of the mathematics CK for Foundation Phase mathematics* teaching capabilities from their *developing CK for Foundation Phase mathematics*	All the interviewees seemed to emphasise that their PD in the third year improved over their PD in the first and second years of their training. They seemed to specifically perceive remarkable improvement in their beliefs about mathematics and the teaching and learning of it; understanding of the mathematics CK and developing PCK during their interaction with the teaching expertise of the lecturer in the third year Foundation Phase mathematics module.	The interviewees' claims of better improvement in their PD in phase B over Phase A could be associated with the survey findings that Phase B led to significant improvement in all the indicators perceived in their developing PCK and the affordances of both their CK and PCK.. Appreciation in the transformation of the PSTs' beliefs in Phase B over Phase A, claimed by the interviewees confirmed the survey findings that the PSTs perceived significant improvement in *overcoming their feelings of incompetence to engage in teaching and learning mathematical problem-solving activities* The interviewees' conviction that their understanding of the mathematics CK and developing PCK were more and better enhanced in Phase B than in Phase A confirmed survey findings that the PSTs perceived significant improvement in all the indicators they perceived in their developing PCK and the affordances of both their CK and PCK.

5.5. SIMILARITIES AND DIFFERENCES IN THE PSTS' PERCEIVED LEARNING ACHIEVEMENTS (PD) IN PHASE A AND PHASE B

Specific learning achievements which differentiated between the perceived impacts of the two phases of learning are presented in Table **5.44,** above. However, the researcher observed other equally important indicators of improvement in the PSTs' PD. These were equally strongly improved according to the findings from both Phase A and Phase B**.** Table **5.45** presents such findings.

Table 5.45: Learning achievements in Phase A compared with Phase B

Learning outcomes or achievements equally remarkably improved in both Phase A and Phase B		**Learning outcomes or achievements significantly improved in Phase A**		**Learning outcomes or achievements significantly improved in Phase B**	
PSTs' perceived improvement in their *understanding of foundation mathematical concepts and procedures*	PSTs' perceived improvement in their *understanding of how learners learn number operations and relationships* PSTs' perceived improvement in their *understanding of how to explain why procedures work they way they do.*			The PSTs perceived improvement in *overcoming their feelings of incompetence to engage in teaching and learning mathematical problem-solving activities.*	The PSTs believed they were able to *select appropriate teaching and learning activities and resources.*
PSTs perceived improvement in their *reflection on learning and actions* (i.e. misconceptions about mathematics, teaching young children, and how they learn).	PSTs' perceived that they were able to *promote learning mathematics for meaningful understanding* PSTs' perceived improvement in their *understanding of how to solve problems using different strategies*				
Improvement in *being critical about learners' needs and characteristics in mathematical instructions*	PSTs' perceived they were able to *adopt a learner-centred approach in teaching and learning*.			The PSTs perceived improvement in their *understanding of how to assist learners to make connections between ideas and strategies in solving problems.*	The PSTs believed they were able to *explain concepts and procedures to enhance learners' understanding.*
Improvement in *willingness or interest in focusing on the content of the mathematics in*	PSTs' perceived they were able to *assist learners to overcome their anxieties and incompetence in learning*.			The PSTs perceived improvement in their *understanding of how to access and assess learners' thinking and understanding.*	The PSTs believed they were able to *implement problem-centred teaching and learning approach.*

mathematical instructions.					
PSTs' perceived they were able to *create ample opportunities for active learner participation.*	PSTs' perceived they were able to *focus instructional decisions on the learners' needs and interests.*				The PSTs believed they were able to *facilitate learners thinking and meaningful understanding of contents.*

5.6. DISCUSSION OF THE MERGED FINDINGS

The side-by-side comparison of the quantitative and qualitative findings showed that the qualitative findings confirmed the quantitative findings. Furthermore, the qualitative findings provided further insight concerning the PSTs' interpretation of their PD during the two-year training as Foundation Phase mathematics teachers. The merged findings are presented under the research questions guiding this study, as follows: In this section, the integrated findings are discussed in relation to some empirically proven frameworks of the various indicators of the adequacy of PSTs' mathematical preparation emphasised in the relevant literature on mathematics teacher education and research. These discussions will be based on the research questions guiding this investigation.

- What/which change(s)/improvement do the PSTs' perceive in their beliefs about mathematics and teaching and learning of mathematics?

The merged findings revealed that the PSTs perceived that their interaction with the ETE's teaching expertise significantly improved or transformed their beliefs to adopt/adapt to following:

1. focusing and reflecting on the mathematics content to gain insight into or understanding of how to make content connections between mathematical ideas or how those ideas are intellectually connected

This could be an indication of improvement in their interest and attitude to encourage learning and appreciation of mathematics and to focus more on learning the content of mathematics. This claim by the PSTs seems to be in line with Ball (1988: 16), Borko *et al.* (1992: 195) and Wedege's (1999: 206-207) emphasis on the acknowledgement that the adequacy of PSTs' PD requires that PSTs should realise that mathematical concepts and procedures are not discrete or compartmentalised, but are related. Thus, PSTs developing the belief that "mathematics is a web of interrelated concepts and procedures". According to

Borko *et al*. (1992: 195), the adequacy of PSTs' PD could be determined when they develop desired knowledge about the "… nature and discourse of mathematics and to understand what it means to know and do mathematics". While supporting these arguments, Ambrose (2004: 92) emphasised that the adequacy of PSTs' PD could be determined when they maximise their potential in advancing their subject matter content. In addition, Ma and Singer-Gabella (2011: 8) confirmed that such perceived improvement is apparent in the PSTs' willingness to design and engaging in learning experiences that stimulate learners' reasoning about quantities; empower learners to create their own strategies; and engage in discourse about learners' thinking and/or solutions to problems. In line with views expressed above, it could be concluded that the PSTs' achievements reported here show that they have fairly adequately improved their PD.

2. *reflecting on and correcting own misconceptions about the subject matter of mathematics and teaching young children mathematics to improve teaching effectiveness* (Ambrose, 2004: 92; Ma & Singer-Gabella, 2011: 8)

Kagan (1992: 156) has emphasised that PSTs should become conscious of their own counter-productive beliefs, misconceptions, or pre-conceived knowledge about mathematics, teachers, learners, and teaching to adequately develop or enhance their PD, and make conscious efforts to correct them through reflection. In addition, Da Ponte and Chapman's (2008: 238) view that PSTs should engage in reflection, which will help them to relearn and correct their wrong perceptions about the nature of mathematics and the teaching of mathematics, confirms the PSTs' claims above. Support for all arguments above is found in Monroe *et al.* (2011: 2), Borko *et al.* (1992: 218), Lampert and Ball (1999: 33), Thomson and Palermo (2014: 59) and Ambrose (2004: 91) who believe that teachers and PSTs alike should engage in reasoning in their own capacity; be open to criticism of their way of reasoning; engage with multiple solutions to a problem; reconstruct their viewpoints about what mathematics is and what is worthwhile in knowing mathematics. Drawing from all the views and emphasis above, it could be concluded that the PSTs' perceived improvements are indications of achieving fairly adequate PD.

3. motivating and stimulating effective learning by posing relevant but challenging problems to improve learners' understanding and thinking; creating ways to make mathematics interesting/fun and challenging for learners; **and** adapting teaching to learners' levels of thinking and understanding

4. encouraging learners to actively participate, engaging learners in discussions of their own ideas, giving learners maximum opportunities to figure out their own strategies in learning or solving problems
5. encouraging teaching and learning mathematics by relating the content to learners' everyday experiences (Ambrose (2004: 92)
6. encouraging learners' own different methods for finding solutions and thinking in teaching and learning mathematics

These could be indications of improvement in their appreciation and adoption of a learner-centred instructional approach. Kagan (1992: 156) is of the view that an improved PD should enable the teacher to make instructional decisions based on the learners' academic needs. All four perceived improvements above are consistent with the view/belief that mathematics should be conceptualised as a problem-solving activity (Kesicioğlu, 2015: 85). Researchers and mathematics educators alike have been advocating for teachers to engage in reasoning, to be open to criticism of their way of reasoning; to engage with multiple solutions to a problem; reconstruct their viewpoints about what mathematics is and what is worthwhile in knowing mathematics (Monroe *et al.*, 2011: 2; Borko *et al.*, 1992: 218; Lampert & Ball 1999: 33, Thomson & Palermo, 2014: 59; Ambrose, 2004: 91). Additionally, the perceived improvements above could be apparent in some desired embodiments of perceiving mathematics (i.e. teaching and learning of mathematics) as a problem-solving activity, as outlined by Ma and Singer-Gabella (2011: 8); designing engaging learning experiences that stimulate learners' reasoning about quantities; empowering learners to create their own strategies; engaging in discourse about learners' thinking and/or solutions to problems; helping learners to make mathematical sense of problems and communicate their reasoning, not just for producing a correct answer; engaging learners with problems meant for promoting meaningful learning of the mathematics activity in focus, not just for practicing skills and replicating procedures. The growing emphasis on PSTs developing the disposition to engage in mathematical problem solving themselves (Wilcox (1992: 25; Buchholtz *et al*., 2013: 108; Shulman, 1986: 7) also confirm all the above-mentioned arguments. Drawing from all the views and emphasis above, it could be concluded that the PSTs' perceived improvements are indications of achieving fairly adequate PD.

7. *encouraging learners to learn* at their own pace and level of thinking, taking into consideration *learners' needs and characteristics*
8. focusing on learners' thinking and the content they are learning or experiencing to enhance their understanding

These could be indications of improvement in the PST's appreciation and adoption of a learner-centred instructional approach. The two perceived improvements above could also confirm the PSTs' perceived improvement in encouraging teaching and learning mathematics by relating the content to learners' everyday experiences, thereby focusing on learners' needs and their characteristics in instructional decision making as well as during instructions. These could be consistent with Kagan's (1992: 156) view that the adequacy of PSTs' PD may be determined when they are able to make instructional decisions based on the learners' academic needs. Similarly, Ma and Singer-Gabella (2011: 8) also believe that such perceived improvement is evidenced in the PSTs' interest in creating opportunities for using learners' reasoning to promote learning effectiveness. With support from these views, it could be concluded that the PSTs' perceived improvements are indications of achieving fairly adequate PD.

9. development of self-confidence in teaching and consistency in thinking to *overcome own feelings of incompetency to engage young learners in solving mathematical problems*

This could be an indication on the part of PSTs of improvement in overcoming anxieties and incompetence; mental blocks in learning mathematics; as well as confidence in learning/doing mathematics. It has also been argued that adequate enhancement of their PD requires that PSTs should use their own reasoning skills to investigate their actions; be open to criticism of their way of reasoning; engage with multiple solutions to a problem; reconstruct their viewpoints about what mathematics is and what is worthwhile about knowing mathematics (Monroe *et al.*, 2011: 2; Borko *et al.*, 1992: 218; Lampert & Ball 1999: 33, Thomson & Palermo, 2014: 59; Ambrose, 2004: 91). Equally important is the growing emphasis on the need for PSTs to develop a disposition for engaging in mathematical problem solving themselves (Wilcox (1992: 25; Buchholtz *et al*., 2013: 108; Shulman, 1986: 7). Furthermore, Hill *et al.* (2005: 372) and Ball and Forzani's (2010:40) emphasis on PSTs abilities to develop the competence and confidence to improve instructional quality in the classroom confirms the PSTs' perceptions above. By virtue of the above views, it may be concluded that the PSTs' perceived improvements are indications of achieving fairly adequate PD.

- What/which affordance(s) do the PSTs perceive from the improvement perceived in their beliefs about mathematics and teaching and learning of mathematics?

The merged findings revealed that the PSTs perceived that their interaction with the ETE's teaching expertise has improved or transformed their beliefs significantly and now they perceive that they can

1. engage learners in learning the mathematics content from practical problems
2. use manipulatives to enhance teaching and learning and to overcome learners' anxieties
3. assist learners to make connections between concepts and procedures, create opportunities for learners to express their understanding
4. take instructional decisions to suit learners' interest/needs
5. create ample opportunities for active learner participation
6. promote learning mathematics for meaningful understanding
7. overcome learners' anxieties and improve learners' incompetence in learning
8. adapt learner-centred approach

- What/which improvement do the PSTs' perceive in their understanding of the mathematics CK and development of their PCK for Foundation Phase mathematics?

The merged findings revealed that the PSTs perceived that their interaction with the ETE's teaching expertise improved their CK and PCK significantly, as in:

1. understanding how to connect mathematics content with practical problems or experiences, e.g. *how to make connections between ideas and strategies in solving problems* and *how to help learners to link their mathematical ideas in problem solving*

Ball's (1988: 37) argument that well-prepared mathematics PSTs should be able to "revise and develop correct understandings of the underlying principles and warrants, of the connections among ideas" confirms the PSTs' claims above. Furthermore, Ball (1990: 14) emphasises that, to adequately develop or enhance PSTs' PD, their understanding of their school mathematics content should be better and deeper than their experiences in school. In line with the arguments expressed above, Wedege (1999: 206-207) and Ball (1990: 14-15) share the view that, to adequately enhance their PD, PSTs should demonstrate understanding

of mathematics in task-oriented contexts and situation-oriented contexts. From a broader perspective, mathematics teacher educators desire that, in order to justify the adequacies of their PD, PSTs improve their understanding of the central facts, procedures and concepts in mathematics; how mathematical concepts, facts, and procedures are connected; how to establish new mathematical knowledge and justify its validity (Borko, 2004; 5; Borko *et al*., 1992: 195/218; Lampert & Ball 1999: 33; Thomson & Palermo, 2014: 59; Ambrose, 2004: 91; Sowder 2007: 158; Ball 1988: 38; Faulkner, 2009: 24, Shulman, 1986: 8; Kinchin & Cabot, 2010: 161). Judged by the requirements listed above, it could be concluded that the PSTs' perceived improvement reported here meet these criteria for judging the adequacy of their PD.

2. considering the diversity in learners' thinking and understanding to facilitate effective teaching and learning of mathematics, e.g. *how to access and assess learner' thinking and understanding in teaching and learning, how to assess learners' understanding of mathematical ideas and procedures; how to access learners' thinking about concepts, procedures, etc.* (Kesicioğlu, 2015: 95).

Wilcox (1992: 25) and Da Ponte and Chapman (2008: 225) argue that improving conceptual understanding of mathematics and development of effective dispositions towards mathematics are necessary to empower PSTs to support children to meaningfully engage in mathematical investigations. In Kagan's (1992: 156) view, PSTs should develop skills in recognising problem contexts, and PSTs should develop realistic and contextual thinking, as well as problem-solving skills. Borko (2004: 6) suggests that there is a need for PSTs to improve their understanding of how children think, their mathematical and scientific conceptions, and typical misconceptions; children's problem solving strategies; problems which pose difficulties to children; how to pose problems to children; and why they must promote effective communication with learners in order to build on their understanding and misconceptions. In addition to enhancing their teaching effectiveness, PSTs should develop in-depth understanding of how to address the instructional challenges they envisage in their classrooms (Borko, 2004: 3). Additionally, in Kagan's (1992: 156) view, PSTs should focus instructional decisions and practices on the learning and the learners. In line with all the views above, it could be concluded that the PSTs' perceived achievements showed that they have improved their PD fairly adequately.

3. creating opportunities for learners to construct their own understanding of the content they are learning, e.g. *solving problems using different strategies, how to assist learners to solve problems requiring multiple ideas and strategies, how to explain methods for solutions in problem solving*

In Monroe *et al*.'s (2011: 2) views, PSTs should demonstrate understanding of the how and why of mathematical ideas; investigate multiple ways to solve mathematical problems; and flexibility in making connections between mathematical concepts. Wilcox (1992: 25) and Da Ponte and Chapman's (2008: 225) arguments that, in order to effectively support children to meaningfully engage in mathematical investigations, PSTs necessarily need to develop conceptual understanding of mathematics and effective dispositions towards mathematics could also support the improvements being perceived by the PSTs in this study. Similarly, the PSTs' perceived improvements, above, could be in line with Kagan's (1992: 156) desired learning achievements in learning to teach, including developing the requisite skills in recognising problem contexts; developing realistic and contextual thoughts about problems; as well as developing problem-solving skills. Further insights about the desired achievements in learning to teach which the PSTs in this study are claiming could also be apparent in Borko's (2004: 6) suggestions that there is a need for PSTs to improve their understanding of how children think, their mathematical and scientific conceptions and typical misconceptions; children's problem-solving strategies; problems which pose difficulties to children; how to pose problems to children; why they must promote effective communication with learners in order to build on their understanding and misconceptions. Drawing from all the views and emphasis above, it could be concluded that the PSTs' perceived improvements are indications of achieving fairly adequate PD.

4. understanding of the content from different examples and situations, e.g. *how to explain mathematical concepts and procedures; how to explain similarities and differences among different representations, solutions, or methods; how to make connections between ideas and strategies in solving problems;* and *how to help learners to link their mathematical ideas in problem solving*

The learning achievements that the PSTs in this study were claiming could be indications of improvements in their conceptual understanding of mathematical concepts, facts, and procedures – understanding of the relationships and/or connections between concepts and procedures or what is going on behind the scenes concerning those ideas. Ball's (1988: 37)

argument that well-prepared mathematics PSTs should be able to "revise and develop correct understandings of the underlying principles and warrants, of the connections among ideas", confirms the achievements of the PSTs in learning to teach. It has also been noted that significant achievements in learning to teach mathematics become evident in PSTs' much better and deeper understanding of their school mathematics contents than their experiences in school (Ball, 1990: 14). Furthermore, high on the agenda for the adequacies of PSTs' PD is the emphasised requirement that they need to understand central facts, procedures and concepts in mathematics; understand how mathematical concepts, facts, and procedures are connected; understand how to establish new mathematical knowledge and justify its validity (Borko, 2004; 5; Lampert & Ball 1999: 33; Thomson & Palermo, 2014: 59; Ambrose, 2004: 91; Sowder 2007: 158; Ball 1988: 38; Faulkner, 2009: 24, Shulman, 1986: 8; Kinchin & Cabot, 2010: 161). While supporting the strength of the indicators of adequate PD, Borko *et al.* (1992; 195/218) earlier pointed out that the adequacy of PSTs' PD depended on PSTs developing in-depth or conceptual understanding of mathematical principles and thorough explanations of mathematical procedures (why they work the way they work) and demonstrate the understanding of explicit and implicit connections between mathematical concepts, facts and procedures. Monroe *et al*. (2011: 2) likewise emphasise that PSTs should demonstrate understanding of the how and why of mathematical ideas; multiple ways to solve mathematical problems; and flexibility in making connections between mathematical concepts. Considering all the views and emphasis above, it could be concluded that the PSTs' perceived improvements are indications of achieving fairly adequate PD.

- What/which affordance(s) do the PSTs perceive from the improvement [they perceive] in their understanding of the mathematics CK and development of their PCK for Foundation Phase mathematics?

The merged findings revealed that the PSTs perceived that their interaction with the ETE's teaching expertise improved their CK and PCK significantly and they believe they are able to:

1. *select appropriate teaching and learning activities and resources, critically reflect on the effectiveness of their teaching methodology,* adapt lessons to meet the needs and levels of their students' thinking and understanding
2. *facilitate learners' thinking and meaningful understanding of contents, e.g. assist learners to solve problems requiring multiple ideas and strategies,* use learners'

understanding and thinking to create effective mathematical instruction and correct their misconceptions

3. *explain concepts and procedures to enhance learners' understanding – explain the similarities and differences among children's representations, solutions, etc.; assist learners in finding answers using different strategies; explain why mathematical procedures work the way they do;* and *explain solution methods or strategies to learners*
4. *implement a problem-centred teaching and learning approach – provide a problem-solving learning context: assist learners to solve problems using ideas and strategies known or unknown to them*
5. choose problems which will suit their learners' abilities and adapt strategies which can improve meaningful understanding of the content they are learning
6. create opportunities for learners to experience their own cognitive conflicts to develop better understanding of the content they are learning
7. adopt the problem-centred approach in mathematical instruction where learners express their own understanding of the problem; engage learners in interactive studies or learning or discussions to enhance their thinking and understanding
8. assist learners to recognise connections between content and context for better understanding; assist learners to develop logical understanding of the content; explore the similarities and differences in their reasoning and solutions
9. assess students' learning needs and provide the necessary scaffolding experiences, e.g. questioning learners' thoughts about the content to assess their understanding of the 'what and how' of the contents
10. facilitate mathematical lessons to follow structurally to help learners to make connections between their ideas or understanding

It can be said that all the above provide more and clearer insight into the holistic knowledge (beliefs, understandings, and conceptions) these PSTs are developing about mathematics and the teaching and learning of it (Shulman, 1986: 8). Prospective teachers' beliefs about mathematics, mathematical knowledge and mathematics pedagogical knowledge are among the important issues of concern in the evaluation and comparison of the effectiveness of initial teacher education programmes (Kaiser *et al.*, 2010: 433). Moreover, what teacher educators in the field of initial teacher education are trying to accomplish is to prepare expert teachers who are well-equipped with content knowledge, pedagogical knowledge, and pedagogical content knowledge (Jegede *et al.*, 2000: 288) for quality mathematical instruction in our classrooms.

This section has discussed the PSTs' perceived achievements (PD) in learning to teach from the ETE's teaching expertise. The discussion highlighted their perceived PD in the light of or within the frameworks of the various indicators of the adequacies of PSTs' mathematical

preparation emphasised in the literature of contemporary mathematics teacher education and research. In the next chapter, the possible implications of the findings concerning the PSTs' perceived PD for teaching and learning practices in the teacher education ecology, as well as instructional practices in the mathematics classroom, are also discussed.

6. CHAPTER 6
CONCLUSIONS AND RECOMMENDATIONS

Overall, the evidence obtained from the inquiry seemed to show that both the two-year and the third-year training have equally improved the PSTs'

a. beliefs about the subject matter of mathematics and teaching and learning of mathematics, and
b. understanding of mathematics CK

However, the PSTs perceived that ...

a. the development of their PCK for Foundation Phase mathematics and the teaching capabilities they perceived from their PCK were more significantly improved during their interaction with the ETE's teaching expertise in the third year than in the two preceding year's training.
b. the teaching capabilities they perceived from their understanding of the mathematics CK for Foundation Phase mathematics were significantly improved during their interactions with the ETE's teaching expertise in the third year than in their two-year training.
c. overcoming their feelings of incompetence to engage in teaching and learning mathematical problem-solving activities were more significantly improved during their interaction with the ETE's teaching expertise in the third year than in their two-year training.

6.1. DETAILS OF THE FINDINGS LINKED TO THE CONCEPTUAL FRAMEWORK OF THE STUDY

The conceptual framework presented in Figure **3.1** comprised the structure of inquiry that provided the evidence for answering the research questions and the understanding of the research problem. The researcher understood that there was a need to provide convincing

evidence about what is happening with regard to the improvement or growth in PSTs' PD while they were learning to teach from the ETE's teaching expertise. In this section, the researcher concludes by relating the evidence obtained to the components of the conceptual framework which guided the entire inquiry.

With reference to Figure **3.1**, **Box 3** presents purposely gathered evidence of the influences listed in **Box 1** on **Box 2,** thus the PSTs' own accounts of the effects of the educator's teaching expertise, parallel to the eight attributes of expert teaching, on their beliefs about mathematics and the teaching and learning of mathematics; understanding the mathematics CK; and development of PCK for teaching Foundation Phase Mathematics. The merged findings (i.e. from the survey and interviews) revealed that the PSTs perceived changes in their beliefs about mathematics and the teaching and learning of it that facilitated acquiring skills to do the following:

a. encourage learners to learn at their own pace and level of thinking, consider learners' learning needs and characteristics;
b. development of self-confidence in teaching and consistency in thinking to overcome own feelings of incompetence to engage young learners in solving mathematical problems;
c. focus on learners' thinking and the content they are learning to enhance learners' understanding;
d. motivate and stimulate effective learning by posing relevant but challenging problems to improve learners' understanding and thinking; create ways of making mathematics interesting/fun and challenging for learners; and adapt teaching to learners' levels of thinking and understanding;
e. encourage learners to actively participate; engage learners in discussion of their own ideas; give learners maximum opportunities to figure out their own strategies in learning or solving problems;
f. focus and reflect on the mathematics content to gain in-depth understanding of how to make connections between the ideas/concepts or how those ideas are intellectually connected;
g. encourage teaching and learning mathematics by relating the content to learners' everyday experiences;
h. encourage learners' own different methods to find solutions and thinking;

i. reflect on and correct own misconceptions about the subject matter of mathematics and the teaching of young children.

The PSTs furthermore perceived the following potential successes in teaching Foundation Phase Mathematics, given the perceived improvement in their beliefs about mathematics and teaching and learning of mathematics. They now perceive that they are able to:

a. engage children in learning the mathematics content through practical problems;
b. use manipulatives to enhance teaching and learning as well as overcome learners' anxieties;
c. assist learners to make connections between concepts and procedures, create opportunities for learners to express their understanding;
d. take instructional decisions to suit learners' interest/needs;
e. create ample opportunities for active learner participation;
f. promote learning mathematics for meaningful understanding;
g. overcome learners' anxieties and improve learners' competence in learning;
h. adapt to the learner-centred approach in teaching mathematics.

The evidence obtained further indicated that the PSTs perceived improvement in their understanding of the mathematics CK and development of their PCK for Foundation Phase mathematics with regard to the following:

a. understanding of how to connect mathematics content with practical problems or experiences, e.g. how to recognise connections between ideas and strategies in solving problems, how to help learners to connect their mathematical ideas in solving problems;
b. considering the diversity in learners' thinking and understanding to facilitate effective teaching and learning of mathematics, e.g. how to assess learners' understanding of mathematical ideas and procedures; how to access learners' thinking about concepts, procedures;
c. creating opportunities for learners to construct their own understanding of the content they are learning, e.g. solving problems using different strategies; how to assist learners to solve problems requiring multiple ideas and strategies; how to explain methods for solving problems;
d. understanding of the content from different example and situations, e.g. how to explain mathematical concepts and procedures; how to explain similarities and

differences among different representations, solutions, or methods; how to make connections between ideas and strategies in solving problems; how to help learners to link their mathematical ideas in problem solving.

Similarly, the evidence showed that the PSTs perceived the following teaching capabilities from the improvements they perceived in their CK and PCK above. They now perceive that they are able to:

a. select appropriate teaching and learning activities and resources, reflect critically on the effectiveness of their own teaching methodology, adapt lessons to meet the needs and levels of their students' thinking and understanding;
b. facilitate learners' thinking and meaningful understanding of contents, e.g. assist learners to solve problems requiring multiple ideas and strategies; use learners' understanding and thinking to create effective mathematical instruction and correct misconceptions.
c. explain concepts and procedures to enhance learners' understanding, e.g. explain the similarities and differences among children's representations and solutions; assist learners to find answers using different strategies; explain why mathematical procedures work the way they do; explain methods or strategies to find a solution to learners;
d. choose problems which will suit learners' abilities and adapt strategies which can improve meaningful understanding of the content they are learning;
e. create opportunities for learners to experience their own cognitive conflicts to develop better understanding of the content they are learning;
f. adapt/implement the problem-centred approach in mathematical instruction whereby learners express their own understanding of a problem; engage learners in interactive discussions to enhance their thinking and understanding; assist learners to solve problems using ideas and strategies known or unknown to them;
g. assist learners to recognise connections between content and context for better understanding; assist learners to develop logical understanding of the content; explore the similarities and differences in their reasoning and solutions;
h. assess learners' learning needs and provide them with the necessary scaffolding experiences, e.g. questioning learners' thoughts about the content to assess their understanding of the 'what and how' of the contents;

i. facilitate mathematical lessons to be followed structurally to help learners to make connections between their ideas or understanding.

With reference to Figure **3.1**, **Box 5** purposely sought evidence from the PSTs' own perceptions about which aspect of their professional knowledge beliefs about mathematics and the teaching and learning of mathematics; understanding of the CK; and development of their PCK for teaching Foundation Phase Mathematics' has/had been most/least improved by the educator's teaching expertise from which they were learning. The evidence revealed that the PSTs perceived their interaction with the ETE's teaching expertise to have significantly improved

a. the development of their PCK for Foundation Phase mathematics and the teaching capabilities they perceived due to their CK as well as their PCK; and
b. their beliefs about the subject matter of mathematics and teaching and learning of mathematics.

Box 4 in Figure **3.1,** unlike **Box 5**, represents the evidence from the PSTs' own views about the most/least influential attribute(s) of the educator's teaching expertise for their beliefs about mathematics and the teaching and learning of mathematics; understanding of the CK; and development of their PCK for teaching Foundation Phase Mathematics. The findings revealed that the PSTs perceived that the ETE's

a. enthusiasm in teaching, articulation of subject knowledge expertise, and preparation for and organisation of teaching to have the strongest effect in *transforming their beliefs about the subject matter of mathematics and the teaching and learning of it;*
b. articulation of subject knowledge expertise, preparation for and organisation of teaching, clarity in lesson presentation/teaching had the greatest impact on the PSTs' *understanding of the Foundation Phase mathematics CK;*
c. motivating/stimulating students' interest and engagement with learning experiences; preparation for and organisation of teaching; clarity in lesson presentation/teaching; articulation of subject knowledge expertise; positive relationships with students and approachability; enthusiasm in teaching and understanding of students' learning needs; and creating a productive learning climate had greatly improved *the development of the PSTs' PCK for Foundation Phase mathematics*.
d. humour in teaching had the least impact on all the components of the PSTs' PD.

Box 6 in Figure **3.1** relates the evidence obtained in this inquiry, regarding PSTs' own understanding of their PD and how they interpreted the growth in their PD from their learning experiences to the relevant literature on the professional knowledge teaching practices of effective mathematics teacher. The discussion of the findings from the study (see **section 5.6**) has provided convincing evidence that the PSTs' perceived improvement in their PD was supported by evidence of effective mathematics teachers' professional teaching knowledge and their instructional practices, gathered from the relevant literature.

All the evidences above provides much deeper insight into the holistic knowledge (beliefs, understandings, and conceptions) these PSTs are developing about mathematics and the teaching and learning of it (Shulman, 1986: 8). In recent times, PSTs' beliefs about mathematics, mathematical knowledge and pedagogical knowledge of mathematics have been high on the agenda concerning evaluation and comparison of the effectiveness of initial mathematics teacher education programmes (Kaiser *et al.,* 2010: 433). These are in line with mathematics teacher educators' focus on preparing expert teachers who are well-equipped with content knowledge, pedagogical knowledge, and pedagogical content knowledge (Jegede *et al.,* 2000: 288). Jegede *et al.'s* (2000) observations seem to confirm that the PSTs' perceived improvement in their PD fits adequately into the accomplishments of educators of mathematics teachers. For example, the evidence about the effects of teaching expertise on the PSTs' PD could mean that the ETE was sharing her teaching expertise with the PSTs. This is supported by Levin's (2014: 61) observations that teacher educators oriented towards the philosophy of knowledge transfer focus on preparing future teachers who can "... sustain themselves when competing expectations challenge their beliefs". Undoubtedly, the ETE was promoting the teaching practices enshrined in the notion of knowledge transfer which universities are advocating. Interestingly, addressing the challenges in knowledge transfer distinguishes between ETEs and non-ETEs.

This study's empirical findings, as presented above, together with the initial argument by the researcher in sections **3.6.1** and **3.6.2**, collectively argue that initial teacher education impact on PSTs' PD.. This collective argument is apparently connected with, for example, most in-service teachers' PD training programmes aiming to change teaching practice from the traditional ways to modern teaching practices integrated with ICT, to challenge teachers' beliefs, enrich their CK and their PCK.

In addition, the PSTs' perceived improvement in the dimensions of their PD seem to be in line with the pressing issues of concern which teacher educators are trying to address internationally, as observed by Kaiser *et al.* (2010). Interestingly, within the framework of the concerns and arguments above, the PSTs' perceived PD described above seem to debunk the perception that PCK could only be developed in the work of teaching but not in the course of learning to teach (Levin, 2014: 51). Equally important, if the PSTs' perceived PD described or interpreted above fairly satisfy the desired achievements within the frameworks proposed by Shulman (1986), Kaiser *et al.* (2010) and Jegede *et al.* (2000), then the voices of the PSTs about their PD could also debunk the perceptions of some people, including teachers, that initial teacher education could not prepare teachers adequately for the real classroom challenges.

Based on both the theoretical and empirical findings of this study, it could be argued that the turning point for the successful transition of PSTs from learners to effective teachers of mathematics is in transforming their beliefs, perceptions, misconceptions, dispositions or attitudes towards the subject matter of mathematics and the teaching and learning of mathematics. It could also be argued that the indispensable role of the ETE towards such achievements should not be underestimated. In this regard, the findings of this investigation also support the views that ETEs are set apart from non-ETEs by their exemplary teaching expertise (Glass *et al.*, 1999; Witt *et al.*, 2013; Hativa *et al.*, 2001; Da Ponte & Chapman, 2008).

6.2. IMPLICATIONS OF FINDINGS ON RESEARCH AND TEACHING AND LEARNING PRACTICES IN MATHEMATICS EDUCATION

Research in mathematics education, especially research concerning PSTs' PD, should give considerable attention to the direct involvement of PSTs via their perceptions about the problem under investigation. The advantage could be that the PSTs' perceptions or interpretations of their PD could motivate their thoughts and actions and, beyond these, the interpretation of their experiences could also motivate their interpretation and application of knowledge, leading to the transformation of pre-existing perceptions (Krauss, 2005: 763; Kinchin & Cabot, 2010: 157).

The findings reported in this study provide teacher educators with a possible framework or the nature, or a sample of prospective teachers' PD (Da Ponte & Chapman, 2008: 243;

Lunenberg *et al.*, 2007: 588) and teacher educators could take action to improve the identified strengths and inadequacies of prospective teachers' PD (Yang & Leung, 2011). The researcher shares San's (1999:19) view that such articulations (findings and interpretations of PSTs' PD) of developing PD are imperative in guiding teacher educators to "provide a framework for making decisions about how to facilitate" the PD of prospective teachers as well as teachers in general.

The voices of the PSTs would inform teacher educators about their own teaching practices and their influence on their students' professional development (Da Ponte & Chapman, 2008: 254; Yang & Leung, 2011: 1008; Smith & Strahan, 2004: 358; Levin, 2014: 50). Hence, the findings of this study could provide sound knowledge and understanding of the role of teaching expertise in promoting effective teaching and learning in higher institutions of learning (Hiebert *et al*., 2002: 3; Schwarz *et al*., 2008: 791).

To enhance PSTs' PD, teacher educators as well as PSTs need to reconceptualise PD in mathematics education by shifting emphasis from PD as, for example, caring, punctuality, loving children, respectful (Helterbran, 2008: 124; Borko *et al*., 1992: 217) to PD as an embodiment of the essential learning outcomes (Berliner, 1988: 65) reported in this study. Thus, we need to change our concept of PD in initial teacher education, especially in mathematics education.

The PSTs' perceptions that the teaching expertise they experienced has changed their beliefs about the mathematics they are going to teach, could mean that the ETE motivated the PSTs, conveyed concepts to the PSTs, and helped PSTs to overcome their learning difficulties (Kreber, 2002: 9). Similarly, it could mean that the ETE creates opportunities for PSTs to learn to develop their teaching knowledge (Yang & Leung, 2011: 1010; Levin, 2014: 51).

In addition, the PSTs' perception that their understanding of mathematics subject matter knowledge has improved (CK) and that they can plan mathematics instructions skilfully (PCK), could confirm the crucial impact of the ETE's command of mathematics subject matter knowledge on the PSTs' PD (Yang & Leung, 2011: 1009; Shim & Roth, 2008). The ETE's articulation of subject knowledge expertise, for example, assist PSTs to create meaningful, coherent representations of knowledge (Kagan, 1992).

The PSTs' perceived improvement in their *misconceptions about teaching young children* and *how young children learn mathematics*, points to the fact that the ETE empowers them to

consider student's ideas more constructively during mathematical instructions (Carney *et al.*, 2014). Furthermore, the PSTs' perceived capabilities that they can engage children in learning mathematics for meaningful understanding, supports the views that ETEs promote learner engagement for meaningful learning in order to eliminate teacher-centred instructional approach (Carney *et al.*, 2014; Mosoge & Taunyane, 2012).

The PSTs' perceived improvement in their *reflections on and corrections of their own misconceptions about the subject matter of mathematics* they will be teaching young children, supports the views that ETEs address the PSTs' misconceptions about mathematics and teaching and learning mathematics with special focus on the structure of the mathematics, as set of interrelated concepts and procedures (Carney *et al.*, 2014). Similarly, the ETEs' expertise above improves PSTs' feelings of competency to engage young children in a problem-solving approach, as evidenced in the PSTs' claims above (Carney *et al.*, 2014). Teaching expertise has been found improve PSTs' resistance to change when the ETE's teaching strategies are adapted to their learning needs (Bronkhorst *et al.*, 2014; Kagan, 1992). Mitchell *et al.* (2004) add that the ETE increases students' appreciation of their own competence and professional strength.

The PSTs' perceived improvement in their willingness or interest to use a content-focused approach in teaching mathematics indicates that ETEs empower PSTs to address learners' misconceptions about mathematics and learning mathematics and focusing on the structure of the mathematics as set of interrelated concepts and procedures (Carney *et al.*, 2014). Research has shown that teaching expertise prepares PSTs to be able to adapt to future challenges related to their professional growth (Hume & Berry, 2011). Howitt (2007) and Haydn (2014) found that teaching expertise helped PSTs to, e.g., view science as a fun learning process rather than a boring subject.

The PSTs' perceptions that they can implement a *learner-centred approach in mathematics lessons to help children learn mathematics effectively*; *assist children to overcome their anxieties by engaging them in problem-solving*; *assist children to overcome their anxieties by engaging them in using manipulatives*; *assist children to overcome their incompetency by engaging them in problem-solving*; and *create opportunities for effective communication and sharing of ideas among children teaching* show that ETEs address PSTs' misconceptions about mathematics and teaching and learning of it (Carney *et al.*, 2014). The effects of the above teaching expertise articulated by ETEs is also evidenced in the PSTs' perceptions that

they were able to *explain why mathematical procedures work to young children*; *assist young children in finding answers to problems by using different strategies*; *help young children connect their mathematical ideas in problem solving tasks*; *explain the similarities and differences among children's representations, solutions, or methods in a problem*; and *use effective questioning skills to access young children's thinking in solving a problem* (Carney *et al.*, 2014). Researchers have shown that ETEs' teaching expertise increased PSTs' knowledge of what and how the contents can successfully be taught (Howitt, 2007; Haydn, 2014). The findings that teaching expertise promotes the development of deep knowledge of the discipline and improves problem-solving skills of students (Mitchell *et al.*, 2004: 281) confirm the claims made above.

The PSTs' perceived improvement in their understanding of *how to explain why mathematical procedures work to young children*; *how to explain methods for finding solutions in problem solving to children*; *similarities and differences among children's representations, solutions, or methods in a problem*; and *how to assist young children to solve problems requiring multiple ideas and strategies*, confirm that ETEs empower PSTs to encourage multiple strategies and models in teaching and learning mathematics, especially in problem solving (Carney *et al.* 2014). Mitchell *et al*. (2004: 281) found that ETEs motivate students to engage with the learning tasks. It has also been found that teaching expertise provide PSTs with the "foundations of professional knowledge" (Hume & Berry, 2011).

6.3. SIGNIFICANCE OF THE STUDY

First, there is a need for knowledge about the effects of mathematics teacher educators' teaching practices on PSTs' PD (Kaiser *et al.*, 2010; Darling-Hammond & Youngs, 2002; Superfine & Li, 2014; Lunenberg *et al.*, 2007; Korthagen *et al*., 2005; Shim & Roth, 2008, Murray, 2006; Berliner, 2004). For example, it is believed that PSTs' relationship and interaction with professionals in their fields of learning can contribute to the development of their professional identities (Da Ponte & Chapman, 2008). According to Bereiter and Scardamalia (1993), Yang and Leung (2011), Smith (2005), Celik (2011) and Berliner (1988), research outputs about teaching expertise with a focus such as in this study can broaden our knowledge about expertise in general and teaching expertise in particular, thereby influencing the development of the society. This knowledge is important because, in order to improve mathematics teacher education in particular and mathematics education in

general, stakeholders in this field need to understand the extent to which the teaching that PSTs are experiencing during training in initial teacher education, have contributed or is contributing to the development of their expert teaching knowledge (Jegede *et al.,* 2000).

Second, the PSTs have confirmed the indispensable impact of the educator's articulation of most of the attributes of teaching expertise modelled for the purpose of this investigation (Jegede *et al.,* 2000). The PSTs' views and satisfaction with the expert's teaching they have experienced show that articulation of the attributes of teaching expertise is realistic and imperative in preparing PSTs for their future work of teaching (Steyn, 2010: 171). Their impressions about the teaching expertise could motivate teacher educators in Mathematics Education as well as in other disciplines to incorporate the attributes of teaching expertise in their teaching practice in order to share their expert knowledge with PSTs (Haydn, 2014; Hativa *et al.*, 2001). Essentially, the findings are pointing to the fact teaching PSTs could be extremely effective if teacher educators focus on transferring or sharing their teaching expertise with PSTs (Dineke *et al.*, 2004; Devlin & Samarawickrema, 2010). Excellent teaching and sharing of teaching expertise with mentees is highly recognised as quality pedagogical practices in the work of teacher educators (Kinchin & Cabot, 2010: 153; Korthagen, Loughran & Lunenberg, 2005: 107). The findings from the study's setting seem to confirm, though not officially documented, the "label" of the teacher educator in focus as an ETE by her colleagues and students. Several cohorts of Foundation Phase PSTs have been given positive feedback about the quality of her expert contributions to their Foundation Phase Professional Development. Recently, this teacher educator was recommended and subsequently selected for teaching awards in Mathematics Education for Foundation Phase education.

Third, towards improving the training of PSTs in Mathematics Education, it is important to consider the PSTs' views about what they have acquired or developed while learning to teach from their educators and what they think they need to acquire or develop in order to address the challenges in teaching mathematics in the classroom to become effective teachers of mathematics (Bezzina, *et al.*, 2004; Jegede *et al.,* 2000; Da Ponte & Chapman, 2008). In either case, such knowledge will help in promoting PSTs' awareness of their own "personal sense of development" in learning to teach, as well as provide the pathway towards developing the desired teaching expertise for their future work in teaching. In Helterbran's (2008) view, such awareness can enhance the PST's continuous growth as a professional.

Equally important, such knowledge could provide a framework for making decisions towards improving learning to teach in teacher education ecologies (San, 1999).

Fourth, there is a need for knowledge about what teacher educators as well as PSTs should consider worthwhile to ensure the successful transition of PSTs from learners of mathematics to effective teachers of mathematics (Shulman, 1986). It is believed that prospective teachers' beliefs about mathematics, mathematical knowledge and pedagogical knowledge in mathematics are among the important transitional issues or fundamental learning outcomes addressed in preparing effective mathematics teachers (Kaiser, *et al.*, 2010; Jegede *et al.*, 2000; Ball, 1988; Da Ponte & Chapman, 2008; Monroe *et al.*, 2011). Borko *et al*. (1992), Schwarz *et al.* (2008), and Buchholtz *et al*. (2013: 108) repeatedly emphasise that understanding school mathematics; understanding the mathematics curriculum and analysis of learners' mathematical abilities; improving beliefs about mathematics; and the teaching and learning of it are the main dimensions of the professional knowledge of prospective mathematics teachers. The quality and effectiveness of initial teacher education programmes in mathematics are determined by the extent to which those transitional issues are adequately improved. Levin (2014), for instance, argues that investigating PSTs' developing beliefs, as is done in this research, should be the initial concern of researchers, including mathematics education researchers. Levin (2014) adds that it is essential for teacher educators and researchers in teacher education alike to focus on the sources through which PSTs develop their pedagogical beliefs and the influences of those sources on their emerging beliefs. In light of the findings of this study, the successful transition of PSTs from learners of mathematics to effective teachers of mathematics could be improved when mathematics teacher educators consider addressing the fundamental components of the PSTs' PD. Certain components of their professional knowledge are the building blocks of their PD and could, as such, be prioritised over others.

Fifth, the findings of this study, which represent the actual views and voices of the PSTs involved, inform teacher educators about their own teaching practices and their influences on the professional development of prospective teachers (Da Ponte & Chapman, 2008: 254; Yang & Leung, 2011: 1008; Smith & Strahan, 2004: 358). Lunenberg *et al*. (2007: 589) argue that there is an "… apparent lack of awareness amongst teacher educators of the influence they may have on their students, merely by being the teachers that they are". In Yang and Leung's (2011) views, such findings may not necessarily provide us with clearer

understanding of the teacher educator's mathematics teaching expertise, but would provide the teacher educator with useful information to improve future programmes and teaching and learning practices in, for example, the Foundation Phase mathematics programme. In San's (1999:19) view, articulations of developing PD as provided by this study are imperative in guiding teacher educators to "provide a framework for making decisions about how to facilitate" the PD of prospective mathematics teachers, as well as teachers in general. Thus, the findings contribute to teacher educators' knowledge of promoting effective teaching and learning in institutions of higher education (Hiebert, Gallimore & Stigler, 2002: 3; Schwarz *et al*., 2008: 791). The findings also inform teacher educators about the development of PSTs' professional identities, especially in mathematics (Da Ponte & Chapman, 2008: 243; Lunenberg *et al.*, 2007: 588). Levin (2014: 50) adds that understanding PSTs' perceptions can help teacher educators to improve their teaching strategies for dealing with both in-service and pre-service teachers to enhance the teachers' professional growth and development throughout the teachers' careers.

Last but not the least, this empirical study gave PSTs an opportunity to evaluate their own developing beliefs about teaching effectiveness, CK, and PCK, which is an effective way of exposing them to core attributes of professionalism (Berliner, 1988: 65), instead of their pre-conceived attributes of teacher professionalism such as caring, punctuality, loving children, being respectful (Helterbran, 2008: 124; Borko *et al*., 1992: 217). Krauss (2005: 763) claims that the meanings that individuals gain from their experiences with phenomena, like the ETE's teaching expertise, could have enormous implications for learning to teach. Krauss (2005) explains that it is the individual's perceptions/meanings that motivate his/her thoughts, actions and that, beyond these, the meaning of experiences motivates his/her interpretation and application of knowledge, leading to the transformation of pre-existing perceptions (p. 763). Kinchin and Cabot (2010: 157) also argue that active participation by novices, such as evaluating their own learning progress in their training is a crucial requirement for their PD: PSTs must not be reduced to or treated as mere observers of the teaching expertise. Self-evaluation leads to awareness of self, which is a way of making most implicit or tacit beliefs explicit and subsequently transformed (Borko *et al*., 1992; Borko, 2004).

In conclusion, the findings have confirmed that the PSTs' PD has improved remarkably while they were learning to teach from the educator's teaching expertise. The findings from this study could motivate interest in studying the impact of ETEs elsewhere in other faculties,

departments and universities. Additionally, the model of the attributes of teaching expertise used in this study could be experimented with in different teacher education settings to improve its reliability.

6.4. LIMITATIONS AND DELIMITATIONS OF THE STUDY

One of the challenges that confronted this study (i.e. the convergent parallel design) was the inadequacy of models of mixed methods design to serve as examples to guide the researcher in the current study (Bryman, 2007: 21; Woolley, 2008: 2; Östlund *et al.*, 2011: 370- 371; Srnka & Koeszegi, 2007: 31; Kerrigan, 2014:10; Pearce *et al*., 2014: 20). According to Srnka and Koeszegi (2007: 31), inadequately defined procedures or models which might guide researchers, novice researchers especially, who have an interest in embarking on mixed methods research in this field of inquiry led to difficulties in understanding, evaluating and replicating mixed method designs like this study's "convergent parallel design" in other disciplines.

Secondly, this study did not seek to measure or assess the students' achievements by, for example, testing their CK and PCK in mathematics. The focus of this investigation was to elicit PSTs' perceptions about their own PD, which include the transformation in their beliefs about mathematics and teaching and learning of mathematics; improvement in their understanding of the mathematics CK; and development of their PCK. We are all witnesses to the fact that teachers in South Africa, for example, have more often been tagged as lacking in-depth CK and PCK (Bantwini, 2012: 518; Letseka, 2014: 4865) to promote quality teaching and learning in our schools. Akyeampong *et al*. (2013: 276) also add that PSTs seem to be confident that they are capable of teaching mathematics perfectly after learning some specific teaching procedures during their preparation. This means that mere claims (such as perceptions) by teachers' that they have adequately developed the desired knowledge base for teaching is not enough to conclude that they have really improved, but this could further be ascertained by testing their CK and PCK in research, as suggested by König (2013: 1000) and Van der Berg *et al.* (2011: 6). König (2013: 1000) argues that PSTs' acquisition of professional teaching knowledge need to be empirically tested, because such information can help improve teacher education. This is one of the limitations of my research, because the results in Mosoge and Taunyane (2012: 195) investigation of teachers' perceptions about their CK and PCK show that the teachers claim they possess an effective knowledge base for

teaching, which the authors said was very surprising because it contradicted Daugla's (2005) and others' clear labels of the teachers' CK and PCK as inadequate. This shows that researchers need to find further concrete evidence of such perceptions of teachers by triangulating findings on perceptions of knowledge by testing the existence of that knowledge.

Thirdly, self-perception is not always absolutely correct and is more subjective, which could affect the reliability and validity of research conclusions (Mosoge & Taunyane, 2012:198). Furthermore, the development of expertise is not a straightforward process; it requires experiencing real instructional challenges in the classroom, and deliberate practice which the subjects in this study have not been adequately exposed to, therefore possible claims that their PD (beliefs, CK and PCK) has developed, or not, may not be a true reflection of having developed their expertise (Yang & Leung, 2011: 1010-1011). Yang and Leung claim that " experience is an essential part for the emergence and development of teaching expertise, and the development of teaching expertise requires many years of deliberate classroom teaching practice." (p. 1010-1011). Such development could be ascertained by making follow-up studies or extensive longitudinal studies of the subjects' actual instructional practices for at least one year, as recommended by Levin (2014: 49) and Berliner (1988: 39).

Fourthly, Yang and Leung (2011) and Levin (2014: 49) share the view that teachers' beliefs need to be investigated beyond their initial training because changes in teacher beliefs may be temporal and situational in nature (Berliner, 1988: 64; Lunenberg *et al.*, 2007: 587). Therefore, perceived changes investigated as in the case of the current research may not be permanent because of future challenges to the PSTs' thinking.

Having highlighted the limitations above, it would be expedient to explain, in particular, the reason(s) for which the researcher focused deeply on surveying PSTs' perceptions of their PD, even though considering testing as a triangulating measure or embarking on follow-up studies of their teaching practices have been highly recommended. One of the reasons, and in fact a major reason, is that the findings from the PSTs' perceptions about their PD without doubt, form the foundation or hypothesis or arguments for embarking on any of the recommendations above. Hence, the findings of the current study could be as important as findings which may be derived from triangulating rigorous tests of PSTs' CK and PCK with their perceptions, or embarking on follow-up studies of their instructional practices in the real classroom to ascertain their perceived PD. For example, there have been "before and after"

surveys which measured teachers' beliefs about the nature of mathematics and students' learning; confidence regarding their own knowledge in mathematics; and their preparedness to teach mathematics, given their learning outcomes in a mathematics PD programme (Carney *et al.*, 2014: 13-14). Carney *et al.* (2014) remark that a survey is recommended especially when we evaluating changes in teachers' PD resulting from teachers' exposure to certain interventions or experiences.

Another reason for undertaking this study was that the PSTs attending the particular module were continuously being assessed in the module by their teacher educators, by way of writing tests, quizzes, end-of-term/semester examinations, individual and group projects, micro-teaching lessons, and internship teaching practice. It is clear that all the PD dimensions that this research was seeking to report on by eliciting PSTs' perceptions were well assessed or tested by the teacher educator. Perhaps the researcher could have sought and integrated such empirical data from the teacher educator for the purpose of data triangulation to give more credibility to the findings of this study. Unfortunately, such data were not easily accessible to the researcher.

Nonetheless, if it may be said that rigorously testing PSTs' CK and PCK would have served as better complementary authenticating evidence, for example of their perceptions of changes/improvement in their CK and PCK, it could equally be agreed that this study is giving another perspective for understanding what PSTs' think they have gained through those traditional and routine forms of assessments. Thus, this investigation, despite its limitations, could serve as a useful tool for triangulating the assessment processes above (i.e. the traditional forms of assessment). Additionally, the instruments designed for this study for eliciting information (questionnaire and interview questions) intellectually challenged the PSTs to recall and reflect (König, 2013: 1003) on very significant situations or scenarios when their learning experiences, for example, were influenced by the ETE's teaching expertise. In doing so, the questions challenged them to examine the phenomenal influences of the attributes of teaching expertise on their beliefs, CK, and PCK. More specifically, the interview questions were challenging the PSTs to reflect and then describe or explain their experiences of the phenomenal influences of the ETE's teaching expertise on their professional growth or changes (König, 2013: 1003). The above questioning orientations could be considered suitable alternatives to König's (2013: 1000) strong convictions that empirical testing in research is the best way to provide information about PSTs' acquisition

of professional teaching knowledge that aim to promote the improvement of teacher education. It would be relevant to mention here that this study covering a much wider scope of the ETE's teaching expertise in the work of teaching than, for example, R. D. Whisonant's (1998) research, which only focused on "The Effects of Humor on Cognitive Learning in a Computer-Based Environment."

Ideally, it would have been enriching and informative to extend this longitudinal study to cover more related issues which are implicitly or explicitly connected to the PSTs' PD after learning to teach from the ETE's teaching expertise. However, regarding this issue of this study's lack of extensiveness with respect to time, as recommended by Levin (2014: 49) and Berliner (1988: 39), it is important to note that this would not be a major limitation on the adequacy of information needed for proof of reliability and validity of the findings regarding the problem under study. For example, a similar study by Gülru Yüksel (2014) sharing the same vision (i.e. "… tracing changes in pre-service English as a foreign language teachers' sense of efficacy") as this investigation, was done in a year and the author termed it a "longitudinal study". In addition, the researcher's resources at the time of the research could not afford him an extension beyond the two-year-long longitudinal study (Onwuegbuzie & Collins, 2007: 285).

In addition to the fact that it is possible for a longitudinal study to be done in one year, as shown above, the methodological design employed for the entire research could also play a major role in minimising the possible limitations of time inadequacy in obtaining sufficient and rich data for securing the reliability and validity of the study. In this case, the convergent parallel mixed method employed in this study could, like other mixed methods, help solve this problem (Wilkins & Woodgate, 2008: 24 ; Macnab & Payne, 2003: 59; Hanson *et al.*, 2005: 225; Onwuegbuzie & Collins, 2007: 283; Frykholm, 1999: 85; Levin, 2014: 60). For example through the use of the convergent parallel mixed method, Gülru Yüksel (2014; 3) obtained rich and sufficient data and was able to point out the significant changes in the participants' efficacy over a year (Gülru Yüksel: 2014: 6).

6.5. RECOMMENDATIONS FOR FUTURE RESEARCH

The researcher sincerely acknowledges that this research could not be flawless. Careful reflection on the strengths and inadequacies of doing this research informed the following recommendations by the researcher.

1) The researcher would like to recommend that prospective researchers should use convergent parallel design as the research approach for future research relating to PSTs' PD and other issues in initial teacher education requiring any mixed method approach. Increasing the adaptation of mixed methods in investigating problems in initial teacher education (Da Ponte & Chapman, 2008: 254; Levin, 2014: 60/62; Brown *et al*., 1999: 301) would not only ensure in-depth understanding of issues and problems under investigation and satisfactorily answered questions, but would also ensure the proliferation of models of mixed method approaches for guiding future researchers/research.

2) The researcher would like recommend that researchers with vested interests in the current problem investigated here should use alternative mixed method designs like sequential mixed method design to provide multiple perspectives for understanding the problem and answering the research questions.

3) It has been noted that the convergent parallel design employed in the current study, could best be employed by a team of researchers who could harness their expertise together for better results. Against this background, the researcher would like to recommend that a team of researchers should investigate similar problems using the convergent parallel design to enhance effective and efficient data collection, analysis, and interpretation of the problem.

4) The researcher would like to recommend that future research with a similar interest should be extended beyond surveying PSTs' perceptions about their PD to include a sort of triangulation phase whereby actual achievement scores/results testing their claimed PD would be correlated with their perceptions. One of the advantages of this suggestion (over surveying PSTs' perceptions) is that triangulating their test scores on CK and PCK with their perceived PD concerning improvement in their CK and PCK would give researchers and teacher educators more detailed information about the adequacies and inadequacies of the PSTs' PD. The findings from research going by this recommendation could help teacher educators to take measures towards the holistic improvement of PSTs' PD (König, 2013).

5) Aside from triangulating their perceptions with rigorous empirical tests of their CK and PCK, the researcher would also like to recommend that future researchers with similar interests (the current problem under investigation) should consider extending this investigation further by embarking on follow-up studies or more extensive longitudinal studies of the subjects' actual instructional practices for at least one year, as recommended by Levin (2014) and Berliner (1988). This attempt could provide practical information/evidence which could be used to ascertain their perceived PD. Thus, the follow-up studies would more or less be triangulating the findings of the current studies to enrich our understanding of the problem under investigation.

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APPENDICES

Appendix 1: Questionnaire for Assessing the two-year PD of PSTs (Phase A)

INTRODUCTION

This academic exercise is intended to collect data on the topic: **"PERCEPTIONS OF PRE-SERVICE TEACHERS IN FOUNDATION PHASE MATHEMATICS ABOUT THEIR PROFESSIONAL DEVELOPMENT".**

This is a PhD research being undertaken in the Department of Curriculum Studies, Faculty of Education, **Stellenbosch University** in South Africa.

The purpose of this exercise is to elicit your viewpoints about your professional development over the two years of your experiences in learning to teach mathematics.

Your voluntary participation in this academic exercise is highly appreciated. If you volunteer to participate in this study, I would like you to **honestly** express your views, on this **questionnaire**, about your:

- beliefs about the mathematics you are going to teach.
- beliefs about teaching and learning of Foundation Phase mathematics.
- content knowledge (CK) and pedagogical content knowledge (PCK) in Foundation Phase mathematics.

All your responses in this exercise will be kept confidential and anonymous in my presentation and analysis.

Please write the last **4-digits** of your student ID:……

There are **five** different sections to be completed. You are required to respond to **all** the questions in **all** the sections.

Section A is requiring your responses to questions about your beliefs about mathematics, and teaching and learning of mathematics.

Section B is requiring your responses to questions about what your beliefs in section**A** can afford you to do in teaching.

Section C is requiring your responses to questions about your content knowledge (CK) and your pedagogical content knowledge (PCK).

Section D is requiring your responses to questions about what your CK and your PCK in section **C** can afford you to do in teaching.

Section E is seeking your responses to questions regarding your expectations from interactions you are going to have with the teaching expertise of the **3rd**Foundation Phase mathematics lecturer on your perceived PD which you indicated in your evaluations.

Thank you. Kassim Alimi Yau (kassimalimiyau@gmail.com)

Section A- ***Evaluating your beliefs about mathematics and teaching and learning of mathematics*****.**

As an aspiring mathematics teacher, you began your professional training with your own views about what mathematics is and how it should be taught and learnt, which you might have eventually intellectually approved or disapproved due to new experiences you went through (e.g. the curriculum you learnt, your interactions with lecturers, different views/opinions you interacted with during discussions). In this section you are assessing the changes or imptovements you perceive in those views during your two-year training.

Please indicate the **degree** to which you agree or disagree with each statement below by circling ***onlyone*** response to the right of each statement.

Key: SD = Strongly Disagree **D** = Disagree **A** = Agree **SA** = Strongly Agree

My experiences in learning to teach Foundation Phase mathematics over the past two years have adequately prepared me to

1. reflect on and correct my***misconceptions*** about teaching young children mathematics	SD	D	A	SA
2. reflect on and correct my ***misconceptions*** about how young children learn mathematics	SD	D	A	SA
3. reflect and correct mymisconceptions about the subject-matter of the mathematics I am going to teach	SD	D	A	SA
4. overcome my feelings of incompetency in engaging young children in solving mathematical problems.	SD	D	A	SA
5. be critical about the needs and characteristics of children when thinking about my teaching strategies	SD	D	A	SA
6. think carefully through my decisions about suitable ways to cater for children's needs and characteristics in teaching mathematics.	SD	D	A	SA
7. focus on content of the mathematics I will be teaching in my teaching strategies	SD	D	A	SA

Section B- ***Assessing the impacts of the changes in your beliefs during your two years experiences on your teaching capacity.***

As an aspiring mathematics teacher, you began your professional training with your own views about what mathematics is and how it should be taught and learnt, which you might have eventually intellectually approved or disapproved due to new experiences you went through (e.g. the curriculum you learnt, your interactions with lecturers, different views/opinions you interacted with during discussions). In this section you are assessing the changes or imptovements you perceive in those views during your two-year training.

Please indicate the **degree** to which you agree or disagree with each statement below by circling ***onlyone*** response to the right of each statement.

Key: SD = Strongly Disagree **D** = Disagree **A** = Agree **SA** = Strongly Agree
My experiences in learning to teach Foundation Phase mathematics over the past two years have adequately prepared me and I believe I can

1. engage children in learning mathematics for meaningful understanding as I reflect and correct my misconceptions	SD D A SA
2. implement a learner-centred approach in my mathematics lesson to help children learn mathematics effectively	SD D A SA
3. assist children to overcome their anxieties by engaging them in problem-solving	SD D A SA
4. assist children to overcome their anxieties by engaging them in using manipulatives	SD D A SA
5. assist children to overcome their incompetency by engaging them in problem-solving	SD D A SA
6. focus my instructional decisions on the interest of my students	SD D A SA
7. create opportunities for effective communication and sharing (active participations and discussions) of ideas among children in my teaching	SD D A SA

Section C- ***Evaluation of your Content Knowledge and Pedagogical Content Knowledge in mathematics*****.**

As an aspiring mathematics teacher, you began your professional training with some understanding of the mathematical concepts, procedures, facts, skills, as well as understanding of how mathematics must be taught or how teaching mathematical concepts, procedures, facts, skills, is done, from your experiences during school mathematics lessons or even with your parents you are going to teach, which you might have eventually intellectually approved or disapproved due to new experiences you went through (e.g. the curriculum you learnt, your interactions with lecturers, different views/opinions you interacted with during discussions). In this section you are assessing the improvement you perceive in those understandings during your two-year training.

Please indicate the **degree** to which you agree or disagree with each statement below by circling ***only one*** response to the right of each statement.

Key: SD = Strongly Disagree **D** = Disagree **A** = Agree **SA** = Strongly Agree

My experiences in learning to teach Foundation Phase mathematics over the past two years have adequately improved my understanding of

1.	the mathematical concepts, facts, and procedures I will be teaching children.	SD	D	A	SA
2.	how young children learn about number operations and relationships	SD	D	A	SA
3.	how to assist young children to find answers to problems when using different strategies	SD	D	A	SA
4.	how to explain to young children why mathematical procedures work	SD	D	A	SA
5.	how to explain solution methods in problem solving to children.	SD	D	A	SA
6.	how to explain the similarities and differences among children's representations, solutions, or methods in a problem	SD	D	A	SA
7.	how to assist young children to solve problems requiring multiple ideas and strategies	SD	D	A	SA
8.	how to access young children's thinking of mathematical ideas in learning	SD	D	A	SA
9.	how to help young children connect their mathematical ideas in problem solving	SD	D	A	SA
10.	how to assess young children's understanding of mathematical ideas and procedures	SD	D	A	SA

Section D- ***Your ability to deliver as a mathematics teacher given the content knowledge and Pedagogical Content Knowledge (PCK) you have developed during yours two years experiences in learning to teach***

As an aspiring mathematics teacher, you began your professional training with some understanding of the mathematical concepts, procedures, facts, skills, as well as understanding of how mathematics must be taught or how teaching mathematical concepts, procedures, facts, skills, is done, from your experiences during school mathematics lessons or even with your parents you are going to teach, which you might have eventually intellectually approved or disapproved due to new experiences you went through (e.g. the curriculum you learnt, your interactions with lecturers, different views/opinions you interacted with during discussions). In this section you are assessing the changes or improvement you perceive in those understandings during your two-year training.

Please indicate the **degree** to which you agree or disagree with each statement below by circling ***only one*** response to the right of each statement.

Key: SD = Strongly Disagree **D** = Disagree **A** = Agree **SA** = Strongly Agree

My experiences in learning to teach Foundation Phase mathematics over the past two years have adequately prepared me and I believe I can:

1.	explain to young children why mathematical procedures work	SD	D	A	SA
2.	provide a problem-solving learning context for enhancing young children's interest in problem-solving	SD	D	A	SA
3.	assist young children to finding answers to problems when using different strategies	SD	D	A	SA
4.	explain solution methods or strategies in problem solving to young children	SD	D	A	SA
5.	explain my understanding of the similarities and differences among children's representations, solutions, or methods on a problem	SD	D	A	SA
6.	assist young children to solve problems requiring ideas and strategies known or unknown to them	SD	D	A	SA
7.	assist young children to solve problems requiring multiple ideas and strategies	SD	D	A	SA
8.	help young children connect their mathematical ideas in problem solving tasks	SD	D	A	SA
9.	select appropriate activities and resources for helping young children's thinking in problem solving	SD	D	A	SA
10.	use effective questioning skills to access young children's thinking in solving a problem	SD	D	A	SA
11.	plan and implement mathematics lessons that cater for young children with different learning abilities	SD	D	A	SA
12.	critically reflect on the effectiveness of my teaching methodology in dealing with young children	SD	D	A	SA
13.	use concrete materials to assist young children to understand mathematical ideas and procedures	SD	D	A	SA
14.	assess young children's understanding of mathematical concepts and procedures	SD	D	A	SA

Appendix 2: Interview Protocol for Assessing the two-year PD of PSTs (Phases A)

SECTION A

PART ONE

As an aspiring mathematics teacher, you began your professional training with your own views about what mathematics is and how it should be taught and learnt, which you might have eventually intellectually approved or disapproved due to new experiences you went through (e.g. the curriculum you learnt, your interactions with lecturers, different views/opinions you interacted with during discussions). During your two-year professional training

1. What change(s) or improvement(s) do you perceive in your:
    a) beliefs about the subject matter of mathematics (what mathematics is)?
    b) beliefs about teaching and learning of mathematics (how it should be taught and learnt)?
    c) misconceptions about mathematics and the teaching and learning of it?
    d) attitudes towards mathematics and the teaching and learning of it?
2. What can the change(s) you perceive above afford you to do to improve teaching and learning Foundation Phase mathematics?
3. Would you say that your two years of learning to teach have adequately transformed your beliefs, attitudes, misconceptions?

SECTION B

PART TWO

As an aspiring mathematics teacher, you began your professional training with some understanding of the mathematical concepts, procedures, facts, skills, you are going to teach, which you might have eventually intellectually approved or disapproved due to new experiences you went through (e.g. the curriculum you learnt, your interactions with lecturers, different views/opinions you interacted with during discussions). During your two-year professional training

1. What improvement(s) do you perceive in your understanding of the mathematics contents you are going to teach?
2. What can the improvement(s) you perceive above afford you to do to improve teaching and learning Foundation Phase mathematics?
3. Would you say that your two years of learning to teach have adequately improved your understanding of the mathematical concepts, procedures, facts, skills, ?

SECTION C

PART THREE

As an aspiring mathematics teacher, you began your professional training with your own understanding of how mathematics must be taught or how teaching mathematical concepts, procedures, facts, skills, is done, from your experiences during school mathematics lessons or even with your parents, which you might have eventually intellectually approved or disapproved due to new experiences you went through (e.g. the curriculum you learnt, your interactions with lecturers, different views/opinions you interacted with during discussions). During your two-year professional training

1. What improvement(s) do you perceive in the development of your PCK for (i.e. knowledge for teaching) Foundation Phase mathematics?
2. What can the improvement(s) you perceive above afford you to do to improve teaching and learning Foundation Phase mathematics?
3. Would you say that your two years of learning to teach have adequately developed your understanding of how to teach or knowledge for teaching the mathematical concepts, procedures, facts, skills, during your two years of learning experiences?

SECTION D

PART FOUR

During this two-year professional training towards becoming a Foundation Phase mathematics teacher, which of the following learning achievements would you say has/have most improved?

1. Changing/transforming your beliefs, attitudes, and misconceptions about mathematics and the teaching and learning of it
2. Improving your understanding of the mathematics contents you are going to teach
3. Developing your PCK for (i.e. knowledge for teaching) Foundation Phase mathematics

Appendix 3: Questionnaire for Assessing PST' PD in the 3rd year (Phase B)

INTRODUCTION

This academic exercise is intended to collect data on the topic: **"PERCEPTIONS OF PRE-SERVICE TEACHERS IN FOUNDATION PHASE MATHEMATICS ABOUT THEIR PROFESSIONAL DEVELOPMENT".**

This is a PhD research being undertaken in the Department of Curriculum Studies, Faculty of Education, Stellenbosch University, South Africa.

The purpose of this exercise is to elicit your viewpoints about your professional development in learning to teach Foundation Phase Mathematics **from the ETE's teaching expertise you have experienced** in the 3rd year Foundation Phase Mathematics module.

Your voluntary participation in this exercise is highly appreciated. If you volunteer to participate in this study, I would like you to **honestly** express your views, on this questionnaire, about the influences/impacts of the teaching expertise you have experienced on:

- transforming your beliefs about the subject matter of the mathematics and the teaching and learning of it.
- improving your understanding of the mathematics content knowledge (CK) you are going to teach.
- developing your pedagogical content knowledge (PCK) in Foundation Phase mathematics.

All your responses in this exercise will be kept confidential and anonymous in my presentations and analysis.

Please write the last **four digits** of your Student ID: …….

There are **five** different sections to be completed. You are required to respond to **all** the questions in **all** the sections.

Section A- Evaluation of the improvements in your beliefs about the subject matter of mathematics and the teaching and learning of mathematics.

Section B- Assessment of the impacts of the improvements in your beliefs about the subject matter of mathematics and the teaching and learning of mathematics on your teaching capacity.

Section C-Evaluation of the improvements in your understanding of Foundation Phase Mathematics CK and development of your PCK.

Section D- Assessment of the impacts of the improvements in your understanding of Foundation Phase Mathematics CK and the development of your PCK on your abilities to deliver as a teacher.

Section E- Identification of specific **attribute(s) of the teaching expertise** you have experienced in this 3rd year Foundation Phase Mathematics module, that is/are connected to the above improvements and what the improvements can afford you to do in teaching.

Some of the teaching expertise you might have experienced

Clarity in lesson presentations/teaching
Enthusiasm in teaching
Articulation of subject knowledge expertise in teaching
Preparation for and organisations of teaching
Motivating/stimulating students' interest and engagement with learning experiences
Understanding of students' learning needs and creating productive learning climate
Humour in teaching
Positive relationships with students and approachability

Section A: Evaluation of the improvements in your beliefs about the subject matter of mathematics and the teaching and learning of mathematics.

Please indicate the **degree** to which you agree or disagree with each statement below, by circling ***only one*** response to the right of each statement.

Key: SD = Strongly Disagree **D** = Disagree **A** = Agree **SA** = Strongly Agree

My experiences in learning to teach Foundation Phase Mathematics from the **teaching expertise** above, during my 3rd year training in Foundation Phase Mathematics module, have adequately encouraged me to …

1.	reflect on and correct my ***misconceptions*** about teaching young children mathematics.	SD	D	A SA
2.	reflect on and correct my ***misconceptions*** about how young children learn mathematics.	SD	D	A SA
3.	reflect on and correct my ***misconceptions*** about the mathematics I will be teaching young children.	SD	D	A SA
4.	overcome my feelings of incompetency in engaging young children in solving mathematical problems.	SD	D	A SA
5.	be critical about the needs and characteristics of children in my teaching strategies.	SD	D	A SA
6.	think carefully through my decisions about suitable ways to cater for children's needs and characteristics in teaching mathematics.	SD	D	A SA
7.	focus on the content of the mathematics I will be teaching in my teaching strategies.	SD	D	A SA

Section B: Assessment of the impacts of the improvements in your beliefs about the subject matter of mathematics and the teaching and learning of mathematics on your teaching capacity.

Please indicate the **degree** to which you agree or disagree with each statement below, by circling ***only one*** response to the right of each statement.

Key: SD = Strongly Disagree **D** = Disagree **A** = Agree **SA** = Strongly Agree

My experiences in learning to teach Foundation Phase Mathematics from the **teaching expertise** above, during my 3rd year training in Foundation Phase Mathematics module, have adequately changed my beliefs about the subject matter of mathematics and the teaching and learning of mathematics and I believe I can …

1. engage children in learning mathematics for meaningful understanding as I reflect and correct my misconceptions.	SD D A SA
2. implement a learner-centred approach in my mathematics lessons to help children learn mathematics effectively.	SD D A SA
3. assist children to overcome their anxieties by engaging them in problem-solving.	SD D A SA
4. assist children to overcome their anxieties by engaging them in using manipulatives.	SD D A SA
5. assist children to overcome their incompetency by engaging them in problem-solving.	SD D A SA
6. focus my instructional decisions on the interest of my students.	SD D A SA
7. create opportunities for effective communication and sharing (active participations and discussions) of ideas among children in my teaching.	SD D A SA

Section C: Evaluation of the improvements in your understanding of Foundation Phase Mathematics CK and development of your PCK.

Please indicate the **degree** to which you agree or disagree with each statement below, by circling ***only one*** response to the right of each statement.

Key: SD = Strongly Disagree **D** = Disagree **A** = Agree **SA** = Strongly Agree

My experiences in learning to teach Foundation Phase Mathematics from the **teaching expertise** above, during my 3rd year training in Foundation Phase Mathematics module, have adequately improved my understanding of …

1. the mathematical concepts and procedures I will be teaching young children.	SD D A SA
2. how young children learn about number operations and relationships.	SD D A SA
3. how to assist young children to find answers to problems by/when using different strategies.	SD D A SA
4. how to explain to young children why mathematical procedures work.	SD D A SA
5. how to explain solution methods in problem-solving to young children.	SD D A SA
6. how to explain the similarities and differences among young children's representations, solutions, or methods in a problem.	SD D A SA
7. how to assist young children to solve problems requiring multiple ideas and strategies.	SD D A SA
8. how to access young children's thinking of mathematical ideas in learning.	SD D A SA
9. how to help young children connect their mathematical ideas in problem-solving.	SD D A SA
10. how to assess young children's understanding of mathematical ideas and procedures.	SD D A SA

Section D: Assessment of the impacts of the improvements in your understanding of the CK and development of your PCK on your ability to deliver as a teacher.

Please indicate the **degree** to which you agree or disagree with each statement below, by circling ***only one*** response to the right of each statement.

Key: SD = Strongly Disagree **D** = Disagree **A** = Agree **SA** = Strongly Agree

My experiences in learning to teach Foundation Phase Mathematics from the **teaching expertise** above, during my 3rd year training in Foundation Phase Mathematics module, have adequately improved my understanding of Foundation Phase Mathematics CK and development of my PCK and I believe I can …

1.	explain to young children why mathematical procedures work.	SD	D	A SA
2.	provide a problem-solving learning environment for enhancing young children's interest in problem-solving.	SD	D	A SA
3.	assist young children to find answers to problems by/when using different strategies.	SD	D	A SA
4.	explain solution methods or strategies in problem-solving to young children.	SD	D	A SA
5.	explain my understanding of the similarities and differences among children's representations, solutions, or methods on a problem.	SD	D	A SA
6.	assist young children to solve problems requiring ideas and strategies known or unknown to them.	SD	D	A SA
7.	assist young children to solve problems requiring multiple ideas and strategies.	SD	D	A SA
8.	help young children connect their mathematical ideas in problem-solving tasks.	SD	D	A SA
9.	select appropriate activities and resources for helping young children's thinking in problem-solving.	SD	D	A SA
10.	use effective questioning skills to access young children's thinking in solving a problem.	SD	D	A SA
11.	plan and implement mathematics lessons that cater for young children with different learning abilities.	SD	D	A SA
12.	critically reflect on the effectiveness of my teaching methodologies in dealing with young children.	SD	D	A SA
13.	use concrete materials to assist young children to understand mathematical ideas and procedures.	SD	D	A SA
14.	assess young children's understanding of mathematical concept and procedures.	SD	D	A SA

Section E: Rank the influences of the teaching expertise listed in the tables below, which you think has/have **adequately** enhanced your PD**.**

Please circle the **ranking** that best represents your impression/opinion. You can choose ***as many of the teaching expertise as*** are applicable in your view.

1. During our interactions with the lecturer, my beliefs or perceptions about the subject matter of mathematics and the teaching and learning of it, were **adequately** transformed by his/her....

Not at all (NAA) Low (L) High (H) Very high (VH)

The teaching expertise of the lecturer

Clarity in lesson presentations/teaching	NAA	L	H	VH
Enthusiasm in teaching	NAA	L	H	VH
Articulation of subject knowledge expertise in teaching	NAA	L	H	VH
Preparation for and organisations of teaching	NAA	L	H	VH
Motivating/stimulating students' interest and engagement with learning experiences	NAA	L	H	VH
Understanding of students' learning needs and creating productive learning climate	NAA	L	H	VH
Humour in teaching	NAA	L	H	VH
Positive relationships with students and approachability	NAA	L	H	VH

2. During our interactions with the lecturer, my understanding of the Foundation Phase Mathematics content knowledge (CK) was **adequately** enhanced by his/her ....

Not at all (NAA) Low (L) High (H) Very high (VH)

The teaching expertise of the lecturer

Clarity in lesson presentations/teaching	NAA	L	H	VH
Enthusiasm in teaching	NAA	L	H	VH
Articulation of subject knowledge expertise in teaching	NAA	L	H	VH
Preparation for and organisations of teaching	NAA	L	H	VH
Motivating/stimulating students' interest and engagement with learning experiences	NAA	L	H	VH
Understanding of students' learning needs and creating productive learning climate	NAA	L	H	VH
Humour in teaching	NAA	L	H	VH
Positive relationships with students and approachability	NAA	L	H	VH

3. During our interactions with the lecturer, the development of my pedagogical content knowledge (PCK)for Foundation Phase Mathematics was **adequately** enhanced by his/her ...

Not at all (NAA) Low (L) High (H) Very high (VH)

The teaching expertise of the lecturer

Clarity in lesson presentations/teaching	NAA	L	H	VH
Enthusiasm in teaching	NAA	L	H	VH
Articulation of subject knowledge expertise in teaching	NAA	L	H	VH
Preparation for and organisations of teaching	NAA	L	H	VH
Motivating/stimulating students' interest and engagement with learning experiences	NAA	L	H	VH
Understanding of students' learning needs and creating productive learning climate	NAA	L	H	VH
Humour in teaching	NAA	L	H	VH
Positive relationships with students and approachability	NAA	L	H	VH

Appendix 4: Interview Protocol for Assessing the PD of PSTs in the 3rd year when they were learning to teach from the ETE

SECTION A

PART ONE (1)

From your interactions with the teaching expertise/competencies of the lecturer for the 3rd year Foundation Phase mathematics module,

1. What change(s) or improvement(s) do you perceive in your:
    a. beliefs about the subject matter of mathematics (what mathematics is)?
    b. beliefs about teaching and learning of mathematics (how it should be taught and learnt)?
    c. misconceptions about mathematics and the teaching and learning of it?
    d. attitudes towards mathematics and the teaching and learning of it?

2. What have you learnt from (or what have been the benefits of) the following teaching expertise of the lecturer for the 3rd year Foundation Phase mathematics module to improve your beliefs, attitudes, and misconceptions above?
    a. Enthusiasm in teaching;
    b. Motivating/stimulating students' interest and engagement with learning experiences;
    c. Positive relationships with students and approachability;
    d. Understanding of students' learning needs and creating productive learning climate;
    e. Humour in teaching;
    f. Articulation of subject knowledge expertise;
    g. Clarity in lesson presentations/teaching;
    h. Preparation for and organisations of teaching

3. Which of the lecturer's teaching expertise above had the greatest impacts on the above improvements you perceive in your beliefs, attitudes, and misconceptions?

4. What can the change(s) you perceive above afford you to do to improve teaching and learning Foundation Phase mathematics?

5. Comparing your learning from the teaching expertise above to your learning in the past two-years towards becoming an effective Foundation Phase mathematics teacher, which would you say had greatly improved your beliefs, attitudes, and misconceptions?

SECTION B

PART TWO (2)

From your interactions with the teaching expertise/competencies of the lecturer for the 3rd year Foundation Phase mathematics module,

1. What improvement(s) do you perceive in your understanding of the mathematics contents you are going to teach?

2. What have you learnt from [or what have been the benefits of] the following teaching expertise of the lecturer for the 3rd year Foundation Phase mathematics module to improve your understanding of the mathematics contents you are going to teach?
   a. Enthusiasm in teaching;
   b. Motivating/stimulating students' interest and engagement with learning experiences;
   c. Positive relationships with students and approachability;
   d. Understanding of students' learning needs and creating productive learning climate;
   e. Humour in teaching;
   f. Articulation of subject knowledge expertise;
   g. Clarity in lesson presentations/teaching;
   h. Preparation for and organisations of teaching

3. Which of the lecturer's teaching expertise above had the greatest impacts on the above improvements you perceive in understanding of the mathematics contents you are going to teach?

4. What can the improvement(s) you perceive above afford you to do to improve teaching and learning Foundation Phase mathematics?

5. Comparing your learning from the teaching expertise above to your learning in the past two-years towards becoming an effective Foundation Phase mathematics teacher, which would you say had greatly improved your understanding of the mathematics contents you are going to teach?

SECTION C

PART THREE (3)

From your interactions with the teaching expertise/competencies of the lecturer for the 3rd year Foundation Phase mathematics module,

1. What improvement(s) do you perceive in the development of your PCK for (i.e. knowledge for teaching) Foundation Phase mathematics?

2. What have you learnt from (or what have been the benefits of) the following teaching expertise of the lecturer for the 3rd year Foundation Phase mathematics module to improve the development of your PCK for (i.e. knowledge for teaching) Foundation Phase mathematics above?
   a. Enthusiasm in teaching;
   b. Motivating/stimulating students' interest and engagement with learning experiences;
   c. Positive relationships with students and approachability;
   d. Understanding of students' learning needs and creating productive learning climate;
   e. Humour in teaching;
   f. Articulation of subject knowledge expertise;
   g. Clarity in lesson presentations/teaching;
   h. Preparation for and organisations of teaching

3. Which of the lecturer's teaching expertise above had the greatest impacts on the above improvements you perceive in the development of your PCK for [i.e. knowledge for teaching] Foundation Phase mathematics?

4. What can the improvement(s) you perceive above afford you to do to improve teaching and learning Foundation Phase mathematics?

5. Comparing your learning from the teaching expertise above to your learning in the past two-years towards becoming an effective Foundation Phase mathematics teacher, which would you say had greatly improved the development of your PCK for (i.e. knowledge for teaching) Foundation Phase mathematics?

SECTION D

PART FOUR (4)

From your interactions with the teaching expertise/competencies of the lecturer for the 3rd year Foundation Phase mathematics module, which of the following learning achievements would you say has/have most improved?

a. Changing/transforming your beliefs, attitudes, and misconceptions about mathematics and the teaching and learning of it
b. Improving your understanding of the mathematics contents you are going to teach
c. Developing your PCK for (i.e. knowledge for teaching) Foundation Phase mathematics

Appendix 5: Sample of qualitative analysis

PSTs' voices: Evidence of PSTs' pre-existing beliefs about mathematics	**Emerging themes**
PST 1:"... I had a very singular view about math; i viewed it like a regimented subject,..." PST 2 : "I had block about mathematics ..." PST 3: "I almost had a "mental block" towards math ..." PST 4: " I was sceptical about mathematics ..."	1. Negative views or experiences about math 2. Viewing math as challenging 3. Anxiety towards math 4. lacking confidence in their mathematical abilities
PSTs' voices: Evidence of perceived transformation in PSTs' beliefs about mathematics	**Emerging themes**
PST 4: "I am beginning to see math as less challenging" PST 2: "... now i can see where a mathematical idea came along and why .... letting the kids figure out for themselves not spoon feeding them" PST 5: "... I am interested in looking at the reasoning behind it [the subject matter knowledge] instead of just like trying to find an answer, ..." PST 3: "... my mental block towards math is gradually diminishing,... I will be "encouraging" learners to do math and appreciate math" PST 1: "…open my mind of how children think…'	1. Beginning to develop positive views about math 2. developing their confidence in doing mathematics 3. mathematics is basically learning how to solve problems
PSTs' voices: PSTs' voice: Evidence of perceived transformation in PSTs' beliefs about the teaching and learning of mathematics	**Emerging themes**
PST 1: "...be open to different manners in which people interpret mathematics; should take in everyone's account of it; creating more cognitive thinking within the learner ... idea of mathematics should be integrated …." PST 3: "... it needs to be built on the foundation of the first concept; "learning math from the point of view of the child; learn how they are going to learn it; understand how they might understand it" PST 5: "... learners figure out their own methods to find an answer, instead of trying to apply someone else's method... ... approach teaching like each child discovering and understanding learning for themselves" PST 2: "...teaching and learning of math has to be fun; teachers should let the kids solve the problem themselves" PST 4: "... teaching/learning should be done through problem solving approach... allow learners to come out with their approaches to solving the problems not to interfere with their processes, ... " PST 6: "... math should be taught from the perspective of the learner, ... see it through the way children think ... understand it in the different ways in which they are thinking, ..."	1. teaching and learning of math should be an interactive approach 2. allow the kids to struggle and figure it out the ideas for themselves 3. teaching and learning of math should be a problem solving approach 4. learning math as interrelated ideas 5. understanding how children learn math

PSTs' voice: Evidence of perceived development of CK	Emerging theme
PST 1: "I think i understand concepts and procedures a lot better ... just the thought of how to teach it the procedure that the teacher should go through improved my CK ... PST 3: "... I think that I have sort of become more comfortable and less overwhelmed with learning math using different methods ..." PST 2: "... I understand what is going on behind the scenes ...; I think of different ways i will teach it ...; I am fixing my mathematical knowledge and coming up with new ideas for myself ..." PST 5: "... many methods is helpful ... it's okay if they have more than one method that you are using in the classroom to solve problem" PST 6: "... I understand why we do it the way we do and why it carries on and interlinks with the things that we do in high school so it has improved and i understand it more ..."	Appreciation of learning math through many different methods and as a result improved their CK: a. understanding concepts and procedures b. understanding procedures why work the way they do c. understanding of the connections between ideas
PSTs' voice: Evidence of perceived development of PCK	**Emerging theme**
PST 1: "... ask questions to make them think deeper ... understand what they are thinking and using how they are thinking to guide them ..." PST 3: "... allowing them to solve a problem using a strategy that they feel comfortable with whether it is drawing their answer or working it out, ..." PST 5: "... guiding the learner from the prior knowledge to understand what the teacher is trying to get across, ... use like physical objects or like real life situations that are motivating the learner and the learning experiences ..." PST 6: "... learn out of their mistakes of my teachers... adjusting your mind to how a small child thinks about idea he/she is learning ..." PST 2: "... i want them to think, discuss it, battle with it, to try and figure it out, ..." PST 4: "... encourage learners to work in smaller groups ..."	Encourage learners to work with different strategies Stimulate learner thinking Encouraging problem solving in teaching and learning Encourage learners' active participation

Appendix 6: Document of Ethical Clearance from the Research Ethics Committee, Stellenbosch University

Approval Notice New Application

25-Sep-2014 Yau, Kassim KA

Proposal #: DESC/Yau/Sep2014/18 Title: Perceptions of pre-service teachers in Foundation Phase Mathematics about their Professional Development

Dear Mr Kassim Yau,

Your New Application received on 04-Sep-2014, was reviewed Please note the following information about your approved research proposal:

Proposal Approval Period: 11-Sep-2014 -10-Sep-2015

Please take note of the general Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

Please remember to use your proposal number (DESC/Yau/Sep2014/18) on any documents or correspondence with the REC concerning your research proposal.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

Also note that a progress report should be submitted to the Committee before the approval period has expired if a continuation is required. The Committee will then consider the continuation of the project for a further year (if necessary).

This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki and the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health). Annually a number of projects may be selected randomly for an external audit.

National Health Research Ethics Committee (NHREC) registration number REC-050411-032.

We wish you the best as you conduct your research.

If you have any questions or need further help, please contact the REC office at 0218089183.

Sincerely,

Clarissa Graham REC Coordinator Research Ethics Committee: Human Research (Humanities)

Investigator Responsibilities

Protection of Human Research Participants

Some of the general responsibilities investigators have when conducting research involving human participants are listed below:

1.Conducting the Research. You are responsible for making sure that the research is conducted according to the REC approved research protocol. You are also responsible for the actions of all your co-investigators and research staff involved with this research. You must also ensure that the research is conducted within the standards of your field of research.

2.Participant Enrollment. You may not recruit or enroll participants prior to the REC approval date or after the expiration date of REC approval. All recruitment materials for any form of media must be approved by the REC prior to their use. If you need to recruit more participants than was noted in your REC approval letter, you must submit an amendment requesting an increase in the number of participants.

3.Informed Consent. You are responsible for obtaining and documenting effective informed consent using only the REC-approved consent documents, and for ensuring that no human participants are involved in research prior to obtaining their informed consent. Please give all participants copies of the signed informed consent documents. Keep the originals in your secured research files for at least five (5) years.

4.Continuing Review. The REC must review and approve all REC-approved research proposals at intervals appropriate to the degree of risk but not less than once per year. There is no grace period. Prior to the date on which the REC approval of the research expires, it is your responsibility to submit the continuing review report in a timely fashion to ensure a lapse in REC approval does not occur. If REC approval of your research lapses, you must stop new participant enrollment, and contact the REC office immediately.

5.Amendments and Changes. If you wish to amend or change any aspect of your research (such as research design, interventions or procedures, number of participants, participant population, informed consent document, instruments, surveys or recruiting material), you must submit the amendment to the REC for review using the current Amendment Form. You may not initiate any amendments or changes to your research without first obtaining written REC review and approval. The only exception is when it is necessary to eliminate apparent immediate hazards to participants and the REC should be immediately informed of this necessity.

6.Adverse or Unanticipated Events. Any serious adverse events, participant complaints, and all unanticipated problems that involve risks to participants or others, as well as any research related injuries, occurring at this institution or at other performance sites must be reported to Malene Fouch within five (5) days of discovery of the incident. You must also report any instances of serious or continuing problems, or non-compliance with the RECs requirements for protecting human research participants. The only exception to this policy is that the death of a research participant must be reported in accordance with the Stellenbosch Universtiy Research Ethics Committee Standard Operating Procedures. All reportable events should be submitted to the REC using the Serious Adverse Event Report Form.

7.Research Record Keeping. You must keep the following research related records, at a minimum, in a secure location for a minimum of five years: the REC approved research proposal and all amendments; all informed consent documents; recruiting materials; continuing review reports; adverse or unanticipated events; and all correspondence from the REC

8.Provision of Counselling or emergency support. When a dedicated counsellor or psychologist provides support to a participant without prior REC review and approval, to the extent permitted by law, such activities will not be recognised as research nor the data used in support of research. Such cases should be indicated in the progress report or final report.

9.Final reports. When you have completed (no further participant enrollment, interactions, interventions or data analysis) or stopped work on your research, you must submit a Final Report to the REC.

10.On-Site Evaluations, Inspections, or Audits. If you are notified that your research will be reviewed or audited by the sponsor or any other external agency or any internal group, you must inform the REC immediately of the impending audit/evaluation.

Appendix 7: Document of Ethical Clearance from the Department of Curriculum Studies, Stellenbosch University,

2 September 2014

Mr Kassim Alimi Yau Department of Curriculum Studies Stellenbosch University

Dear Mr Yau

Concerning research project: Perceptions of pre-service teachers in Foundation Phase Mathematics about their Professional Development

The researcher has institutional permission to proceed with this project as stipulated in the institutional permission application. This permission is granted on the following conditions:

• The researcher must obtain ethical clearance from the SU Research Ethics Committee before proceeding with this study.

• Participation is voluntary.

• Persons may not be coerced into participation.

• Persons who choose to participate must be informed of the purpose of the research, all the aspects of their participation, their role in the research and their rights as participants. Participants must consent to participation. The researcher may not proceed until he is confident that all the before mentioned has been established and recorded.

• Persons who choose not to participate may not be penalized as a result of non-participation.

• Participants may withdraw their participation at any time, and without consequence.

• Data must be collected in a way that ensures the anonymity of all participants.

• The data must be responsibly and suitably protected.

• The use of the collected data may not be extended beyond the purpose of this study.

• Individuals may not be identified in the report(s) or publication(s) of the results of the study.

• The privacy of individuals must be respected and protected.

• The researcher must conduct his research within the provisions of the Protection of Personal Information Act, 2013.

Best wishes,

Prof Ian Cloete Senior Director: Institutional Research and Planning

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