Pre-service teachers'
mathematics profiles
and the influence thereof on their
instructional behaviour

by

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ABSTRACT

This study examined the influence of the mathematics profiles of secondary school pre-service mathematics teachers on their instructional behaviour. The mathematics profile construct was determined with respect to four components, namely, subject matter knowledge, pedagogical content knowledge, conceptions of mathematics and beliefs about the teaching and learning of mathematics. The instructional behaviour construct was studied with regard to participants' use of a traditional versus reform approach to teaching, and whether learners were afforded an authoritarian versus democratic style of learning. Social constructivism formed the epistemological underpinning. The context for the study was a Post Graduate Certificate in Education (PGCE) course at a university in South Africa. The study adopted a qualitative post-hoc research approach of seven case studies. The final portfolios submitted by participants as part of their PGCE course were used as the main source of data. Through participant and researcher reflections, a visual representation of each participant's mathematics profile and instructional behaviour was constructed. These were then compared in within-case and cross-case comparisons. Findings indicated that the mathematics profiles of pre-service mathematics teachers have an influence on either enabling or constraining the development of their instructional behaviour. An improvement in the pedagogical content knowledge of mathematics teachers without positive changes in their conceptions and beliefs and the quality of their reflections and subject matter knowledge does not result in reformed instructional behaviour. The mathematics profile as a package needs to be developed in order for pre-service mathematics teachers to make the required changes in their instructional behaviour towards a more reform-orientated approach to teaching and learning of mathematics.

Keywords: pre-service, mathematics, teaching, learning, secondary, instructional behaviour, profiles, social constructivism

To God be all the glory

Isaiah 58 vs 8

Then shall your light break forth like the morning, and your healing (your restoration and the power of a new life) shall spring forth speedily; your righteousness (your rightness, your justice, and your right relationship with God) shall go before you [conducting you to peace and prosperity], and the glory of the Lord shall be your rear guard.

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LIST OF ACRONYMS

PGCE	Post Graduate Certificate in Education
OBE	Outcomes-based education
DoE	Department of Education
FET	Further Education and Training
TIMSS	Third/(Trends in) International Mathematics and Science Study
NGO	Non-governmental organisation
NCS	National Curriculum Statement
C2005	Curriculum 2005
IPET	Initial Professional Education and Training
CPTD	Continuing Professional Training and Development
NQF	National Qualifications Framework
SAQA	South African Qualifications Authority
CHE	Council for Higher Education
HEQC	Higher Education Quality Committee
LTD	Learning Task Design
PCK	Pedagogical content knowledge
SBE	School-based education
BSc	Bachelor of Science
BSecEd	Bachelor of Secondary Education
BEd	Bachelor of Education
BA	Bachelor of Arts

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1.1 Introduction

How does one mathematically determine whether the gradient of a straight line is positive or negative? I asked this of a mathematics student teacher I was observing and was surprised that he could provide no mathematical explanation. Instead he explained that a positive gradient could be recognised by the fact that if you were walking along the line, it would be like walking up a mountain so you would feel really positive. On the other hand the negative gradient or slope is like coming down a mountain and one usually feels negative coming down a mountain. He confessed that he relied mainly on memorisation to explain mathematical concepts.

This is one of many similar examples where mathematics is endorsed as a process of rote memorisation rather than a discipline requiring understanding. In my role as a mathematics educator (or specialisation lecturer), I became increasingly concerned about the low level of content knowledge as well as teaching and learning strategies being demonstrated by pre-service mathematics students during practical teaching periods. Despite the global reform being initiated in mathematics education, the students continued to demonstrate a traditional and rote learning approach to teaching mathematics with only superficial motions towards a more constructivist paradigm. With their own experiences of mathematics teaching at school most likely being limited to a traditional approach, and the lack of deep change occurring in most schools where they would teach, I began to wonder how we could most effectively achieve the change in pedagogy we are aiming towards.

Along with many other countries, South Africa has experienced radical curriculum reform during the past ten years. Our latest curriculum, based on a philosophy of Outcomes-Based Education ([OBE], see for example Jansen, 1998, 1999; Muller, 1998), demands a range of teaching strategies and roles on the part of the teacher as outlined in the Norms and Standards for Educators (Department of Education [DoE], 2000). These include being mediators of learning, interpreters and designers of Learning Programmes

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and materials, leaders, administrators and managers, scholars, researchers and lifelong learners, community members, citizens and pastors, assessors and Learning Area or Phase specialists. The curriculum statement also makes the point that setting and achieving outcomes encourages a learner-centred and activity-based approach to education.

This reform in the type of teacher envisioned has also brought about changes in pre-service teacher training programmes. Much of the research focusing on teacher training makes an attempt to find out how training should be tailored in order to optimally prepare students and teachers for the changing role of teaching they have to fulfil (e.g. Shulman, 1986, 1987; Ball, 1990; Ma, 1999; Peressini, Borko, Romagnano, Knuth & Willis, 2004; Adler, 2005; Adler, Davis & Kazima, 2005). The aim of this research project is to contribute to the existing body of research in this regard, by *investigating the relationship between the **mathematics profiles**[1] of secondary school pre-service mathematics teachers, and the **instructional behaviour** they develop relating to the teaching and learning of mathematics.*

I hold the position of lecturer at a university in South Africa. I graduated from this same university in 1993 with a Bachelor of Arts (majoring in Psychology and Northern Sotho[2]) and a Higher Education Diploma, specialising in teaching Northern Sotho, Mathematics and French. In 1994 I began to teach mathematics at an urban girls school where I remained for eight years. The headmistress of the school during that time was a mathematics educator herself and provided me with the freedom to try new approaches in the teaching and learning of mathematics. This largely formed the basis for the social constructivist approach I assume within my role as a mathematics educator. During this time I also spent some time teaching in the United Kingdom and writing a series of

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[1] The term "mathematics profile" I introduce in this study is further elaborated on in the following section. It refers to the combination of each participant's subject matter knowledge, pedagogical content knowledge, conceptions of mathematics and beliefs about the teaching and learning of mathematics. The term profile is more commonly used in the field of Psychology, for example, a personality or a brain profile.

[2] This is one of the 11 official languages of South Africa. It is an indigenous language spoken predominantly in the Limpopo and Gauteng provinces.

mathematics textbooks with an experienced panel of authors. These opportunities kept challenging me with regard to the traditional approach to teaching mathematics that I had experienced as a learner at school and how these practices could be reformed in order to equip learners to be stronger mathematical thinkers rather than rote learners. In 2002 I joined the university as a lecturer in mathematics education. While making that shift from a teacher orientation to a researcher, I found literature that supported what I had been experiencing during my prior years of teaching with regard to the traditional versus reform tension. I embraced social constructivism and this gave me a framework within which I could develop my instructional behaviour as a mathematics educator. In this position, however, I also became increasingly frustrated at the apparent lack of change evident in the mathematics pre-service training as well as in mathematics classrooms I visited when assessing my students. This frustration pre-empted a curiosity about what either enables or constrains pre-service teachers in reforming their approach to the teaching and learning of mathematics. This curiosity eventually led to this study. This is further outlined in Section 1.2.1.

One of my responsibilities at the university is teaching the mathematics specialisation module for the one-year Post Graduate Certificate in Education (PGCE)[3] programme. I therefore elected to use data obtained from these students[4], specifically those enrolled for a Further Education and Training (FET)[5] qualification. As part of their end-of-year summative evaluation for the PGCE, students are required to prepare portfolios representing their professional development as mathematics facilitators throughout the year. These include personal profiles such as brain profile tests, personality assessments, their daily reflections, their lesson plans, video-recordings from their school-based practice, assessment records from their specialisation lecturer, their school-based mentor

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[3] This was previously known as the Higher Education Diploma. Students complete an undergraduate degree, such as a Bachelor of Arts and then enrol fulltime for this one-year diploma that certifies them as teachers. The other academic option that students in South Africa have to qualify as teachers is to enrol for a four-year Bachelor of Education degree.

[4] I use the term student and pre-service teacher interchangeably in this study with regard to tertiary education. The term "learner" refers to school education.

[5] The 12 years of compulsory schooling in South Africa comprises four phases of education, namely, the Early Childhood Education (Grade R – 3), the Intermediate phase (Grades 4 – 6), the Senior phase (Grades 7 – 9) and the Further Education and Training phase (Grades 10 – 12).

(a teacher at the school), peers (fellow PGCE students) and self-evaluations. Their final presentation of their portfolio as well as their verbal defence thereof is also video-recorded by the university. I chose to do the study "in arrears" (post-hoc) and at the end of 2008 obtained permission from the 2006, 2007 and 2008 FET students in mathematics to use their portfolios and any other relevant documentation/material from their PGCE year as my data set.

Using this data set I embarked on three data reduction processes. The first was to select data from the participants' portfolios to compile the participants' reflections, which are written in their own voice. The second was to use these reflections as well as the mathematics specialisation lecturers'[6] assessment reports and my own experience of working with each participant to write a researcher reflection. The researcher reflection is divided into two parts: one part reflects on the mathematics profile and the other on the instructional behaviour of each participant. The third reduction involved using participant and researcher reflections are to construct a visual representation of each participant's mathematics profile and instructional behaviour profile. These visual presentations facilitated the in-case and cross-case comparisons to establish the possible influence or links between their mathematics profiles and the instructional behaviour/approach the pre-service teachers display during their school-based practice teaching periods.

The main aim of the study was to explore the influence of the mathematics profiles of pre-service teachers on their instructional behaviour. The mathematics profiles were constructed from four components foregrounded in the literature, namely subject matter knowledge, pedagogical content knowledge, conceptions of mathematics and beliefs relating to the teaching and learning of mathematics. The instructional behaviour of each participant portrays their approach to teaching and learning mathematics. This is depicted specifically with regard to traditional versus reform teaching practices and democratic versus authoritarian learning experiences offered to learners. The seven participants came

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[6] During 2006 I was the only specialisation lecturer in mathematics responsible for the students. In 2007 and 2008 I had study leave for one of the semesters each year during which another lecturer took responsibility for the module and visited the students during their school-based experiences. On occasion we also both visited a student as part of the training process of the relief lecturer and to ensure consistency.

from the same university in South Africa and all enrolled for a one-year Post Graduate Certificate in Education between 2006 and 2008.

1.2 Background to the research

The intellectual puzzle I engage with in this research project has emerged from a variety of experiences I have had over the last few years in my position as a lecturer training pre-service mathematics teachers. The experiences involved workshops, lectures, interviews, observations and general interactions with pre-service as well as current teachers. The problem is encapsulated in the limited conceptual understanding of mathematics demonstrated by teachers and students of mathematics and the poor performance of learners in South Africa in mathematics. My assumption is that improving the mathematical understanding of mathematics teachers will result in stronger mathematics learners. In the sections that follow, further insight into the background to the problem is provided.

1.2.1 Training of pre-service mathematics students

Ma (1999) conducted a study investigating and comparing the mathematical understanding of a cohort of teachers in the United States and China. She concluded that the Chinese teachers demonstrated a deeper conceptual understanding of division in fractions than teachers in the United States. Using her research I adopted some of the questions she posed to the participants as a departure point for discussions in my methodology classes. Students in a third year methods class were asked if the calculation in Figure 1.1 could be performed by dividing the numerators and then dividing the denominators.

$$\frac{21}{35} \div \frac{3}{7} = \frac{7}{5}$$

Figure 1.1 Division of fractions calculation

The immediate response of most of the class was a resounding "no." After doing the calculation their own way (see Figure 1.2), most of the students then noted that the

solution presented in the calculation in Figure 1.1 was in fact correct. At least half the class were still adamant, however, that the calculation could not be done using the thinking process suggested above, even though the answer was correct. When asked to write down why they thought it could not be done that way, the general response was that "we were not taught to do it that way."
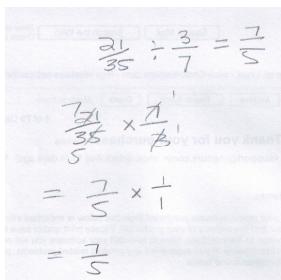
Figure 1.2 Example of a solution provided by a student

Students were then further requested to indicate how they would approach teaching the topic of division of fractions to a class. All the students focused their approach on teaching learners to multiply by the reciprocal. Without exception, none of the students could produce a mathematically correct reason why the method they were proposing to teach learners is acceptable and why it worked. The most common reason they gave was that division and multiplication are inverse operations and that the second fraction should therefore be inverted. When confronted with the counter example of applying their conjecture to the addition and subtraction of fractions, although aware of the incorrectness in their thinking, students were unable to find a suitable mathematical reason why we multiply by the reciprocal instead of dividing fractions.

This is one of many available vignettes providing anecdotal evidence of how students demonstrated their lack of conceptual understanding and their limited, instrumentalist view of mathematics. Ernest (1988, p.10) explains an instrumentalist view of mathematics as:

> …the view that mathematics, like a bag of tools, is made up of an accumulation of facts, rules and skills to be used by the trained artisan skilfully in the pursuance of some external end. Thus mathematics is a set of unrelated utilitarian rules and facts.

I became increasingly concerned about students who may continue to hold this view of mathematics as they enter the teaching profession. How would this view of mathematics

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enable them to be effective "mediators of learning" and "Learning Area specialists" as required by the norms and standards set out for educators[7] (DoE, 2000, p. 3)? Would this view and lack of insight perhaps confine them to a more traditional approach to teaching mathematics in their pedagogy?

1.2.2 South African learners' performance in mathematics

South Africa took part in the Third International Mathematics and Science Study (TIMSS – now referred to as Trends in Mathematics and Science Study) in 1995, 1999 and 2003, of which the latter two were conducted on Grade 8 learners. On all three occasions, South Africa was placed in the last position (in 2003 out of approximately 50 countries), being outperformed by other African countries such as Botswana, Tunisia, Egypt and Morocco (Howie, 2002; Reddy, 2006). TIMSS made use of Item Response Theory to calculate the achievement scores, with a scale of 800 points and a standard deviation of 100 points. In the 2003 results, the average scale score for Grade 8 South African learners was 264 (SE = 5.5) which was significantly lower than the international average scale score of 467 (SE = 0.5). The average scale score of South Africa in the 2003 TIMSS study compared to the average scale scores of other African countries that took part is depicted in Table 1-1 below (Mullis, Martin, Gonzalez & Chrostowski, 2004).

Table 1-1 Comparison of South African average mathematics scale score in TIMSS 2003 with other African countries

Country	Average age of learner	Average scale score	Standard Error
South Africa	15.1	264	5.5
Botswana	15.1	366	2.6
Tunisia	14.8	410	2.2

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[7] This document outlines the norms and standards required of teachers entering the profession and acts as a guideline for teaching training programmes.

Country	Average age of learner	Average scale score	Standard Error
Ghana	15.5	276	4.7
Egypt	14.4	406	3.5
Morocco	15.2	387	2.5

Table 1-2 is a breakdown of the mathematics enrolment and performance at Senior Certificate level from 2003 - 2007, the national performance in terms of the mathematics achievement of South African learners at school-leaving level is also of concern.

Table 1-2: National Senior Certificate Examination results (2003 - 2007)

	2003	2004	2005	2006	2007
Total no. candidates passing	322 492	330 717	347 184	351 217	368 217
Percent passing mathematics	40%	40%	40%	39%	41%
Pass on SG	33%	33%	32%	32%	34%
Pass on HG	7%	7%	8%	7%	7%

SG: Standard Grade

HG: Higher Grade

In 2008, there was no longer a distinction between Higher and Standard Grade. All learners in Grade 12 in 2008 had to write either mathematics or mathematical literacy[8]. There were 298 821 learners who wrote mathematics of which 46 % of them passed.

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[8] Prior to 1996 learners in Grade 10 were able to select mathematics as one of their six subjects for the FET phase. They then had the option to take mathematics on the higher (more difficult) grade or on the standard grade. From 1996 the policy was amended to ensure that all learners take some form of mathematics throughout their FET phase. Higher grade and standard grade options were removed and all learners have to now either select mathematics or mathematical literacy as one of their six subjects for the FET phase.

There were 263 464 learners who wrote mathematical literacy with 79 % of these learners passing.

According to the above results, learners in South Africa are underperforming in mathematics both nationally and internationally. Studies, where factors that contribute to mathematics performance have been analysed (Howie, 2002; Reddy, 2006), have been done to explore why this is the case. Howie (2002), analysing data collected from teachers in the TIMSS 1999 study found that in South African classrooms significantly more time (21%) was spent on re-teaching and clarification of content or procedures than in other countries on average (13%). South African teachers also spent more time on administrative tasks (13% compared to average 5% in other countries) and reviewing homework (26%) compared to the average of other countries (12%). The same study found that with respect to pedagogical practices, teachers of 16% of South African learners placed a high emphasis on mathematics reasoning and problem solving, which was comparable with the international average. However, while the pattern internationally appeared to be that learners of teachers who claimed to have this approach would achieve a correspondingly higher achievement, this was not the case with South African learners. In fact, the opposite was true. South African learners whose teachers reported placing a high emphasis on reasoning and problem solving achieved lower results (260 points) compared to learners whose teachers placed a lower emphasis on this approach (303 points).

Reddy (2006) compared the results of the 1999 and 2003 TIMSS data to find that on average the scores had decreased, although the difference was not statistically significant. She makes the following comment in her report (p. 52):

> Since 1998 (with the introduction of C2005), there have been many professional development courses and programmes for teachers. In addition, numerous interventions by government, private sector, business and non-governmental organisations have been made in schools, especially the African schools, with the objective of improving the state of mathematics and science education. However, it seems that despite these programmes there has been a decrease in mathematics performance in many schools.

Perhaps it is time to start asking ourselves why our professional development courses (both in-service and pre-service) are not having the desired improved effect on the

mathematics performance of our learners. Are we perhaps expecting teachers to change their pedagogical beliefs and practices when in fact their subject matter knowledge is a limiting factor in enabling them to effectively do this? Is there a specific type of mathematics profile that is more likely to end up breaking out of a more traditional approach? Perhaps teachers' views of teaching and learning mathematics are the factor we need to be foregrounding in professional development? These are the corner pieces of the puzzle I hope to unravel and understand more of within the context of this investigation on pre-service teachers.

1.2.3 Contract research project

During the course of 2004 I managed an independent evaluation for a non-governmental organisation (NGO) in the form of contract research (Barnes, 2008). The task was to evaluate the impact/effectiveness of an intervention[9] they were funding. The particular intervention was aimed at additional training and support for Intermediate Phase mathematics educators, mostly in rural areas. The evaluation was carried out in a randomly selected sample of 12 schools in one South African province. The evaluation sought to examine the impact and effect of the intervention on firstly the educators (at which the intervention was primarily aimed) and as a more distant outcome, the learner performance.

The evaluation collected data from approximately 1 104 learners and an average of 17 educators from the 12 schools. Three instruments were used in collecting data from educators. These included semi-structured interviews (that were recorded and transcribed), observation schedules (completed by fieldworkers sitting in on lessons) and educator questionnaires that the educators involved completed. Learner performance was measured through the administration of pre- and post-tests, which were identical. Once completed, the tests were manually coded (marked) by fieldworkers and the data captured

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[9] According to the NGO, the intervention focused on the following key aspects (outcomes): content knowledge of teachers, curriculum management, assessment and teaching practices. The intervention was designed with a view to improving teachers' skills with regard to the four aspects mentioned, in order to have a positive effect on learners' performance.

by data typists. A team from the university consisting of a statistician and two researchers specialising in mathematics education analysed and interpreted the data.

During the semi-structured interview, educators were asked by a fieldworker to offer their definition and views of mathematics as a subject. This was done in order to ascertain how the educators valued the place of the subject in the curriculum and how confident they were in teaching it. An educator's view of mathematics is often an indicator of the way they are likely to teach it. To quote Dossey (1992):

> *The conception of mathematics held by the educator may have a great deal to do with the way in which mathematics is characterized in classroom teaching. (p. 42)*

Hersh (1986) makes the same point:

> *One's conception of what mathematics is, affects one's conception of how it should be presented. One's manner of presenting it is an indication of what one believes to be most essential in it…*
> *(p. 13)*

Most of the educators that were interviewed held positive views of mathematics and claimed that it was a very necessary part of the curriculum. Quotes from the educators[10], such as those included below substantiate this:

> *I would say it's a very lovely subject, what is important is we are doing maths everyday of our lives. You go to the bus you pay, that's maths, you look at the watch, you go to the shop you buy that's maths. We are doing maths unconsciously, so maths is the subject to be taught everywhere.*

> *I would say it's the mother of all the subjects because even if you didn't go to school but maths is always there, even if you can't read or write but some other people are able to calculate their money, they are able to say I want 1kg bag of rice or I want 10kg, that is maths, it's the most important subject, whether you like it or not but you are doing it anyway, unconsciously.*

However, some also admitted they find it difficult and challenging to teach, but that they are "trying to rub all those stereotypes" that learners and educators often attach to the subject. Some of the educators felt they were succeeding in this since they had learnt

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[10] Grammatical corrections to respondent comments were only made when meaning was adversely affected. Respondents were not first language English speakers.

ways to make more use of practical resources in their teaching, through the intervention. Others voiced their continued fear and concerns about the subject.

> *… but although we are not good on it but we love it.*

> *Because even our learners they are so difficult to grasp, so you don't know whether it's language or what.*

> *You can say that maths is an interesting subject, but we, including our kids we are afraid of it.*

The definitions of mathematics provided by the educators pertained mainly to the use of the subject as it relates to figures and the four basic operations (addition, subtraction, multiplication and division) as used in our daily lives.

> *But if I can define it* [mathematics]*, with the knowledge I've got - I can say mathematics is measurement, because everything you measure is mathematics included. It can be information because you can get information from the radio, bearing in mind that it's four o'clock now, it's use, so now I'm using a watch through mathematics. There are so many things that I can say about defining, it can be measurement, I can say the distance, the counting ..,learners can count, they can count change, when they get into the bus they must know the bus here from to town it's R10, it's R9.50, so they must know if I gave them R10 they must know that there's 50 cents change. So that is how mathematics works to me.*

> *Maths is a subject dealing with numbers and measurements. It is used daily in our lives e.g. when buying groceries.*

Only one of the educators alluded to it in the sense of "problem-solving" and another to the benefits of mathematics in improving the thinking of learners.

> *… maths to me as a whole it, is dealing with problem solving. It's true, the main concept of maths is to solve the problem.*

> *… just in short I can say - I would say mathematics creates fast thinking in our pupils, they think very fast. So they will think very fast.*

Data collected from the interviews were supported by observations from the fieldworkers who observed the educators teaching lessons. Out of the 25 classes observed, most of the educators explained the work by means of showing the learners examples. In 16 of these lessons, the educators used examples relating to real life situations, while in 15 of the classes fieldworkers also observed learners solving contextual problems relating to their

lives. However, only seven of the classes showed learners having the opportunity to negotiate meaning through discussing their understanding of concepts and strategies for solving problems with each other and the educator. In addition to this, learners posing problems to their educator and to each other was only observed in six of the lessons.

 What can be concluded from the analysis done in relation to the educators' views and definitions of mathematics is that although the educators believe it is an important and worthwhile subject, they are not all very comfortable or confident teaching it. This could be due to a limited level of content knowledge as depicted in many of the definitions offered by the educators of what mathematics is. An emerging trend though is that educators are making an effort to teach the subject in a practical manner and to make it as relevant as possible to the daily lives of learners.

While it was encouraging to see educators moving towards a more practical approach to teaching mathematics, it concerned me because this encompasses only a small part of the scope of mathematics as a subject. In the National Curriculum Statement (NCS) for the FET phase the Department of Education provides the following definition for mathematics (DoE, 2003, p.9):

> Mathematics is a human activity that involves observing, representing and investigating patterns and quantitative relationships in physical and social phenomena and between mathematical objects themselves. Through this process, new mathematical ideas and insights are developed. Mathematics uses its own specialised language that involves symbols and notations for describing numerical, geometric and graphical relationships. Mathematical ideas and concepts build on one another to create a coherent structure. Mathematics is a product of investigation by different cultures – a purposeful activity in the context of social, political and economic goals and constraints.

It is my understanding that this definition, as well as the purpose, unique features and scope of mathematics as provided in the NCS (DoE, 2003) is calling for more than a greater emphasis on a practical approach to teaching mathematics. The definition and purpose require educators to apply a range of teaching and learning strategies so that learners can gain the full benefit of mathematics. I therefore began to question what it is that either enables or limits educators from being more flexible in the range of teaching and learning strategies they apply in their classrooms. Reflecting on the data obtained

from the evaluation outlined above, I noticed that this particular sample of educators did not seem resistant to making changes in their teaching strategies. They also felt that the resources and training provided during the course of the intervention had enabled them to be more practical in their teaching. I decided to further analyse the definitions teachers provided for mathematics to gain further insight into their conceptions and knowledge of mathematics. As the literature suggests (Ball, 1990; Ma, 1999), teachers' conceptions and understanding of what mathematics is could be a factor limiting the optimisation of a broader range of teaching and learning strategies within their classrooms. Many of the educators interviewed emphasized the practical day-to-day uses of mathematics when stating their definitions for the learning area. Classroom observations provided evidence of a greater emphasis on this practical aspect in their teaching. I began to see an articulation between educators' knowledge of mathematics, how they acquire this knowledge and how this manifests in relation to the range of teaching and learning strategies they employ in their classrooms. This awareness became foundational to the conceptualisation of this study.

In summary, there are three main parts that constitute the background to this study. Firstly, mathematics pre-service teachers I was training demonstrated limited depth of mathematical understanding that appeared to constrain them in the traditional approach to the teaching and learning of mathematics. Secondly, the international, regional and national performance of South African learners does not demonstrate a trend of strong mathematics learners. Finally, teachers in an in-service programme began adopting a more practical approach to the teaching of mathematics. However, their conceptions of mathematics appeared to limit broader and deeper changes in their practices aligned with the definition of mathematics as defined by the new curriculum in South Africa. This background led me to adopt two assumptions underpinning this study. Improving the mathematics performance of learners in South Africa requires a focus on the training of mathematics teachers. This training should consider the complexity of the mathematics "make-up" of the teacher, including their content knowledge and conceptions of mathematics and their beliefs about the teaching and learning thereof. The challenge of this complexity led me to the literature on content knowledge for mathematics teachers, which is expanded in the following section.

1.2.4 Consulting the literature

To begin the process of searching for relevant literature on the content knowledge of mathematics teachers, I used a combination of the following keywords (content knowledge; mathematics; education; pre-service; student teachers) and initiated a search on various internet search engines and academic databases. This led me to a paper entitled "Developing measures of teachers' mathematics knowledge for teaching" by Hill, Schilling and Ball (2004). The article contains an overview of literature on content knowledge for teaching which was most helpful in setting me off on a literature "trail".

The literature trail led to me to more work, mostly by Ball (1988a; 1988b; 1990; 1991) on mathematics knowledge for teaching. Ball and her colleagues draw on Shulman's contribution (1986) of pedagogical content knowledge as well as the well-known work of Ma (1999). Other authors, such as Grossman, Wilson & Shulman (1990) and Leinhardt and Smith (1985) are also regarded as experts on the research in this regard.

Through the literature trail it became evident that the term "content knowledge" is generally accepted as being more loaded than one's knowledge of mathematical content. Shulman (1986), for example, distinguishes three categories of content knowledge: subject matter content knowledge, pedagogical content knowledge and curricular knowledge. Ball (1990) differentiates between the execution of a mathematical operation and the teacher's ability to represent that operation accurately for learners. She therefore coined the terms "knowledge of mathematics" and "knowledge for mathematics". Her later work, supported by other researchers such as Hill and Bass, attempts to identify, measure and address the mathematics knowledge necessary for teaching.

Leinhardt and Smith (1985) suggest that the most important two distinctions one should make regarding content knowledge of teachers relates firstly to their lesson structure knowledge and secondly to their subject matter knowledge. Grossman et al. (1990), on the other hand, extended the number of categories to four. They suggest subject matter knowledge, general pedagogical content knowledge, pedagogical content knowledge and knowledge of the context. Ma (1999) did not define categories. She studied the profound understanding of fundamental mathematics in order to compare the subject matter school knowledge of elementary mathematics teachers in the United States and China.

In a current research project in South Africa, known as the Quantum Project (e.g. Adler, Davis, Kazima, Parker & Webb, 2005; Adler & Davis, 2006a; Adler & Davis, 2006b; Adler & Pillay, 2007), Adler and her colleagues investigate and describe mathematics for teaching within an in-service training context. Their project is mostly focused on middle and senior school mathematics teachers, foregrounding what mathematics they need to know and their knowledge of how to use this mathematics in order to teach mathematics effectively in diverse classroom contexts. Adler and Pillay (2007) summarise mathematics for teaching as "the mathematical 'problems' a teacher confronts, the knowledge resources he [the teacher] draws on to solve these problems and the teacher's explanations of why he does what he does" (p. 16).

Reflecting on my puzzle through the lens I had now constructed from the literature, I first decided that the term "subject matter knowledge" was most appropriate for the particular input that I wanted to investigate. It is central to all the findings emerging from the "content knowledge" literature and depicts the specific construct I planned to examine more closely. My aim was therefore initially to study the classroom practice of pre-service secondary school mathematics teachers in order to ascertain how their subject matter knowledge manifests in their classroom practice.

However, this term did not fully embrace my experience that not only subject matter knowledge but also students' conceptions of mathematics play an influential role in the teaching practice they adopt in the teaching and learning of mathematics. This also ties in with literature where the relationship between single components such as subject matter knowledge (Ball, 1990) or conceptions (Thompson, 1984; 1992) and instructional behaviour is not a simple one. I was also concerned about the limitation of only looking at students' classroom practice instead of also investigating how they think about teaching mathematics and what theories and beliefs they subscribe to in this regard. Reviewing the literature again, I identified a pattern in the research of four main components that researchers have investigated in relation to the instructional behaviour or classroom practice of mathematics teachers. These are the subject matter knowledge, pedagogical content knowledge, conceptions of mathematics and beliefs about the teaching and

learning of mathematics. Each of these components is discussed in more detail in chapter 2.

I therefore broadened the focus of my study to look at the mathematics "make-up" or profiles of the students in relation to their instructional behaviour that they develop as student teachers. The Oxford Dictionary (1994, p. 637) defines the word "profile" in its noun form as:

- A drawing or other representation of this;
- A side view, especially of the human face;
- A short account of a person's character or career.

This definition encouraged me to construct the term "mathematics profile". As I view it, the pre-service teachers all present the "faces" of their professional development through their final portfolios. Looking back on the data, I am taking on a side rather than front view. The term "mathematics" indicates my intention to focus this profile on data from their PGCE year that are possible indicators of their mathematical knowledge, understanding, beliefs, experiences and performance. The mathematics profile of each participant is depicted by a narrative and visual representation of their subject matter knowledge, pedagogical content knowledge, conceptions of mathematics and their beliefs relating to the teaching and learning of mathematics.

I was also not satisfied with the term "classroom practice". This is of course a broad term to define and in general terms could be understood to be what happens in a classroom. The European literature (see for example, Brosseau, 1997; Goffree, Oliveira, Serrazina & Szendrei, 1999) often describes classroom practice by the components of the so called didactic contract or didactical triangle between the learner, the teacher and the subject matter and the interaction between these components. This practice includes classroom management, administration, instructional practices, discipline, assessment practices, questioning techniques, communication between teachers and learners, time on task, planning, learning environment and media, to mention a few.

However, this study aims to determine a relationship between the mathematics "make-up" of pre-service teachers and the approach to teaching and learning they adopt during

their school-based practices. I therefore needed a term that would put the focus specifically on the teacher and their instruction, rather than on what was generally happening in the classroom. I have therefore selected the term *instructional behaviour*[11] to denote actions, decisions and interpretations the participant makes in the classroom. This particular construct is limited to observable behaviour and, where necessary, I also consider reference to applicable reflections by the participant being observed. The two main components of the instructional behaviour construct are: the type of teaching stance that the pre-service teachers adopt and the approach to learning that they encourage from their learners.

1.3 Problem Statement

This study seeks to investigate the relationship between the mathematics profiles of secondary school pre-service mathematics teachers and the instructional behaviour they develop in the teaching and learning of mathematics.

1.3.1 Rationale

In South Africa, the last ten years have been full of an educational reform initiative that was conceived after the demise of apartheid. This educational reform has been driven by two imperatives: firstly the need to overcome the damage done by apartheid, and provide a system of education that builds democracy, human dignity, equality and social justice and secondly to establish a system of lifelong learning (DoE, 2002).

In order to do this, one of the key policies created to facilitate this process in South Africa was Curriculum 2005 (C2005), which:

> *… envisaged for general education a move away from a racist, apartheid, rote learning model of learning and teaching to a liberating, nation-building and learner centred outcomes-based one. In line with training strategies, the re-formulation is intended to allow greater mobility between different levels and institutional sites, and the integration of knowledge and skills through "learning pathways." (DoE, 2002, p. 9)*

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[11] I borrowed this term from Thompson (1984) who conducted a similar study, but focused on the relationship between the mathematics conceptions of teachers and their instructional behaviour.

In addition to this, C2005 also defined a set of critical and developmental outcomes that are intended to overarch all programme development. All learning programmes and assessment standards in curriculum design are required to express these critical outcomes in the various defined fields of learning, of which mathematics is one. The critical outcomes include skills such as problem-solving, critical thinking, working in teams, communicating and using science and technology (DoE, 2002). The principles of Outcomes-based education have been employed in defining these outcomes in the curriculum and underpin the design and intended implementation of the new curriculum.

This implementation has been fraught with challenges, one of which has been and continues to be the training of teachers. Teachers are ultimately responsible for defining and delivering the curriculum at classroom level (Hargreaves, 1989) and a grasp of the relationship between teachers and the curriculum and to curriculum reform is therefore vital. Teachers' beliefs and knowledge of a subject may have a direct impact on their decisions, which in turn could affect the classroom instruction they embark on (Ernest, 1991).

Research projects that have been carried out in South Africa since the introduction of OBE and the new curriculum (see for example Howie, 2002; Howie, Barnes, Cronje, Herman, Mapile & Hattingh, 2003; Barnes, 2004; Venter, Barnes, Howie, & Janse van Vuuren, 2004; Aldous-Mycock, 2008) indicate that the type of classroom instruction dominant in many mathematics classrooms in South Africa does not resemble the intended curriculum or philosophy as outlined in our reform policy documents. We know from existing literature that a strong relationship between teachers' content knowledge and how they teach has certainly been empirically established in research done in the United States, predominantly in Elementary and Primary schools. In South Africa, the work being done by Jill Adler and her colleagues (see Section 1.2.4) focuses on middle and senior school mathematics with in-service training. The empirical gap I have therefore identified in the research is one that focuses on pre-service teachers in the secondary (high school) phase. The conceptual gap I am researching focuses on the relationship between not just one component (such as subject matter knowledge) of pre-service mathematics teachers and their instructional behaviour. Rather I am trying to

understand the relationship between the complexity of their mathematical make-up (or profiles) and their instructional behaviour.

Beyond a personal interest, I believe this research can have an impact on the way we train our pre-service mathematics teachers for the FET phase. It could also inform the continued support we could provide to beginning teachers during their first few years of teaching. My intention is that this study should produce rich data that will help us further understand the influence of pre-service teachers' subject matter knowledge, pedagogical content knowledge and their conceptions and beliefs about mathematics as a whole, on their resulting instructional behaviour. This in turn will hopefully shed more light on furthering our progress in solving the quest for optimum pre-service training of mathematics teachers. If South Africa can produce more effective mathematics teachers, the opportunities to improve learner achievement are much greater. The results of the TIMSS studies conducted in 1995, 1999 and 2003 (see for example Howie, 2002) revealed that this is a domain within education which remains a great challenge to our education system. With the introduction of Mathematical Literacy as a compulsory subject for all FET learners from 2006, the need for effective mathematics teachers is even more foregrounded.

In summary, the rationale for the study is embedded in a personal interest and experience of working with and training mathematics teachers, an empirical gap in the research literature on teachers in the secondary phase, and an intention to add value to the pre-service training programmes of secondary school mathematics teachers at tertiary institutions. The research questions that guide the inquiry follow.

1.3.2 Research Questions

The research questions configured to direct the study consist of a main research question that has been divided into subsidiary questions that will help to operationalise the inquiry. The main research question is as follows:

*How does the **mathematical profile** of a pre-service teacher of mathematics influence instructional behaviour?*

To address this main question, the following subsidiary questions guide the inquiry:

a) How are the mathematics profiles of PGCE pre-service mathematics teachers reflected in their instructional behaviour?

b) What similarities or incongruities are there between the pre-service teachers' instructional behaviour and the mathematics profiles they portray?

c) Are differences among the pre-service teachers in their instructional behaviour related to differences in their mathematics profiles?

1.4 Conceptual framework

The theoretical underpinning of my own instructional behaviour is premised on a social constructivist framework. This therefore implicitly influenced my initial search for and selection of literature. However, as the study progressed and my literature base gained depth and breadth, I began to examine other theories such as the theory of educational change (e.g. Fullan, 1982; 1995), sociocultural theory (e.g. Lave, 1988), symbolic interactionism (e.g. Blumer, 1969), constructivism (e.g. Piaget, 1970) and radical constructivism (e.g. von Glaserfeld, 1984; Steffe & Kieren, 1994) as possible lenses for doing the analysis and discussing the results.

The two main constructs of this study focus on the individual (namely the pre-service teacher) and therefore one could argue that constructivism would have been an appropriate underpinning theory for the study. However, in this study the participants exist and develop within a number of social contexts: the main contexts being the PGCE course and the classrooms within which the pre-service teachers conduct their school-based experiences. This adds the additional dynamic interplay of lecturers, fellow students, mentor teachers, learners and the subject of mathematics. I therefore considered sociocultural theory as an alternative option. Sociocultural theory makes it possible to characterise mathematics as a complex human activity by foregrounding meaning through an emphasis on taken-as-shared meanings, instead of on socially accepted ways of behaving. However, historically this stance assumes that the developed disciplines of mathematics, teaching and learning exist independently of the pre-service teachers and the learners. In this study, practice is viewed as an emergent phenomenon as opposed to

an existing manner of reasoning and communicating (Cobb, Stephan, McClain & Gravemeijer, 2001). Social constructivism solved this dualism for me in its acknowledgement of the development of the participants and their interaction with mathematics and the social contexts of the classroom and their PGCE course.

The literature review not only confirmed my choice of social constructivism as the overarching theory being applied, but also assisted me in developing a more focused conceptual framework to apply in dealing with the complexity of the constructs being studied within the cases. The conceptual framework draws extensively on the work of Ernest (1988, 1991, 1998) in analysing the two main constructs of mathematics profiles and instructional behaviour. However, where there was not sufficient literature in Ernest's work, the conceptual framework was supplemented by other authors such as Ball (1988a, 1988b, 1990, 1991), Thompson (1984, 1992), Shulman (1986), Mason (1989), Veal and MaKinster (2001) and Davis (1997). The literature reviewed and the resulting conceptual framework are presented in chapter 2.

There are a number of studies in the literature (as cited in chapter 2) that explore the relationship between one of the components, for example, *conceptions of mathematics and the teaching thereof* and *instructional behaviour* (Thompson, 1984) or the level of *subject matter knowledge* and the quality of *classroom practice* (Leinhardt & Smith, 1985) or *pedagogical content knowledge* and *classroom practice* (Leinhardt, 1989). While much light has been shed on these relationships and the complexities thereof, my aim is to try to present and study the components as a "package" and to explore the relationship between the package and the instructional behaviour. I do not intend to go into the depth on each component as the afore-mentioned studies have done, but to rather explore the complexity of the four components that comprise the mathematics profile. This study therefore investigates the relationship between the participants' mathematics profiles (the "package") and how this profile relates to the instructional behaviour they exhibit towards the teaching and learning of mathematics.

1.5 Teacher training in South Africa

Qualifying as a teacher in South Africa currently requires one of two possible routes: a Bachelor of Education (four year degree) or an appropriate undergraduate degree (e.g. Bachelor of Science, Bachelor of Arts, Bachelor of Commerce) followed by a Post Graduate Certificate in Education. This pre-service phase is known as the Initial Professional Education of Teachers (IPET), with in-service training being referred to as Continuing Professional Teacher Development (CPTD) in the latest policy documents (DoE, 2006).

Tertiary education in South Africa is outlined in the National Qualifications Framework (NQF) using credits and levels 1 – 8 (South African Qualifications Authority [SAQA], 2000; see APPENDIX A). The PGCE is a 120 NQF credit, Level 6 qualification. According to the *Norms and Standards for Educators* (DoE, 2000) the PGCE is defined as:

> *…a generalist educator's qualification that 'caps' an undergraduate qualification. As an access requirement candidates are required to have appropriate prior learning which leads to general foundational and reflexive competence. The qualification focuses mainly on developing practical competence reflexively grounded in educational theory (p. 29).*

The Council on Higher Education (CHE) conducted a national review of PGCE courses in South Africa during 2006 and 2007 through their Higher Education Quality Committee (HEQC)[12]. The document released by the HEQC (2006) on the criteria and minimum standards for PGCE courses stated that a one year full-time or two year part-time PGCE programme should:

- Consolidate subject knowledge and develop appropriate pedagogical content knowledge.

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[12] The Council on Higher Education (CHE) is an independent statutory body responsible for advising the Minister of Education in South Africa on all matters related to higher education policy issues, and for quality assurance in higher education and training. The Higher Education Quality Committee is the only permanent committee of the CHE and is responsible for carrying out the quality assurance.

- Cultivate a practical understanding of teaching and learning in a diverse range of South African schools, in relation to educational theory, phase and/or subject specialisation, practice and policy.
- Foster self-reflexivity and self-understanding among prospective teachers.
- Nurture commitment to the ideals of the teaching profession and an understanding of teaching as a profession.
- Develop the professional dispositions and self-identity of students as teachers.
- Develop students as active citizens and enable them to develop the dispositions of citizenship in their learners.
- Promote and develop the dispositions and competences to organise learning among a diverse range of learners in diverse contexts (HEQC, 2006, p. 1).

Students achieving these exit level outcomes should be competent novice teachers who over time, through experience and with the appropriate support will develop as fully-fledged extended professionals. Such professionals (teachers) are required to be specialists in: their particular learning area, subject or phase, teaching and learning, assessment and curriculum development. Each one is also expected to be a leader, administrator and manager, a lifelong learner and a professional who plays a community, citizenship and pastoral role (DoE, 2000).

These are all very general guidelines that are offered by the current policies in guiding tertiary institutions with the training of teachers. Institutions are left to develop their own conceptual frameworks and content for their PGCE programmes. The outline of the PGCE programme that forms the context for this study is presented in chapter 3, Section 3.4.1.

1.6 Research design and methods

As already outlined, the purpose of this study is to investigate how the mathematics profiles of pre-service mathematics teachers influences the instructional behaviour they develop and exhibit during their school-based practice. This implies, firstly, a detailed understanding of their mathematics profiles as well as insight into their instructional behaviour.

When this study was first conceptualised, I had intended to measure the subject matter knowledge of the teachers using only a quantitative instrument. Subsequent readings in the literature led me to broaden the study to the use of mathematics profiles instead, and to the conclusion that the design of the study would benefit from a qualitative nature. Grossman et al. (1990) report on how the earliest research on teacher subject matter knowledge tried to identify statistical relationships between the knowledge of teachers and the achievement of their learners. The subject matter knowledge of teachers was represented either as the number of classes that a teacher had taken in the subject, their grades obtained in the subject or their score on a standardised achievement/performance test. The majority of studies, however, showed no significant relationship and it was suggested that perhaps teacher subject matter knowledge had not been adequately conceptualised (Byrne, 1983 as cited in Grossman et al., 1990) and that it is a complex phenomena that encompasses more than can be measured on a test or by the level or grades of a teacher's qualification. To operationalise my main research question, therefore, I chose a qualitative design for this study within a social constructivist epistemology as outlined in the following section.

1.6.1 Paradigm

Social constructivism is discussed in chapter 2 as a philosophy of mathematics education (Ernest, 1991) as well as a paradigm or worldview which is "a basic set of beliefs that guide action" (Creswell, 2007). This epistemology informs my approach to the teaching and learning of mathematics as well as to research. It was interesting during the study to reflect on the development of the inquiry and the writing up of this study in relation to how I usually approach my instruction of mathematics. Both foreground my ontological assumption that individuals may not share the same "reality" (Creswell, 2007) and therefore multiple perspectives need to be presented. I favour transparent thinking and presenting the challenge, while facilitating the learner (in the case of this study, the reader) through the process of understanding my thinking while also constructing their own autonomous understanding. As previously indicated, the lens of social constructivism guided my literature review, but also later became my chosen theoretical underpinning for the analyses. I suspect this was largely motivated by the fact that social

constructivism also guides my interpretation and approach to the teaching and learning of mathematics.

This type of paradigm views the world as an emergent social process (Burrell & Morgan, 1979) and aims to characterise how people experience the world, ways in which they interact together, and the settings in which these interactions take place (Packer, 2007). It seeks to explain behaviour from the individual's point and understand the subjectively created world "as it is" (Burrell & Morgan, 1979).

1.6.2 Research approach

To provide depth in investigating the research questions, I selected a case study approach and used a convenience sample of seven participants. The participants were selected through convenience sampling based on their willingness to be part of the study, as well as the fact that they were all enrolled for the mathematics specialistion course in obtaining a Post Graduate Certificate in Education (PGCE) at the same university in South Africa in 2006, 2007 or 2008. They completed this one-year post-graduate qualification on completion of their undergraduate degrees, in order to qualify as teachers. I was the mathematics specialisation lecturer for all of the participants. The education backgrounds of the participants were different, but they all followed a similar route to qualify in becoming teachers.

This setting simulates that of a *case study* as defined in the literature on research designs (e.g. Adelman, Jenkins & Kemmis, 1980; Guba & Lincoln, 1981; Merriam, 1988; Cohen, Manion & Morrison, 2000; Yin, 2003). Merriam (1988) cites definitions from various authors who support this, such as a case study being defined as "the examination of an instance in action" (MacDonald & Walker, 1977, p. 181) and a process "which tries to describe and analyse some entity in qualitative, complex and comprehensive terms not infrequently as it unfolds over a period of time" (Wilson, 1979, p. 448). The context of this inquiry is also dynamic and provides a unique example of real teachers in a real classroom situation (Cohen et al., 2000).

More specifically, Bennet and George (1997) refer to the type of case study research I used as the "method of structured, focused comparison" (p. 2). They make the point that:

> *Comparative case studies can use within-case analysis of individual cases as well as case comparisons to assess and refine existing theories, and more generally, to develop empirical theory. The method of doing is "__structured__" in that the same general questions are asked of each case in order to guide the data collection, thereby making possible systematic comparison and cumulation of the findings of the cases. The method is "__focused__" in that it deals with only certain aspects of the cases; that is, a selective theoretical focus guides the analysis of the cases.*

The theoretical focus that guides these case studies is to establish the existence, nature and extent of any relationship between the mathematics profiles and instructional behaviour of the participants. The point of departure was to first examine that relationship within the individual cases before comparing the different cases, namely the seven students. Bennet and George (1997) identify this type of theory-building objective as having "heuristic purposes" (p. 5). This includes searching for new variables, hypotheses and causal mechanisms and paths, through an inductive process. They propose that the structure and focus of such studies are more easily attained when a single investigator plans and carries out all of the case studies. The data collection and analysis are further outlined in the sections that follow.

1.6.3 Data collection strategies

This study has been placed within a social constructivist worldview thereby drawing on qualitative data collection and analysis methods. The primary source of data comes from the final portfolios that the pre-service teachers hand in as part of their final summative mark for the PGCE. As indicated, these portfolios contain a selection of personal information such as a storyline, brain profiles, personality tests, daily reflections during their school-based period, learning task designs, video-recordings from their school-based periods, their vision and mission statements on education and any other information they deem important to demonstrate their professional development throughout the year. In addition to this, I also had documents available from a baseline assessment (see Appendix D) on mathematics content that students complete on entering the course as well as assessment reports from lessons I had observed the students presenting. More details on the data set are provided in chapter 3.

1.6.4 Data analysis

Since the inception of this study, the ideas on data analysis evolved as I worked through more literature on other empirical studies conducted in this domain. The dynamic nature of interpretive, qualitative studies allows and encourages the iterative process but my reading and experience were fundamental to the conceptualisation and design of this study.

I analysed the data using a deductive but, to a lesser extent, also an inductive approach. The deductive approach facilitated the indicators and categories already identified in the literature. The inductive approach allowed for the formulation of new themes that came out of the data (see Section 3.6). This means that the scheme for analysing the themes associated with the content become apparent during the analysis itself and are not predetermined as is the case with the deductive approach. This type of inductive analysis (Miles & Huberman, 1994; Creswell, 2003; Gay & Airasian, 2003) allowed me to construct patterns that emerge from the data in order to make sense of them. In such an analysis one usually starts with a large set of issues and, through an iterative process, progressively narrows them down into small important groups of key data. From this data variables are then identified through further examination and analysis that can be interpreted and discussed. This therefore creates a multistage process of organising, categorising, synthesising, interpreting and reporting on the available data (Gay & Airasian, 2003).

1.6.5 Methodological norms

The data collected for this study took the form of video data and documents. My own reflections, thoughts, observations and uncertainties during the course of the study were recorded in a journal to provide an audit trail and assist me in identifying and acknowledging possible personal biases and preferences that affected the data analyses (Gay & Airasian, 2003). Due to the post-hoc nature of the research approach, member checking was not employed with the participants. However, I did use member checking in consultation with two other colleagues with regard to the participant reflections, mathematics profiles and instructional behaviour profiles. For the visual representation of the mathematics profiles I consulted an architect who assisted me to conceptualise and design the symbolic drawings and interrogate their meaning and consistency.

A further source used to increase the trustworthiness of the qualitative data was to draw on literature discussing (where possible) similar and conflicting findings to the outcome of this study (Eisenhardt, 2002). It is also envisioned that the theory building process (Bennet & George, 1997; Eisenhardt, 2002) strengthened the study in its credibility and transferability by the high number of case studies (7 in total) being depicted and compared.

1.6.6 Ethical considerations

As I was the lecturer of the participants, I wanted to ensure that they did not feel coerced or compelled to be part of the study. I also did not want to engage with the power-play element that is present when a lecturer chooses to use their students as participants. I therefore waited until after their final portfolios had been handed in and defended in order to request their permission (see Appendix E for participant consent form) to be part of the study. In approaching the participants, the following steps were followed (Gay & Airasian, 2003):

- The purpose and an outline of the study were provided to them and they were asked if they would consider availing their portfolios and other relevant documentation from their PGCE year as data for this study;
- It was emphasised that their participation was entirely voluntary.
- They were promised full confidentiality and anonymity on events that took place during the study, but were given the option to give full release on the video data for use in public domains such as training and presentations or to limit the use of video data display to this report. Six of the participants signed full release of their video data.

I did not obtain ethical clearance from any of the learners present in the classes that were video-recorded. The reason for this is that they were not the focus of the study. Any data used as evidence here or in presentations arising from the study have been suitably "doctored" or edited to ensure anonymity of the learners. This was mainly done through an editing technique known as blurring.

1.7 Limitations of the study

I was confronted with two initial main limitations of this study. Firstly the fact that I am both a lecturer of the participants and the researcher has an impact on the investigation. Although I did the data analyses on a post-hoc basis, I still had a relationship with each of the students as their lecturer and therefore also formed opinions of them during their PGCE year. The advantage of this situation is that it affords me even further insight into the participants outside of the data being collected. I envision this contributing to the overall depth and richness of the case studies.

The second limitation pertains to the lack of generalisability of case studies. While this study is restricted to one tertiary institution, the participants have gained their undergraduate degrees at a variety of different institutions and represent a variety of gender, cultures and languages. It has not been my intention to generalise these results of individual cases but to add to the body of knowledge on the influence of pre-service teachers' mathematics profiles on their instructional behaviour.

1.8 Outline of the study

This dissertation is divided into seven chapters, each serving an individual purpose, but overlapping and intertwining nonetheless. The first chapter serves as an introduction to the study and its origins. Chapter 2 reports on the literature review, during which the theoretical and analytical frameworks of the study are also foregrounded. Chapter 3 serves as the research design chapter. It firstly establishes the epistemological paradigm of the study before discussing the methodology (case study) and elaborating on the methods to collect and analyse data. The context and sample of the study are also further introduced in chapter 3 and ethical issues as well as issues of quality control are dealt with. The fourth chapter of this report depicts the first data reduction in the form of the participant reflections. In chapter 5 the researcher reflections are included as the second data reduction, followed in chapter 6 by the third data reduction, the visual representation of the profiles. In chapter 6 the cross-case comparison is also discussed. The final chapter reflects on the study and its research process as a whole before making final conclusions and recommendations.

CHAPTER TWO   LITERARY FRAMEWORK

2.1 Introduction

This chapter presents the literary framework. This is the interaction between my epistemological underpinning of social constructivism with the literature reviewed, resulting in a conceptual framework. The conceptual framework is defined by the two main constructs within this study (mathematics profiles and instructional behaviour) and the complexity of their relationship. Within the conceptual framework the various components of each of the main constructs were identified through the literature review and draw mainly on the work of Ernest (1988, 1991, 1998) supplemented by the work of other researchers.

The literature review informed the proposed conceptual framework for the study but was also initially informed by social constructivism as the lens through which I regard my own teaching and research. An iterative process of reviewing developments relating to research within mathematical content knowledge[13] was first studied, followed by a synthesis of recent empirical studies that are relevant to this domain and the broader range of components that may influence the classroom practice of teachers. Further literature on theories and approaches to the teaching and learning of mathematics was also then explored. Subsequently the theory of social constructivism was chosen as the preferred overarching theory. The literature was then again reviewed with regard to this epistemological underpinning. It presents both the position I take on the teaching and learning of mathematics as well as offering the necessary interpretive framework for this research. From this above-mentioned iterative process, the conceptual framework for analysing the data was constructed.

Consequently this chapter firstly discusses social constructivism as the overarching epistemological underpinning for this study. A synopsis of the literature review is then

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[13] Although the focus of this study is on mathematics profiles, I use the phrase content knowledge purposely here to denote the more comprehensive domain of pedagogical content knowledge and subject matter knowledge.

provided, leading into the conceptual framework that was constructed to guide the presentation and analysis of the data.

2.2 Social constructivism

Ernest (1991, 1998) suggests social constructivism as a philosophy of mathematics and also discusses it as a philosophy of mathematics education. Through this lens mathematics is viewed as a social construction and knowledge is a result of a process of coming to know including processes leading to the justification of mathematical knowledge. Ernest (1991) mentions three philosophical perspectives as a basis for his "unified philosophy of mathematics" (p. 85) of social constructivism namely quasi-empiricism, conventionalism and radical constructivism. From quasi-empiricism social constructivism takes the fallibilist epistemology, including the view that mathematical knowledge and concepts develop and change. From conventionalism, it draws on the notion that human language, rules and agreement play a key role in establishing and justifying the truths of mathematics. However, the most central claim of social constructivism is that "no certain knowledge is possible, and in particular no certain knowledge of mathematics is possible" (Ernest, 1991, p. 89), which has its origins in radical constructivism. These latter two tenets of conventionalism and radical constructivism may seem to contradict each other and Ernest reconciles this contradiction with the following explanation:

> Thus although the primacy of focus of each of conventionalism and radical constructivism is sacrificed in social constructivism, their conjunction in it serves to compensate for the individual weaknesses, yet this conjunction raises the question as to their mutual consistency. In answer it can be said that they treat different domains, and both involve social negotiation at their boundaries. Thus inconsistency seems unlikely, for it could only come about from their straying over the interface of social interaction, into each other's domains (p.86).

Ernest (1991) also foregrounds the relationship between objective and subjective knowledge (see Figure 2.1) as part of his theory of social constructivism. This view places subjective and objective knowledge in mutually supportive and dependent positions. I offer a summarised overview of the distinction Ernest (1991) makes between subjective and objective knowledge here. For a more detailed explanation see Ernest (1991, 1998).

PRIVATE REALM

SOCIAL REALM

CREATION

Public Criticism and
Reformulation

New Knowledge

New Knowledge

Subjective Knowledge
of Mathematics

SOCIAL
NEGOTIATION
PROCESS

Objective Knowledge
of Mathematics

New Knowledge

New Knowledge

Personal
Reformulation

LEARNING
Re-construction
Mathematical Enculturation
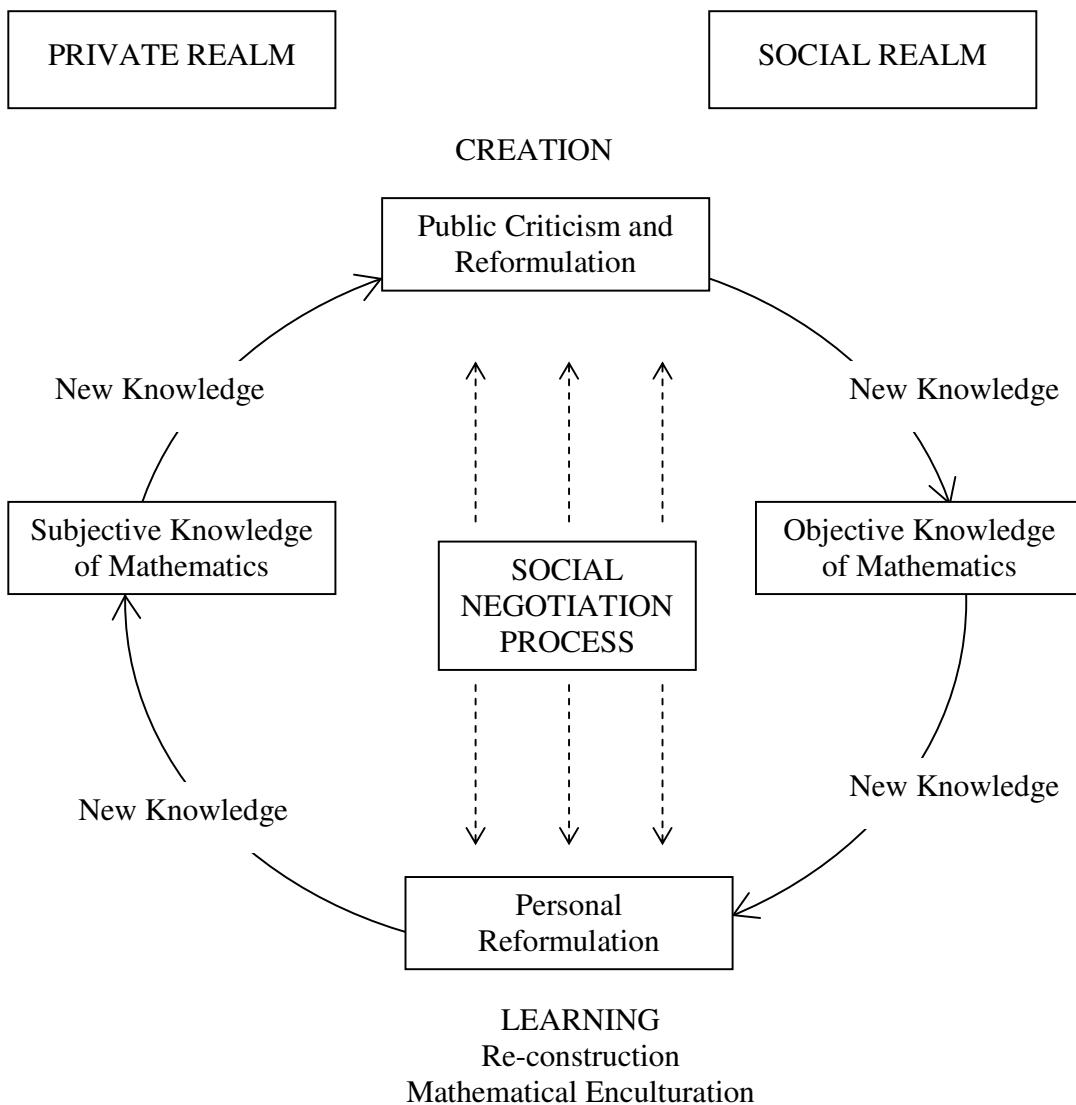
Figure 2.1 The relationship between subjective and objective knowledge (Ernest, 1991)

Ernest (1991) describes *subjective thought* as the mathematical thought of an individual (both the process and its product, mathematical knowledge). This is mostly learned or reconstructed objective knowledge, but it is subject to certain powerful constraints in that the process of re-creation results in unique subjective representations of mathematical knowledge. Individuals then use this knowledge to construct their own, unique mathematical productions which leads to the creation of new subjective mathematical knowledge.

In order for an individual's subjective mathematical knowledge production to become objective, it must first enter the public domain through publication. This allows it to become scrutinised and criticised by others which may result in its reformulation and acceptance as *objective* (socially accepted) *knowledge* of mathematics, although this objective knowledge still always remains open to challenge. During the "genesis of mathematical knowledge" (p. 84), objective criteria are used in the critical scrutiny of mathematical knowledge. These include shared ideas of basic inference and other basic methodological assumptions. These criteria rest ultimately on the common knowledge of language (linguistic conventions) which are also socially acceptable. Ernest (1991) therefore sums objective knowledge up as both "published mathematical knowledge and the linguistic conventions on which its justifications rest…" (p. 84).

Ernest (1991) uses Popper's (1979) definition of three distinct worlds, and the associated types of knowledge to clarify his distinction between objective and subjective knowledge. According to Popper (1979, p. 74, as cited in Ernest, 1991):

> *We can call the physical world 'world 1', the world of our conscious experiences 'world 2', and the world of the logical contents of books, libraries, computer memories, and suchlike 'world 3'.*

Ernest (1991) places subjective knowledge as a world 2 knowledge and objective knowledge as a world 3 knowledge, which includes products of the human mind, such as published theories, discussions of such theories, related problems and proofs. All of these are human-made and changing and in mathematical terms include theories, axioms, conjectures and formal and informal proofs. Ernest (1991) then also adopts the social theory of objectivity as offered by Bloor (1984) to extend objective knowledge to also include shared (but possibly implicit) conventions and rules of language usage. According to Bloor (1984, p. 229 as cited in Ernest, 1991):

> *Here is the theory: it is that objectivity is social. What I mean by saying that objectivity is social is that the impersonal and stable character that attaches to some of our beliefs, and the sense of reality that attaches to their reference, derives from these beliefs being social institutions.*
>
> *I am taking it that a belief that is objective is one that does not belong to any individual. It does not fluctuate like a subjective state or personal preference. It is not mine or yours, it can be shared. It has an external thing-like aspect to it.*

This places objective knowledge and its rules outside of individuals (in the community) where, like culture, it develops autonomously in keeping with tacitly accepted rules rather than the arbitrary dictates of individuals.

Creswell (2007) depicts social constructivism as a worldview in which individuals

> *… seek understanding of the world in which they live and work. They develop subjective meanings of their experiences – meanings directed toward certain objects or things. These meanings are varied and multiple, leading the researcher to look for the complexity of views rather than narrow the meanings into a few categories or ideas (p. 20).*

Research in this worldview relies on the participants' views of the situation. These subjective meanings of individuals are formed through interaction with others and through historical and cultural norms that operate in individuals' lives. In order to understand these historical and cultural settings, constructivist researchers focus on the specific contexts in which people live and work. It is therefore also important for the researcher to recognize and acknowledge how their interpretation flows from their own personal, cultural and historical experiences. My intent in this study was to make sense of the meanings participants have relating to the main constructs, but this interpretation was shaped by my own background and experiences. These are further outlined in chapter 3.

2.3 Literature review

In the initial design of the study, I focused the literature review on subject matter knowledge as one of the two main constructs, the other construct being classroom practice. However, as the study proceeded and the two main constructs evolved into *mathematics profiles* and *instructional behaviour*, the literature review had to be broadened. Not discarding the literature I had already synthesized on subject matter knowledge, I went back to the literature and started to look for additional studies on pre-service mathematics teachers as well as other studies researching the components of the mathematics profile.

The components of the mathematics profile construct as I define it, appear in the literature within studies focusing on one or two components, for example, subject matter knowledge (for example Ball, 1988a, 1988b, 1990, 1991, 2002), beliefs and conceptions

of mathematics (Thompson, 1984, 1992), pedagogical content knowledge (Shulman, 1986) or classroom practice (Cobb et al., 2001). I could not find a similar study where the complexity of mathematics profiles of pre-service teachers had been constructed in order to determine the influence thereof on the instructional practices they develop as student teachers. However, a number of researchers acknowledge (for example, Ball, 1988a; Fenemma & Franke, 1992; Nespor, 1987) that the interaction between quality of teaching and learning and aspects of the teacher, such as subject matter knowledge, beliefs, etc. is a complex one. It is my aim to try and embrace some of that complexity within this study. However, as I examined a number of components to make up the mathematics profiles of the participants, it is not possible to get an in-depth view and analysis of each. I have opted rather to go for a broader (and therefore possibly less accurate) description of each in order to foreground the mathematics profile as a whole rather than the individual components.

The most closely related empirical study I identified was an ongoing study conducted by Rowland and his colleagues from Cambridge as well as Thompson's (1984, 1992) work on conceptions. Rowland, Martyn, Barber and Heal (2001) looked at how the subject matter knowledge of pre-service primary teachers manifests in their classroom practice. Thompson (1984) studied the relationship of teachers' conceptions of mathematics and the teaching thereof to instructional practice. I report on their work later on in this section. This gave me a good starting point from which to build my review.

From there I sought other scholarly work (mainly within the domain of mathematics education) pertaining to the various components that make up the two main constructs. I drew largely on the work of Ernest (1988, 1991, 1998) in developing the conceptual framework in this regard. For the mathematics profile construct, I discuss the following components identified in the literature and define them for the purpose of this study: subject matter knowledge, pedagogical content knowledge, conceptions of mathematics and beliefs regarding teaching and learning of mathematics. The instructional behaviour construct draws on literature relating to classroom practice and the components contained therein are: teacher's ideology (teaching approach) and learners' mathematics experiences (learning approach).

2.3.1 Subject matter knowledge

Leinhardt and Smith (1985) offer a basic definition of subject matter knowledge that is still quoted by more recent researchers in this domain (Hill, Schilling & Ball, 2004). They define it as including "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" (p. 247). Both Shulman (1986) and Grossman et al. (1990) expanded this definition to include the syntactic and substantive structures of a subject. Drawing on the work of Schwab (1978), they identified substantive structures as the different ways in which the fundamental principles and concepts of a discipline are organised (Shulman, 1986), that guide inquiry in the field and enable one to make sense of the data (Grossman et al., 1990).

The syntactic structure relates to the set of rules that assists one in determining what is true or false, valid or invalid within a discipline (Shulman, 1986). New knowledge or claims can be deemed legitimate or unwarranted through these rules. Syntactic structures also consist of the tools of inquiry within a discipline (Grossman et al., 1990). Grossman et al. (1990) then also included an additional dimension into their view of subject matter knowledge which relates to teachers' beliefs about and orientation towards the subject matter. In her work Ball (1988b) makes a differentiation between knowledge *of* mathematics (knowledge of concepts and ideas, and how they work) and knowledge *about* mathematics (for example how one decides that a solution is correct). Grossman et al. (1990) refer to these two collectively as content knowledge for teaching.

Dewey (1983) claimed that "every study of subject thus has two aspects: one for the scientist as a scientist; the other for the teacher as teacher" (p. 273). Teachers do not just teach, they teach a specific subject. Their knowledge therefore needs to extend beyond just the tacit knowledge of that subject to a more explicit knowledge (Ball, 1991) that enables them to make the subject accessible to their learners. It is not uncommon to find pre-service teachers who hold a high qualification in mathematics, who appear to get answers right when they do mathematics and yet do not show advanced proficiency in connecting underlying concepts, principles and meanings (Ball, 1988a). It is therefore important to not only look at the knowledge pre-service teachers have about mathematics but the conceptual depth of this knowledge and how it is organised. As Grossman et al.

(1990) concluded, when teachers demonstrated a deeper knowledge, this resulted in more emphasis on conceptual explanations in their teaching. Concurring with Leinhardt and Smith (1985), they agreed that teachers who displayed a better organisation of subject matter knowledge tended to be more effective in their teaching. In this study, I have therefore sought to evaluate the subject matter of the participants in terms of the depth and organisation thereof, rather than how much mathematics they know.

Ball's work (later assisted by other colleagues) has made a good theoretical contribution to literature on subject matter knowledge in mathematics during the last two decades. In her initial work, Ball (1988a) challenged three existing myths on the preparation of prospective mathematics teachers by studying 19 teacher education students' knowledge of mathematics relating to the topic of division. She analysed their substantive knowledge along three qualitative dimensions, namely the value of truth in their knowledge, the legitimacy of their knowledge and the connectedness thereof. She firstly challenged the myth that "traditional school mathematics is simple" (p. 32) by showing that even students majoring in mathematics struggled when required to work below the surface of simple maths. While these students could perform procedures, they seemed to lack the warranted understanding of the content. They would for example know how to "invert and multiply" when required to do division by fractions but not be able to provide any mathematical explanation for why this procedure is valid (see Section 1.2.1 where I experienced a similar phenomenon with my students). The second assumption she contested was that "elementary and secondary school math classes can serve as subject matter preparation for teaching mathematics" (p. 33). She found that when teacher candidates tried to respond to tasks and questions drawing on what they had learnt in school, they typically exhibited loose fragments in their knowledge and understanding. Most of them did not display meaningful understanding. The third myth she opposed was that "majoring in mathematics ensures subject matter knowledge" (p. 33). Some of the students in her study were mathematics majors and had obviously done more maths than some of the other students. Although these students appeared to know more (in that they got more of the answers right), the additional studies did not seem to afford them any significant advantage in explaining and connecting underlying concepts, principles and meanings. This work of hers is important in my study in that a departure point of this investigation is one that stands on the falsehood of these very myths.

Ball (1988b, 1990) then went on to develop a framework for understanding what prospective mathematics teachers know and believe when they enter teacher education. She used interviews and structured tasks to explore the students':

- knowledge of and about mathematics
- ideas about the teaching and learning of mathematics
- feelings about themselves in relation to mathematics

She then presented the thesis that "teachers' subject matter knowledge interacts with their assumptions and explicit beliefs about teaching and learning, about students, and about context to shape the ways in which they teach mathematics to students" (Ball, 1991, p. 1). She developed this argument in three parts. Firstly she analysed past investigations of the role of teachers' subject matter knowledge in teaching mathematics. Secondly by unpacking the concept of subject matter knowledge for teaching mathematics and what is entailed in finding out what teachers know, and finally by presenting three case analyses of teachers' understanding of mathematics as displayed in their teaching of multiplication.

Her work has since gone on to focus on the subject matter preparation of teachers (Ball & Cohen, 1999; Ball & McDiarmid, 1990), intertwining pedagogy with knowledge (Ball, 2002; Ball & Bass, 2000) and how to go about measuring teachers' mathematics knowledge specifically for teaching (Hill et al., 2004). Hill, Blunk, Charalambous, Lewis, Phelps, Sleep & Ball (2008) examined the relationship between five teachers' knowledge for teaching and the mathematical quality of their instruction. Their study illuminated claims that teachers' mathematical knowledge plays an important role in their teaching of the subject.

Finally the work of Skemp (1971, 1989) on understanding also plays an important part in evaluating the mathematics subject matter knowledge of students in this study. Skemp differentiates between *relational* and *instrumental* understanding. Instrumental understanding on the one hand, he suggests is "rules without reasons" in that learners may possess the necessary rules and ability to use them, without actually comprehending why or how that rule works. Often learners will need to memorise more and more of these rules in order to avoid errors and this type of understanding therefore encompasses a

"multiplicity of rules rather than fewer principles of more general application" (1989, p. 5). Relational understanding, on the other hand, involves integrating new ideas into existing schemata and understanding both "what to do and why". This building up of a schema (or conceptual structure) becomes an intrinsically satisfying goal in itself and the result is, once learnt, more lasting. Skemp (1989) uses an analogy of a stranger in a town to differentiate between the two types of understanding. One could have a limited number of fixed plans that take one from particular starting locations to particular goal locations in the town. He provides this as an example of instrumental understanding. On the other hand one could have a mental map (schema) of the town, from which one can produce, when needed, an almost infinite number of plans to guide one from a starting point to a finishing point, provided only that both can be imagined on the mental map (relational understanding).

Other research I also found useful in the domain of subject matter knowledge in mathematics is the work of Tim Rowland and his colleagues in the United Kingdom[14]. Although they are working with primary school teachers, their study supported the rationale for this study. Their research provided statistical evidence that sound knowledge of mathematics topics[15] is associated with more competent teaching of mathematics in the case of pre-service primary school teachers (e.g. Rowland, Martyn, Barber & Heal, 2001). Similarly they were also able to relate weak subject matter knowledge with less competent teaching of the subject. When a similar study was carried out in Ireland though (using the same instruments), they were not able to establish any significant association between a quantitative measure of the subject matter knowledge of pre-service primary teachers and their teaching performance (Corcoran, 2005).

2.3.2 Pedagogical content knowledge

This phrase was coined by Shulman (1986, 1987) when he started asking questions about how subject matter is transformed from the knowledge of the teacher into the content of instruction. In order to investigate this, he worked with colleagues on a research

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[14] Their project is known as SKIMA (subject matter knowledge in mathematics) and is ongoing collaborative work between researchers at the universities of Cambridge, London, Durham and York.

[15] This includes topics that extend beyond those found in the primary curriculum

programme aimed at addressing issues such as knowledge of teaching, how teachers decide what to teach, the questions they ask and the explanations and content they provide in their lessons. In his study, he acknowledged along with other researchers in this domain (e.g. Leinhardt & Smith, 1985; Grossman et al., 1990) the fallibility and inaccuracy of administering achievement tests as the index of teacher knowledge. Instead they followed participants (secondary teachers in English, biology, mathematics and social studies) through their post-graduate teacher-education year as well as into their first year of teaching where possible. The theoretical framework that emerged from their inquiry into how content knowledge grows in the minds of teachers distinguished between three categories of content knowledge, namely, subject matter knowledge, pedagogical content knowledge and curricular knowledge. In this section I will foreground their discussion of pedagogical content knowledge as a means to defining this construct for the purpose of this particular study.

While subject matter content knowledge focuses on the facts, concepts, connections, structures and syntax of a subject, pedagogical content knowledge also includes the subject matter knowledge for teaching. As Shulman (1986) puts it:

> *Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations – in a word, the ways of representing and formulating the subject that make it comprehensible to others. Since there are no single most powerful forms of representation, the teacher must have at hand a veritable armamentarium of alternative forms of representation, some of which derive from research whereas others originate in the wisdom of practice. (p. 9)*

Also included in his explanation of pedagogical content knowledge is an understanding of what makes the learning of specific topics easy or difficult for learners of different ages. This encompasses knowledge of common misconceptions and the errors learners typically make (Hill et al., 2004). This means teachers need to have strategies to call on in order to assist learners in re-organising their understanding, depending on the conceptions and preconceptions brought into the subject by learners (Shulman, 1986).

Leinhardt and her colleagues (Leinhardt, 1989; Leinhardt, Putnam, Stein & Baxter, 1991) analysed teachers' pedagogical content knowledge and reasoning using constructs of "script", "agenda" and "explanation". The "script" acts as an organising structure that

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underpins the planning of the lessons. It consists of the goals, tasks and actions for a particular curricular topic and incorporates sequences of action and argumentation, relevant representations and explanations and markers for anticipated learner problems. The lesson "agenda" fits into the script and is a mental plan that guides lesson outcomes, how to achieve these and the order thereof and important decision points in the lesson. Within the script is an "explanation" of each new idea and these include the teachers' systematic organization of learners' experiences designed to help them construct a meaningful understanding of the concept or procedure. This may include actions of the teacher as well as managing contributions from learners.

In the PGCE course, students are required to provide similar documentation as part of their planning for their school-based practices. In the mathematics specialisation module, students develop a Learning Task Design (LTD) for each topic or section of work. This corresponds to the "script" used by Leinhardt. The LTD's are broken up into individual planning for each lesson which parallels this concept of "agendas". Within the individual lesson plans, students are required to outline their role as well as that of the learners, which has aspects of the "explanations" described above.

Mason (1989) suggests six levels of mathematical process that provide a basis for designing mathematics assessment and a technique for helping learners make sense of a topic for themselves through forming and verifying their own meanings. A picture of these levels is presented below in Figure 2.2.

Level 4

Level 5
Describing in general terms: accounting for details

Giving illustrative examples

Level 6

Recognise relevance of technique/topic in new contexts

Movement: particular to and from general

Awareness

Function

Recognise relevance of technique/topic in standard contexts

Concentration on particular examples

Level 3

Describing in specific instances

Level 2

Doing, functioning in particular cases

Level 1

Figure 2.2 Six levels of mathematical processes

This figure can be read from right to left as a flow from the functional to the perceptive, from left to right as an unfolding of the essence into the functional, or as levels developing clockwise from bottom right round to top right. Levels 1 to 3 relate to describing while levels 4 to 6 are more about explaining. A short synopsis of each level is presented in Table 2-1 below:

Table 2-1 Mason's levels of mathematical process

Level	Summary	Examples
1	Doing specific calculations,	Add fractions of a particular type
	Functioning with practical apparatus	Make measurements

Level	Summary	Examples
	Recalling specific aspects of a topic and specific technical terms	Fractions can be added, multiplied, compared
2	Giving an account of how a technique is carried out on an example in own words and describing several contexts in which it is relevant	You multiply these together and add those
		Fractions arise as parts or shares of a whole
	Giving a coherent account of the main points of a topic in relation to a specific example	Fractions can be compared by subtracting or by dividing
	Giving a coherent account of what a group did, in specific terms	We tried this and this and noticed this … .
3	Recognising relevance of technique or topic/idea in standard contexts	If two thirds of a team have flu … .
4	Giving illustrative examples (standard and own) of generalisations drawn from a topic, or of relationships between relevant ideas	The simplest denominator is not always the product – give an example
	Identifying what particular examples have in common and how they illustrate aspects of the technique or topic	What does 5/6 + 3/8 = 29/24 illustrate about adding fractions?
5	Describing in general terms how a technique is carried out to account for anomalies, special cases, particular aspects of the technique	To add two fractions you … .
6	Recognising relevance of technique or topic in new contexts	
	Connecting topic coherently with other mathematical topics	Fractions are one way to get hold of certain kinds of numbers

I decided these levels would be useful in analysing the tasks participants designed for their learners in terms of what Leinhardt (1989) describes as scripts, agendas and explanations. Investigating the lessons that participants prepare and present to their learners and analysing these according to Mason's levels can act as an indicator of the participants' pedagogical content knowledge. Participants with a stronger pedagogical content knowledge should be able to design and implement lessons and tasks for learners that cover a range of Mason's levels, including the higher levels of 4, 5 and 6.

Even (1990, 1993) investigated pre-service teachers' subject matter knowledge and its interrelations with pedagogical content knowledge, in the context of the concept of functions. She concluded that better subject matter preparation for teachers needs to focus on constructing mathematics courses for these teachers differently. The courses need to be presented in line with the constructivist views on teaching and learning and include "environments that foster powerful constructions of mathematical concepts" (p. 113).

Even (1993) also suggests that results of her study concurred with similar findings (Ball & McDiarmid, 1990) that teachers tend to follow their own teachers' footsteps unless they have developed a different repertoire of teaching skills. Developing this repertoire forms part of pedagogical reasoning which is the process of transforming subject matter knowledge into forms that are pedagogically powerful (Shulman, 1987). Hence she reinforces the notion that while subject matter knowledge has a strong influence on the quality of pedagogical content knowledge, it is not sufficient to focus on one without considering the development of the other.

In the domain of science education, Veal and MaKinster (2001) suggest two taxonomies of pedagogical content knowledge (PCK); a general taxonomy and the taxonomy of pedagogical content knowledge attributes. In their general taxonomy, they differentiate between *general*, *domain specific* and *topic specific* pedagogical content knowledge. The *general* PCK refers to the discipline being taught, in the case of this study, mathematics. The *domain specific* PCK focuses on specific subject matter within the discipline, for example, algebra. The topic specific PCK is the various sections within the domain that each have their own set of concepts and terms (some of which overlap), for example, the topic of functions within the domain of algebra. Topics may be introduced differently in

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different domains. For example, the concept of gradient in mathematics is taught in both the algebra and analytical geometry domains of mathematics, but it is approached differently depending on which domain it is being taught in. In my understanding of the literature, a teacher demonstrating a high level of pedagogical content knowledge will be able to create learning environments for learners that will enable them to see the different use of the topic in the two domains but still recognize and understand that the topic or concept remains the same.

In Veal and MaKinster's (2001) taxonomy of PCK attributes, they identify content knowledge as the basis, with knowledge of learners building on that, and PCK with its components of context, assessment, environment, nature of discipline, pedagogy, curriculum, socio-culturualism and classroom management hierarchically on top of the knowledge of learners (see Figure 2.3). Given that the aim of this study is not focusing solely on PCK, it is not possible to report on the participants' knowledge of their learners except where direct reflections, statements or observations are offered from the data from their portfolios. Also for the purpose of this report, the PCK components or attributes reported on are limited to assessment, pedagogy, curriculum, context and classroom management.
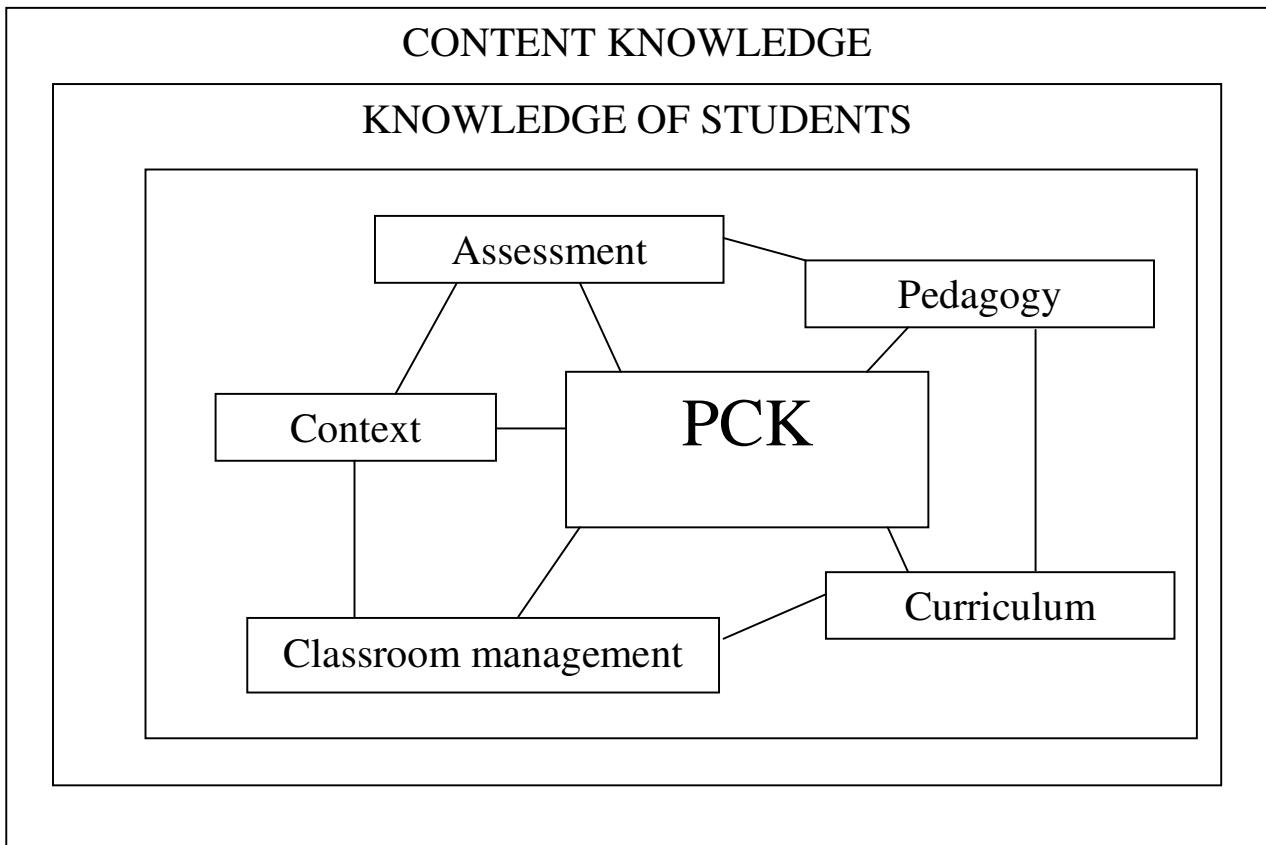
Figure 2.3 Taxonomy of attributes of pedagogical content knowledge (Adapted from Veal &
MaKinster, 2001)

The major distinction I make in this study between subject matter knowledge and pedagogical content knowledge relates to the interface between the participant (as the teacher), the mathematics and the learners. In evaluating the participants' subject matter knowledge, I investigate their interaction with the mathematics through their lesson preparation and presentation. For pedagogical content knowledge, the communication between the participants, the mathematics and the learners is the focus. Subject matter knowledge focuses on the pre-service teachers' knowledge of mathematics in general, the domains contained therein (e.g. algebra) and their knowledge and understanding of the various topics (e.g. functions) within that domain and how they relate to other topics and domains within the subject (Veal & MaKinster, 2001). Pedagogical content knowledge, however, foregrounds the pre-service teachers' knowledge and understanding of the learners they will be teaching within the context of the subject and how to translate subject matter to a diverse group of learners (Veal & MaKinster, 2001). This includes the conceptual and procedural knowledge learners bring to the learning of the topic, the

stages of understanding learners are likely to pass through in mastering the content as well as possible errors, misconceptions or alternative conceptions learners may have or develop with regard to the topic (Carpenter, Fennema, Peterson & Carey, 1988). It also includes the pre-service teachers' knowledge of assessment, instructional techniques (pedagogy), context, curriculum and classroom management.

2.3.3 Conceptions of mathematics

I specifically distinguish between the use of the terms "beliefs" and "conceptions" in these next two sections. In my view, conceptions are a more general construct: the set of positions a teacher has about something (in this case mathematics) that are probably mostly subconscious and elusive (Ponte, 1999). I see beliefs as being more overt in both the individuals' thinking as well as their actions, with the individual having more of a conscious awareness of them than of conceptions.

The design of the PGCE course that forms the context for this study puts a lot of emphasis on the pre-service teachers engaging with and reflecting on their instructional practice. They are therefore continually encouraged and required to explicitly discuss and reflect on their beliefs about teaching and learning. However, this is not the case with regard to the nature of mathematics. While I touch on this aspect within the mathematics specialisation module of the course, the pre-service teachers do not engage or reflect extensively on how they view mathematics as such (beyond whether or not they enjoy it). Therefore, it remains a more subconscious and elusive construct than their beliefs on teaching and learning. Hence I use the word "conceptions" in relation to their views on mathematics.

Thompson (1984) uses the term conceptions as an umbrella term for the teachers' beliefs, views and preferences about mathematics and its teaching. Cooney (1994) and Thompson, Philipp, Thompson and Boyd (1994) also refer to conceptions as "orientations" towards mathematics. Ernest (1988) summarises the teachers' conception of the nature of mathematics as "his or her belief system concerning the nature of mathematics as a whole" (p.1). These need not be consciously held views but may rather be implicitly embedded philosophies. Ponte (1992) views conceptions as a conceptual

substratum that has a key role in thinking and action, providing ways of seeing the world and organising concepts. For the purpose of this study, the term conception of mathematics is taken to mean the way that the participant views the nature of mathematics as a whole. This may be either implicitly embedded or explicitly apparent and pertains specifically to the participant's definition and views of mathematics as a subject.

Ernest (1988) presents three possible views of mathematics. The *instrumentalist view* of mathematics assumes the stance that mathematics is an accumulation of facts, rules and skills that need to be used as a means to an end, without there necessarily being any relation between these components. The *Platonist view* of mathematics sees the subject as a static but unified body of certain knowledge, in which mathematics is discovered rather than created. The *problem solving view* of mathematics is a dynamic, continually expanding and evolving field of human creation and invention that is in itself a cultural product. Thus mathematics is viewed as a process of enquiry, not a finished product. The results remain constantly open to revision. Ernest (1988) suggests that a hierarchal order exists within these three views, placing the instrumentalist view at the lowest level and the problem solving view at the highest.

Thompson et al. (1994) discuss two main orientations towards mathematics that emerged from their research on how different teachers approached the teaching of the same task. They also allude to a third orientation which is also discussed here. A teacher with a *computational orientation* regards mathematics as a composition of computational procedures. Such teachers subscribe to "doing mathematics as computing in the absence of any reason for the computation aside from the context of having been asked to do so" (p.86). Teachers who hold a *calculational orientation* are driven by an image of mathematics as the "application of calculations and procedures for deriving numerical results" (p. 86). While not only focused on computations, this view does remain intent on procedures in order to get the answer. Typical "symptoms" of such an orientation include:

- the answer being the most important element of problem solving;
- speaking exclusively in numbers and numerical operations;

- remediating learners' difficulties with calculational procedures, not taking into account the context within which the difficulties arise;
- an emphasis on identifying and performing procedures.

Conceptually orientated teachers on the other hand strive for conceptual coherence within the subject, focusing learners' attention on the rich conception of situations, ideas and relationships rather than on the thoughtless application of procedures. Their activities are mainly motivated by:

- the expectation that learners intellectually engage in tasks and activities;
- an image of a system of ideas and ways of thinking that the learners should develop;
- an image or plan of how to develop these ideas and ways of thinking.

The latter two appear to correspond respectively to what Thompson (1984) refers to as a *content-orientated approach* and a *process-oriented approach*. Her research showed that teachers' beliefs, views and preferences about mathematics and its teaching played a significant role in shaping their instructional behaviour. The two participants in her study who conceived of mathematics as a "rather static body of knowledge (p. 119) both presented the content in their instructional practices as a finished product (content-orientated approach). One participant used a more conceptual approach though while the other portrayed mathematics as a collection of rules and procedures for finding answers to specific questions, which Thompson classified as a computational approach. The third participant, however, held a more dynamic view of mathematics, believing that engaging in creative and generative purposes is the best way for students to learn. Her practice in turn was more process-orientated.

In a more recent and slightly different study, Agudelo-Valderrama, Clarke and Bishop (2007) examined the relationship between Columbian mathematics teachers' conceptions of beginning algebra and their conception of their own teaching practice. They concluded that "teachers' conceptions of the nature of beginning algebra underpinned their conceptions of the crucial determinants of their teaching practices" (p. 86). From this they were able to establish two basic groups: teachers for whom algebra knowledge is produced externally and those for whom it is produced internally. For the "external"

group the crucial determinants of their teaching related to learners' behaviour and the knowledge was passed on from books to learners. For the "internal" group the knowledge and dispositions of the teacher were regarded as crucial determinants by the teacher for the teaching being enacted. For teachers in this group, the learners needed to create meaning in their algebra work through suitable classroom situations and activities. This again highlights the complex but important relationship between how teachers' conceptions of mathematics affects their conception of how it should be presented (Hersh, 1986).

Another way of classifying conceptions is on a continuum from *absolutist* to *constructivist views* of mathematics (Ernest, 1991). On the *absolutist end* of the continuum, teachers with this conception view mathematics as a collection of fixed and infallible skills and concepts (Romberg, 1992) and as a subject that contains absolute truths and is value-free, culture-free and has universal validity (Ernest, 1991). On the other end of the continuum, the *constructivist view* challenges the basic assumption that mathematical knowledge is infallible. This view emphasizes the reconstruction of mathematical knowledge within the practice of mathematics, using the learners' knowledge and experience as a starting point. Teachers working in this paradigm see mathematics as continually growing and being revised (Ernest, 1991) and prefer to act as facilitators rather than teachers in the teaching and learning process.

The following figure summarises the information presented above. This figure aligns the instrumentalist view with the computational orientation, the Platonist view with the calculational orientation and the problem solving view with the conceptually orientated approach. The content-orientated approach mentioned by Thompson (1984) spans across the computational and calculational (more conceptual) categories specified by Thompson et al. (1994) while the process-orientated approach corresponds with the conceptual and problem-solving views. These can be placed on a spread on the absolutist-constructivist continuum as I understand them from the literature.

Instrumentalist	Platonist	Problem solving
Content-orientated approach		Process-orientated approach
Computational	Calculational	Conceptual
Absolutist		**Constructivist**
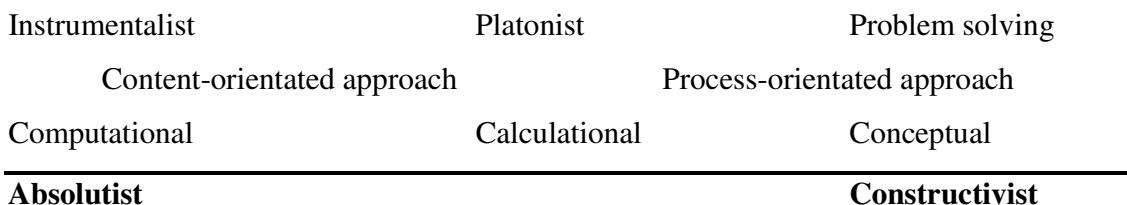
Figure 2.4 Summary of conceptions of mathematics

2.3.4 Beliefs regarding the teaching and learning of mathematics

The influence of teachers' beliefs about mathematics and the teaching thereof on what they do in the classroom has been well established in the mathematics education literature (e.g., Thompson, 1984, 1992; Cooney, 1985; Confrey, 1990; Wilson & Goldenberg, 1998; Agudelo-Valderrama et al., 2007). This is therefore an integral component of the mathematics profile.

Malara and Zan (2002) see beliefs and knowledge as impossible to separate; that tacit knowledge embeds teachers' deep beliefs that influence practice. They therefore suggest studying individual teachers in depth and providing detailed analyses of their cognitive processes as a means to measuring changes in teachers' beliefs. In this study, the subject matter knowledge and beliefs of teachers are depicted as two separate components, they are still viewed as an inseparable part of the mathematics profile as a whole. Malara and Zan (2002) also highlight the importance of getting teachers to study their own practice through self-awareness and reflection. Both these suggestions are worked into this study as part of the research design as well as the design of the PGCE course through which the students qualified as teachers.

As noted by Ponte (1999) the word "belief" is often used with different meanings and regarded as a "messy" construct to define. Beliefs may be seen as dispositions to action and major determinants of behaviour (Brown & Cooney, 1982 as cited in Ponte, 1999) that are context specific (Lerman, 1994). They can also be viewed as "inconvertible personal truths, that are idiosyncratic, have strong affective and evaluative components, and reside in the episodic memory" (Nespor, 1987, p. 320). They can be implicit or explicit, espoused or enacted (Ernest, 1988) and often there can be a mismatch between

the espoused beliefs and the beliefs that are enacted in practice (Thompson, 1984; Hoyles, 1992).

Ernest (1988) identifies three models that depict the teacher's role and intended outcome of instruction. This first is the role of *instructor* where the intended outcome is skills mastery with correct performance. The second role is as *explainer* where the intended outcome is conceptual understanding with unified knowledge. And the third role is that of *facilitator* where confident problem posing and solving are the intended outcome.

With regard to a teacher's beliefs of the learning of mathematics, he includes "the teacher's view of the process of learning mathematics, what behaviours and mental activities are involved on the part of the learner, and what constitutes appropriate and prototypical learning activities" (p. 2). The two key constructs in these models are *active construction* of understanding versus *passive reception* of knowledge and *developing autonomy* in the child versus the learner as *submissive and compliant*.

For the purpose of this study, beliefs regarding the teaching and learning of mathematics are therefore regarded as espoused and enacted, verbal and non-verbal indications of how the participants view teaching (their role in the instruction and what they hope to achieve with it) as well as their view on the role of the learner (mental and prototypical activities they engage in) in the teaching and learning process. These are now portrayed on a continuum.

Instructor	Explainer	Facilitator
Passive reception of knowledge		**Active construction of knowledge**

Figure 2.5 Summary of beliefs regarding the teaching and learning of mathematics

2.3.5 Teacher's ideology (approach to teaching)

Goldin (2002) presents two "camps" as an overview of mathematics education ideologies. He calls these traditional and reform ideologies and I agree with his acknowledgement that establishing these "risks great oversimplification" (p. 199) of the picture. However, throughout the literature, it is evident that researchers are

acknowledging this divide albeit with different terms (for example, Jaworski, 1989; Rogers, 1992). While I see these as two opposing ideological stances, a continuum prevents oversimplification of the representation of these stances. Through the use of the continuum, the teaching approach of participants can be plotted according to the extent of the dominant ideology they demonstrate rather than merely labelling their instructional behaviours as one of the two opposing extremes. My assumption is that traditional practices cannot be totally abandoned in favour of only reform practices. However, in order to produce more independent and mathematical thinkers, the reform ideology needs to be embraced by teachers as the dominant approach within their instructional behaviour.

On the one end of the continuum, the *traditional ideology* values content, the correctness of learners' responses and the mathematical validity of their methods. Teaching methods include a lot of individual drill and practice. This is to ensure the correct use of efficient mathematical rules and algorithms and learners' mastering the application thereof in order to successfully move on to more complex ideas. Mathematical skills at each level are developed step-by-step and then generalised in higher level mathematics. Class groupings are dominantly homogeneous by ability and expository teaching is valued (Goldin, 2002). Rogers (1992) refers to the teaching approach that embraces this ideology as "academic mathematics" and describes it as "learning by the feet of the master" (p. 154). As Polyani (1964 as cited in Rogers, 1992) so eloquently puts it:

> *To learn by example is to submit to authority. You follow your master because you trust his manner of doing things even when you cannot analyse and account in detail for its effectiveness. By watching the master and emulating his efforts in the presence of his example, the apprentice unconsciously picks up the rules of the art including those which are not explicitly known by the master himself (p. 53).*

This type of teaching is also often referred to as "a transmission process where mathematical knowledge exists and may be conveyed by the teacher to the learner" (Jaworski, 1989, p. 171). The assumption underlying this approach is that if the teacher gives a clear exposition of the mathematical knowledge, the learners who have heard it should then be able to provide evidence of understanding it through exercises designed for this purpose. Boaler (1997, 2002, 2004) conducted research on different approaches to teaching mathematics and their impact on learning. In Boaler (2004) she depicts a classroom where a conventional (or traditional) approach to the teaching of algebra was applied. She calls this teaching mathematics through "demonstration and practice" (p. 1).

She explains how in such a classroom learners sat individually, the teachers presented new mathematical methods through lectures and the learners worked through short, closed problems. The vast majority of the questions teachers asked were procedural.

On the other end of the continuum, the *reform ideology* places more value on learners finding patterns, making connections, communicating mathematically and problem-solving from the earliest grades. This problem-solving usually takes the form of open-ended, real-life, contextualised problems. Alternative and authentic assessment is often used. There is a reduced emphasis on routine arithmetic computation, with hands-on, guided discovery methods, exploration and modelling being preferred approaches. High-level mathematical reasoning processes are central to this ideology which encourages learners to invent, compare and discuss mathematics techniques. Learners are also required to construct their own viable mathematics meanings and in this it is acknowledged that learners have different learning styles. Where co-operative groups are used, learners are usually grouped heterogeneously to allow interaction with these varying learning styles and other characteristics (Goldin, 2002). This is more in line with what Rogers (1992) labels as "interpreted mathematics" which he describes as "the context-bound use of mathematics as a tool, a means to an end, to solve problems in the 'real' world" (p. 155). Jaworski (1989) refers to this as an "investigative approach to teaching and learning" (p. 172) where opportunities are provided that impel the learners to express and explore ideas for themselves. Discussion is encouraged so that the teacher can find out what learners are thinking and so that learners can ask questions.

Boaler (2004) refers to this type of approach to teaching as "project-based" (p. 1) where learners are taught mathematics in mixed-ability groups through open-ended projects. In her research the teachers in such a classroom posed longer, conceptual problems and combined learner presentations with teacher questioning. Teachers were seldom observed lecturing the learners who were taught in heterogeneous groups. The teachers asked more varied questions than the teachers in traditional classes, including less procedural and more conceptual questions.

2.3.6 Learners' mathematics experiences (learning approach)

This component represents values communicated to learners through their mathematics learning experiences (see Figure 2.6 as an illustration). Ernest (1989) differentiates between authoritarian and democratic experiences of learning. Learners' mathematics experiences are termed *authoritarian* when what the teacher dictates must be followed and taken in without question. Learners submit to the teacher and depend (in the extreme) on the teacher for every aspect of their mathematics learning (Ernest, 1989).

On the other hand, learners have *democratic* experiences of learning mathematics when they are respected and respect each other. The classroom atmosphere can be described as one of relative freedom, and learners are free to navigate and discuss many aspects of the curriculum. Learners therefore become increasingly independent of the teacher.

'official' methods taught	algorithms/ techniques	learners' methods encouraged
stylised 'mystifying' forms	approach to proofs	learners' reasoning encouraged
learners seated separately working silently	organisation	learners grouped by their choice/discussion of work
individual competition	learner relations	collaborative group work
didactic expository class teaching	teaching style	learners' methods encouraged

Figure 2.6 Illustration of authoritarian versus democracy continuum (Ernest, 1989)

Various aspects of school mathematics can be included in constructing the authority versus democracy continuum (Ernest, 1989):

- The ways the subject is presented (status of definitions, approach to proof, attitude to techniques and algorithms);

- The ways a learner's work is dealt with (the forms of assessment used, how errors are handled, answers checked);

- Classroom management (seating, access to resources, the way learners' tasks are selected, the sort of questions a teacher asks);

- Relationships which are permitted, encouraged or discouraged (between learners, between learners and teacher);

- The curriculum (how it is chosen, the way different parts are approached, its orientation – whether it is directed towards the learners' experience or interests).

Davis (1997) adds another aspect to these described above by using the manner in which the teacher listens to the learners as a metaphoric lens through which to interpret practice. He suggests three forms of listening: evaluative listening, interpretive listening and hermeneutic listening.

He explains the primary reason for *evaluative listening* as rather limited and limiting, as the teacher is most often listening for something (i.e. a "mathematical" explanation) rather than listening to the speaker. The motivation of such listening lies in evaluating the correctness of learner's contribution by judging it against a preconceived standard. Questions posed in this type of listening already have a "correct" answer in mind. Davis suggests that the teacher whose listening is merely evaluative "would strive for unambiguous explanations and well-structured lessons" (p. 360). He goes on to suggest that this manner of teaching (through evaluative listening) is associated with a conception of mathematics primarily as a system of already established, formal truths where mathematics teaching is a process through which one strives to avoid ambiguity.

Interpretive listening encompasses more of an attempt by the teacher to listen to the learner and to make sense of the explanations they are offering. The sorts of questions asked require more elaborate answers and may also entail a demonstration or explanation. However, although learner articulations and subject sense-making are more foregrounded

here, they might not affect the trajectory of the lesson. Passive taking in or absorption of what learners are saying in evaluative listening is replaced here by "an awareness that an active interpretation – a sort of reaching out rather than taking in" (p. 364) is involved. Communication is therefore understood to be more of a "negotiatory" process and listening becomes as vital as telling or explaining in this manner of teaching.

Davis (1997) makes the point that in both of the above manners of listening (which he likens to manners of teaching), the authority in the classroom remains with the teacher. For example, learners' explanations are modelled on the teacher's explanations and the teacher is the authority in deciding which answers are adequate and which require elaboration. In the third mode, *hermeneutic listening,* a collective authority is established. Such listening "demands the willingness to interrogate the taken for granted and the prejudices that frame our perceptions and actions" (p. 370). The teacher now becomes a participant in the exploration of the mathematics where class members are jointly exploring a mathematical issue rather than attempting to master already formulated bits of knowledge. This proposes that the teacher does not subscribe to the belief that teaching is a matter of causing or making learners acquire, master or construct particular understandings through some planned instructional sequence. Rather learning is viewed as a social process where the teacher participates, interprets, transforms and interrogates – in short, listens (Davis, 1997).

2.4 Conceptual Framework

The conceptual framework emerged from the background explained in chapter 1 as well as the literature review (see Figure 2.7). Two main constructs in the framework are the *mathematics profiles* of the pre-service teachers and their *instructional behaviour*. The components of the *mathematics profile* construct are subject matter knowledge, pedagogical content knowledge, conceptions of mathematics and beliefs relating to the teaching and learning of mathematics as identified in the literature. The components of the *instructional behaviour* construct are teacher's mathematics education ideology (teaching approach) and learners' mathematical experiences (learning approach).

Mathematics profiles

Instructional behaviour

Subject matter knowledge

Instrumental - Relational

Beliefs on teaching and learning mathematics
Absolutist - Constructivist

Conceptions of mathematics
Instructor - Facilitator

Pedagogical content knowledge
Incomplete - complete

Teacher's mathematics education ideology
Traditional - Reform

Learners' mathematical experiences
Authoritarian - democratic
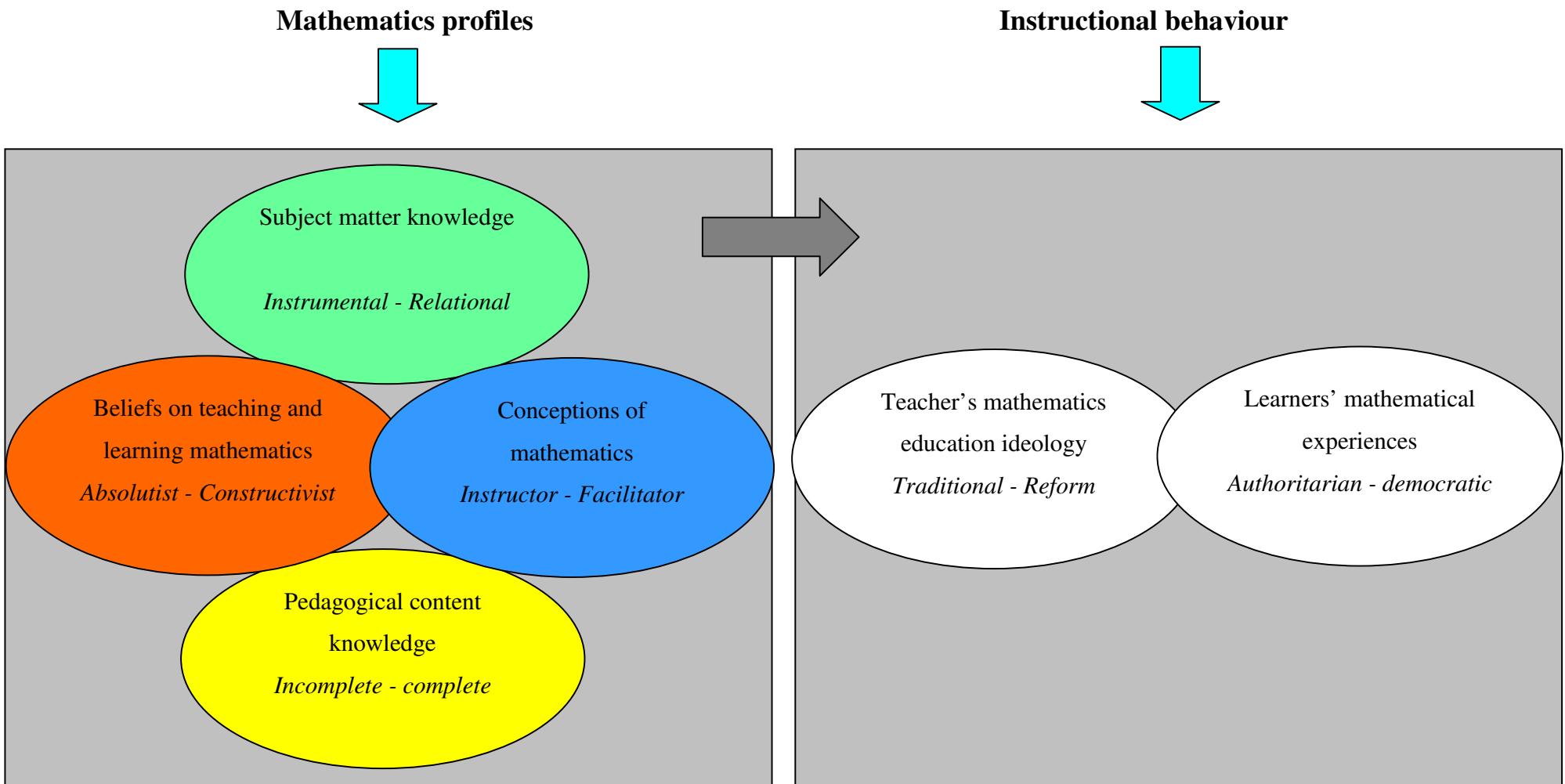
Figure 2.7 Conceptual framework

Ernest's (1991, 1998) theory of social constructivism underpins and holds together the conceptual framework represented visually above. This is an exploratory study and thus, according to Ernest's definitions of subjective and objective knowledge, the results of this study initially emerge as subjective knowledge. As the study becomes subjected to public examination and further criticism, with various reformulations, the results may then start to become more objective knowledge.

It was also Ernest's work on conceptions of mathematics (1988) and beliefs about the teaching thereof (1991) that inspired my thinking of placing participants in categories for the visual profiles. Ernest used three categories in both cases, but my data suggested that an additional category would be more explicative of the participants' profiles. I therefore added an added a fourth category to each of Ernest's three categories and for consistency conceptualised the other two components (subject matter knowledge and pedagogical content knowledge) of the mathematics profile with four categories. For the instructional behaviour profile, I drew largely on Ernest's work (1991) relating to authoritarian or more democratic learning experiences afforded to learners by the teacher. For the other components of both the mathematics as well as the instructional behaviour profiles, I drew on the ideas and research of other researchers in mainly mathematics education, but also in science and general education domains.

The component of subject matter knowledge in the mathematics profile was mostly informed by the ideas of Ball (1988a, 1988b, 1990, 2002) and Skemp (1971, 1989). The component of pedagogical content knowledge draws on the work of Shulman (1986), Mason (1989) and Veal and MaKinster (2001). The other two components in the mathematics profile (beliefs and conceptions) were developed from the work of Ernest (1988, 1991) supplemented by research from Thompson (1984) and Thompson et al. (1994). For the instructional behaviour construct, Goldin's work (2002) formed the basis for the teacher's mathematics education ideology (traditional versus reform teaching approach). Ernest's work (1989) informed the learners' mathematical experiences (authoritarian versus democratic learning approach) component, with additions from Davis (1997). The components in the mathematics profile are linked indicating my assumption that these by nature overlap each other. This is also the case for components within the instructional behaviour construct. The blue arrows indicate the

literature review process to develop the two main constructs and the grey arrow shows the focus of this study in examining the influence of the mathematics profiles on pre-service teachers' instructional behaviour. How each of these components was applied in the data analyses is discussed in chapter 3.

2.5 Conclusion

This chapter has discussed the epistemological underpinning, social constructivism, as a philosophy of mathematics as well as a worldview. Literature relevant to the scope of the study has been presented and a conceptual framework was developed from the interaction between my own background in mathematics education, social constructivism and the synthesis of the literature. The literature review covered the main aspects of the mathematics profile construct (subject matter knowledge, pedagogical content knowledge, conceptions of mathematics and beliefs on the teaching and learning of mathematics) and the instructional behaviour construct. A working definition for each for this study was espoused and a discussion of research in each domain presented. From this literature review the conceptual framework was compiled. Chapter 3 now outlines the research approach and the intricacies thereof for this study.

CHAPTER THREE   RESEARCH DESIGN AND METHODS

3.1 Overview

This chapter describes the research design and methodology. A retrospective or post-hoc case study design was selected as the most appropriate approach in attempting to understand the influence of the *mathematics profiles* of pre-service mathematics teachers on their *instructional behaviour*. This study aims to explore the afore-mentioned relationship in the hope of generating additional theory in this domain. The case study encompasses seven single cases from one university in South Africa and draws on qualitative data. The chapter first expands on the case study design, followed by a brief description of the social constructivism epistemology that underpins the study. The site and sample are then discussed prior to an explanation of data collection methods and analyses procedures. The chapter concludes with an outline of the quality control of the data before the actual data is presented in chapter 4.

3.2 Research design

A qualitative approach was chosen to guide the methodology of this study with the approach being a case study. A case study seeks to understand the dynamics present within a setting through single or multiple cases. It allows one to examine features on people or units in depth for a specified duration, depict the context of the case and examine how the parts are configured (Neuman, 1997). The method also aims to provide a description of the phenomena or constructs being investigated, and to either test or generate theory (Eisenhardt, 2002). Utilising case studies permits one to use numerous levels of analysis (Yin, 2003) while also providing a rich and in-depth description of each case. It is on this basis that I elected a case study approach to guide the research design of this study. It is however a **retrospective or post-hoc case study**; in other words events that have already happened are being investigated in an attempt to describe and understand them (Porter & Carter, 2000).

The intention is not to provide a cause-effect relationship between the mathematics profiles of the pre-service teachers and their instructional behaviour. Rather my aim was to use

descriptive research to present a picture of the specific details of the participants' mathematics profiles and their instructional behaviour within the social context of the PGCE course. Using this I tried to understand how the composition of each profile may or may not have an influence on the instructional behaviour the respective students develop and display during the course of the year (Neuman, 1997).

Although I was the specialisation lecturer for the students, I did not actively analyse data during the course of their PGCE year. The data used are being used retrospectively (from the past 3 years) and were part of students' standard requirements for their PGCE course. No additional data were gathered for the purpose of this study. However, the study was being conceptualised during that time. Initially I considered collecting and analysing data during the course of the PGCE academic year, but decided against this for two reasons. Firstly, from an ethical perspective, I did not want to the students to feel obligated to take part in the study or that my assessment of them would be influenced by their being part of the study or not. Secondly, during the process of conceptualising the study I took a methodological decision to work with "private" data that participants chose to make "public" (Ribbens & Edwards, 1998). The professional portfolios that students submit at the end of the year in substantiating their professional development are compiled by the students from their choice of lesson plans, reflections, video recordings of lessons, personal profiles and any other information they deem important. This decision provided me with a different research perspective compared to if I had decided when and where to collect the necessary data. In effect, for this study, the participants did the initial selection of the data.

3.3 Research procedures

As their lecturer during their PGCE year, I was emotionally involved with the participants during the time that the data were being generated. At the time I did not assume the role of researcher. Gans (1982) terms this type of involvement as "total participant" (p. 357). Of course, because I am not blindly studying the portfolios, but know each of the participants, my personal knowledge of and potential bias towards individuals needs to be made as transparent as possible. In order to do this I first discuss the participants in this chapter and in chapter 4, as they present themselves in the data. Subsequently in chapter 5, I present their mathematics

portfolios and instructional behaviour descriptions as my second-order interpretation (Neuman, 1997) of the data in their portfolios mixed with my knowledge and experience of them as PGCE students. In chapter 6, I draw on both their first-order interpretations of themselves as well as my second-order interpretation of the data in constructing and comparing the third-order interpretation in the form of visual representations of each profile. These are then used for the cross-case comparisons and to draw the final conclusions.

3.4 Research paradigm

In this investigation the seven individual participants are viewed as the main source in shedding light on the research question being addressed. Their actions, thoughts and knowledge are seen as crucial determinants to establish and investigate the relationship being examined. Creswell (2007) focuses on four worldviews (or paradigms): postpositivism, social constructivism, advocacy/participatory and pragmatism. Simply, postpositivism is more reductionistic and logical with an emphasis on empirical data collection and an orientation towards cause-and-effect. Research in the advocacy/participatory paradigm follows the central tenet that research should contain an action agenda for reform that may change the lives of the participants, institutions or the researcher. Pragmatism comes in many forms but individuals subscribing to this worldview are usually focused on the outcomes of the research rather than antecedent conditions. The problem being studied is the focus of the research rather than the methods being employed. According to Creswell (2007) social constructivism is often combined with interpretivism. As he puts it:

> *The goal of this research then is to rely as much as possible on the participants' views of the situation. Often these subjective meanings are negotiated socially and historically….The researchers intent, then, is to make sense (or interpret) the meanings others have about the world. This is why qualitative research is often called "interpretive" research (p.21).*

Methodologically, the positioning of my research within the social constructivism paradigm assumes a participatory stance for myself as the researcher and requires the description of specific cases through narrative articulation and interpretation. In terms of epistemology, an underlying assumption I bring into the inquiry is that people have and use interpretive schemes

that should be understood. Ontologically, this social constructivist paradigm locates the participants in this study, as well as the constructs being investigated, within inter-subjective social fields (in this case the educational context) which structure and constrain activity (Packer, 2007). As the researcher I am ontologically focused on investigating the complexity within this contextualised and authentic situation. This therefore highlights the need to explicitly articulate the character of the local context within the study. The broader local context of teacher training and education in South Africa was discussed in chapter 1. In the next section I elaborate on what I see as the more central and immediate context of the study: the PGCE course within which the study was conducted, followed by a brief introduction to each of the participants in the sample.

3.5 Research methods

3.5.1 Site

The population of this study is the Post Graduate Certificate in Education (PGCE) course at a large university in South Africa. The PGCE course is a one-year professional diploma in which students who have obtained an initial degree are trained to become teachers. Students are required to specialise in a particular phase of education, i.e. the Early Childhood Education phase (Grades R – 3), the Intermediate phase (Grades 4 – 6), the Senior Phase (Grades 7 – 9) or the Further Education and Training Phase (Grades 10 – 12). They subsequently carry out two school-based education (SBE) periods, of one school calendar term each, within the specific phase and subject(s) in which they have elected to specialise.

Students complete a number of professional modules which pertain to more generic educational principles such as assessment, diversity within the classroom, facilitating learning and compiling their professional portfolios. They are then also required to study certain specialisation modules according to the phase and subject(s) in which they intend to specialise. Intermediate and Senior Phase students specialise in two subjects during the year, while the Further Education and Training students only specialise in one subject. When the students are not on their school-based practical periods at the school, they spend intensive time at the university completing theory and assignments relating to their professional and specialisation

modules. Specialisation lecturers of the students are required to then also visit and assess the practical teaching of their students at least three times during each school-based teaching period.

The particular context of this study is the Mathematics Specialisation module within the PGCE course (see Appendix B). I am the lecturer for this module and have been the lecturer thereof for the past five years. The contact times I spend with the students are often more pedagogical by nature rather than content based. The reason for this is that the orientation of the PGCE course assumes that students come to the course with an initial degree in the subject they have chosen to teach. There are approximately nine months in which to equip students as much as possible to be effective facilitators of learning in their chosen field. This entails introducing them to the new curriculum as well as equipping them to stand up in front of a class and make the knowledge they have gained accessible to their learners. My concern relating to this approach is that the students often do not gain the necessary content knowledge required to teach mathematics in their initial degrees. They appear to study a lot of mathematics without gaining the necessary conceptual depth or understanding thereof, especially within elementary, school-related topics that they will be required to teach. It is my experience that in their initial degrees, the mathematics courses they take are not geared towards providing them with the knowledge to teach mathematics, but rather with the knowledge of how to use it.

The PGCE course forms the broader context for the study, and I believe the design thereof hopefully can be enhanced by this study. However, the PGCE course is not being researched or evaluated herein, although I do offer my own critical reflection on the current design through the course of this study. In chapter 1 an overview of the training of teachers in South Africa was provided. Within that context and according to the policy guidelines, the PGCE I am involved in has developed a programme with the explicit purpose:

> …to educate facilitators of learning to engage in the highest possible level of education quality with the result of the highest possible level of learning quality in every possible context, recognising the requirements of existing education requirements, as well as the challenging demands on education for an unknown future (Slabbert, 2007, p. 1).

The theoretical/conceptual framework of the PGCE (Slabbert, 2006 – see Appendix B) is founded on teacher self-knowledge, radical socio-constructivism, experiential learning, holistic education and contingency theory. The development of the course was mainly informed by the work of Korthagen (2001). His research has shown that when student teachers are exposed to and challenged with living through new experiences that they continually have to reflect on, they understand the principles that cause their practice to be successful. This allows them then consciously to construct new conceptions and internalise fundamental change in their own learning and the way they educate learners. This construction process represents the theory of practice. In the PGCE course, this is known as the practice-theory.

The practice-theory is the pivotal point around which everything in the PGCE programme revolves. It is the student's construction of a personal practice-theory of and for facilitating learning. It is intended to be a principle-centred, context-dependent theory that forms the foundation for guiding students' instantaneous decision-making to solve the problems of their professional practice and improve subsequent practices (Korthagen, 2001; Slabbert, 2006). The rationale for this is based on the departure point that education as a professional practice requires professional knowledge (rather than disciplinary-based theory) that is derived from practice.

According to Korthagen (2001), the traditional goal of teacher education focussed on equipping students with expert knowledge (resulting from psychological, sociological and educational research) so that they can use this expertise in their practice. Research shows that this scientific understanding of education (episteme) has "very little effect on practice" (Korthagen, 2001, p. 255) and does not produce the fundamental change necessary in education. Korthagen (2001) suggests that practical wisdom (phronesis) is required and the practice-theory approach outlined above is a means to achieving this knowledge derived from practice. The practice-theory, while serving as a theory (practical wisdom – phronesis) of education is also continuously informed, enriched and improved by each individual student's practice through reflection by the student and/or action research on their own practice. It can also be enlightened and enhanced by practices of other facilitators of learning as well as other existing theories (research) in education (Slabbert, 2006).

All PGCE students complete a module known as Facilitating Learning which takes them through five phases intended to prepare them as facilitators during the course of the year. The first phase is designed to help students find their personal voice to answer the question: Who am I and what do I need to maximise me? The second phase affords students the opportunity to compile a repertoire of education methods, tools and techniques that suit their personal strong points, and to implement these in practice. Phase three focuses more on the nature and structure of the students' areas of specialisation (for example mathematics) and adding to and implementing the repertoire of education methods, tools and techniques in this regard. The fourth phase requires that students construct a macro practice-theory that uses as its basis the facilitating actions necessary to ensure the highest possible level of quality learning, irrespective of personal preferences or the area of specialisation demands. The fifth and final phase builds on the fourth phase in that students develop their own personal (micro) practice-theory that incorporates all the essential professional decisions to be made to ensure the highest possible learning quality that a context may demand. A more detailed explanation of this module can be found in Appendix B.

The explanation above is an ideal theory though guiding the PGCE programme. In practice, during these five phases, students are still "taught" the theory of facilitating learning and what actions (stages, approaches and methods) are essential to ensure the highest possible level of learning quality. As part of the course requirements, students are required to implement these actions in their practice in order to defend their professional development. Students are given a framework that outlines four major teaching paradigms (see Appendix C) mainly drawing on the work of Miller's holistic education (Slabbert, 2006). By the end of the year, students need to be able to demonstrate their competency in the highest teaching paradigm (transcendental) in order to pass the course. The paradigms are now briefly discussed in hierarchical order from low to high.

The transmission paradigm is best described as imparting knowledge or lecturing. The transaction paradigm requires participatory understanding and questioning, involving the learner more in the lesson. The transformation paradigm also requires more participation from the learners in the form of exploration and projects. The highest learning quality (according to

Slabbert, 2006) emanates from lessons in the transcendental paradigm where real-life learning tasks are designed so that learners can create their knowledge.

The PGCE students are allowed to frame their lessons during their first school-based education (during the second term of the year) in the transmission and transaction paradigms. However, having gained experience during the first school-based education and also from their specialisation modules, students are required to produce a learning task design and video evidence of facilitating learning in the transcendental paradigm for at least two lessons. While I see the value in this, I question this as being the envisioned phronesis (practical wisdom) rather than episteme (scientific understanding) as the students are required to implement a prescribed and structured framework (see Appendices B and C) according to rigid guidelines. In saying that, however, it has been my experience while lecturing the mathematics specialisation module over the past seven years, that when students actually implement their first transcendental lesson with success, it has an enormous impact on their practice-theory and subsequent practice. The problem is that not all (or even many) of our students get to the point of *successfully* implementing a lesson in the transcendental paradigm. For them it remains a compulsory but elusive challenge from which they never really gain any phronesis.

The PGCE course is made up of a professional curriculum and a specialisation curriculum. The entire Professional Curriculum, and in particular, the comprehensive, integrated, holistic practice-theory of facilitating learning in the form of a concept map informs (is the foundation of and supports) the specialisation curriculum in which the actual professional practice is manifest. This means that the practice-theory of facilitating learning (in the form of a concept map) contains the fundamental (core) concepts that constitute facilitating learning. However, how the particular field of specialisation is practised, depends on the nature and structure of that particular specialisation. The specialisation curriculum, therefore, focuses on the identification of the nature and structure of the field of specialisation and the identification and selection of the relevant education practices of that specialisation. It is the particularisation of the specialisation and personal assets and preferences – where applicable – which will give the practice-theory of facilitating learning in a particular specialisation its individual and personal character and will contribute largely to the differences between the practice-theory of one individual and another (Slabbert, 2006).

The professional curriculum consists of the following subjects: Facilitating learning, Learning theories, Assessment, Global perspectives in education (including dealing with learners with special needs), Foundations of education, Social context of education (including diversity and HIV/Aids), Professional ethics and law, Professional portfolio development and Information and communication technology. The specialisation curriculum is the learning area(s) in which the student chooses to specialise. In the case of this study, all of the participants chose to become teachers in the FET phase and therefore all of them only had one specialisation learning area, namely mathematics. These participants are now introduced.

3.5.2 Sample

In this population, the sample chosen was selected based on a theoretical (Eisenhardt, 2002) rather than random sampling. Students specialising in the FET phase during 2006, 2007 and 2008 were asked if they would be prepared to make their portfolios and other relevant documents available for the study. From the 2006 cohort one of the two students gave consent for her data to be used, both students who completed the course in 2007 gave their consent and from the 2008 group, all four students signed consent. This resulted in a convenience sample of seven cases, varying in their backgrounds as far as their schooling and prior university experiences, but similar in their training in becoming teachers (i.e. the PGCE course).

The sample consists of six female students and one male student varying in age between 21 and 50. All of the students speak Afrikaans as their home language but are all competent in English as their second language and this was also used as the common language of instruction throughout their PGCE course. Students could choose to teach at either Afrikaans or English schools during their SBE's and could also decide on the language in which to present their portfolios in. Some of the students taught both of their school-based education terms, and later also wrote their portfolios in Afrikaans. Where quotes have been used, these have been translated. My home language is English but I am also competent in Afrikaans. I therefore did the necessary translations, with assistance and verification from an Afrikaans speaking colleague.

As part of the requirements for the final professional portfolio, each PGCE student is required to select a metaphor that they think best depicts the information presented in their portfolios. This metaphor needs to be explained and carried throughout the portfolio. It is also used in the final oral presentations where they present and defend their professional practice. I have chosen to include narratives on each of these metaphors as they provide good insight for the reader into the thinking, experiences and perspectives of the participants. They therefore provide more background on and context for each participant against which the mathematics profiles and instructional behaviour profiles can be understood in the chapters that follow.

Each participant is now introduced individually below as they portray themselves in their final portfolios. Figure 3.1 shows an initial "snapshot" of their initial visual mathematics profiles. These are further explained in chapter 6. For ease of narrative purposes, I have re-written the introductions below in the third person but want to stress that no interpretation has been added; these introductory narratives are completely constructed from information that the students made available in their portfolios.
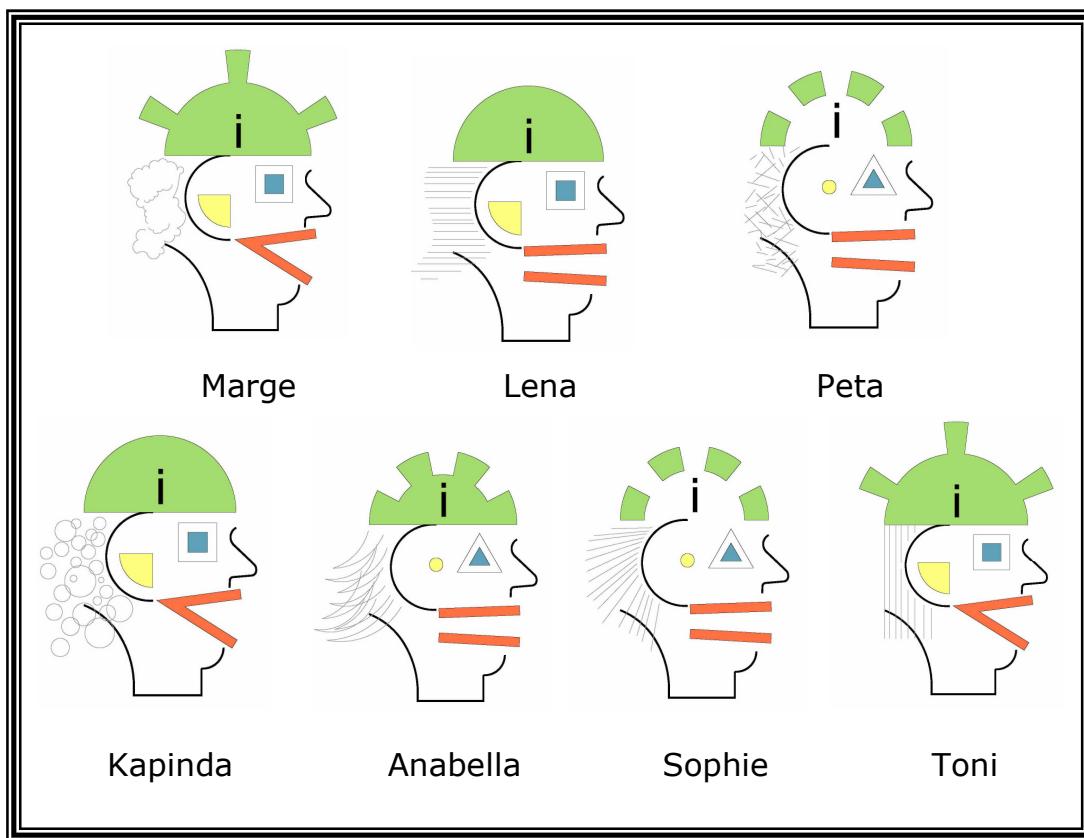
Figure 3.1   Initial "snapshot" of participants (Class of 2006 – 2008)

Marge (2006)

Marge has a different background compared to many of the PGCE students who register for the course in that she is older than the average PGCE student. She was born in 1958 and completed her initial Bachelor of Science (BSc) degree in mathematics and chemistry at the University of the Freestate in 1976. She then worked for a few years before having children. Marge stopped working for 20 years in order to raise her children, before she took on some part-time work again teaching extra mathematics. From 2003, Marge taught mathematics part-time at a local FET college before deciding to qualify as a mathematics teacher through our PGCE programme. Marge completed the PGCE course during 2006 and openly admits that she was "not prepared for what facilitating of learning implies." In her portfolio she describes the self-examination she went through during the year and the "bravado" she was freed from on which her self-image and confidence were based at that stage.

Marge describes her strengths as being a sense of responsibility and her self-sacrificing nature. Her weaknesses she admits come in the form of "fear, perfectionism and control freak". Her ideal is to eventually qualify academically so that she can lecture at a tertiary institution. The PGCE was her first step to realizing this ideal, and she has since also enrolled for a research Masters degree in education.

Marge describes herself as having a passion for mathematics. She says not a day goes by without her thinking of herself within the context of mathematics. She views herself as someone who is qualified and able to teach mathematics to Grade 12. She sees herself as someone who will continually and repeatedly strive to make the mathematics clear to learners in a variety of ways. She admits to being unsure of the new curriculum content such as financial mathematics, statistics and transformation geometry but she claims that her confidence and ease with the other parts of the content put her in good stead to master these sections.

Toward the beginning of the year she confessed that she understood her role in the classroom only in terms of the transmission and transaction paradigms. She saw motivating learners to develop a passion for mathematics, to infuse learners with self-confidence, to explain concepts in mathematics, and to prepare learners for examinations, as her main roles within the

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classroom. In a reflection she sent to me in May 2006, after I sent her a report on a class I had visited during her first SBE, she makes the following statement:

I still agree that Mathematics is not a set of rules, recipes or algorithms, but simultaneously I doubt very much whether negative learners taking a compulsory subject like mathematical literacy are capable of constructing their own, CORRECT knowledge…I am always under pressure not to waste too much time. I feel concerned about letting them construct wrong ideas and then have to demolish again. I have always thought that is more harmful to construct wrong ideas than no ideas at all. My idea always has been to show the way with clear explanations, embedded in theory and have the learners exploring with those examples as analogy.

Marge takes readers through her portfolio by likening herself to Paul of Tarsus from the Bible. She claims that her journey through the PGCE reminded her of Paul's journeys as he depicts them in the Bible. She adds that she could always identify with Paul's style and his way of reasoning. Her school-based periods at two different and unfamiliar schools are paralleled with Paul's temporary visits to synagogues in each town that he visited. She explains that "just like him [Paul], some accepted the new ideas and the majority rejected them. Just as Paul had to make adjustments to his programme or had to negotiate about travel companions or had to consolidate about problems, I had to also adjust my practice-theory."

Lena (2007)

Lena attended a local Afrikaans school after which she immediately went on to do a Bachelor in Secondary Education (BSecEd) degree at the University of Pretoria. In 2007 she enrolled for the PGCE programme which is the compulsory fourth year of the BSecEd course. Since she can remember Lena wanted to become a teacher and later on in her life she dreamt of becoming a great mathematics teacher who makes mathematics a subject that is loved and enjoyed by all the learners. That is why she decided to do the BSecEd(Sci) degree. This is a BSc mathematics degree combined with the PGCE programme. She decided to do this degree because it presented more of a challenge than doing a normal Bachelor of Education (BEd) degree and she felt that doing the PGCE programme was a great chance to develop all the necessary personal and professional skills needed to be a great facilitator of learning. She

experienced the PGCE programme as a good way to find out who you are and develop the weak points in your life to become good attributes.

Lena says that her life revolves around her Christianity in that she tries to do everything for the Lord. She wants to make Him smile when He looks at her life! She states that this is what keeps her motivated and why she tries to do everything as best she can. The most important things in her life are her family, friends and dancing! Her family and friends are always there for her and she shares everything with them, they make life so much better! Lena portrays herself as someone who always tries to help other people and who has a very tender heart. She tries to always keep her word. She admits that she sometimes lets people walk over her because she is not aggressive enough, and that she sometimes says things before thinking. Her biggest fear is growing old alone.

Lena presents her strengths as her self-discipline, self-respect and character. Her good self-discipline enables her to be organized and punctual. She adds that she also has integrity, faith and trust. Her one weakness she says is that she doesn't see the bigger picture; that she usually concentrates on the here and now, failing to think bigger.

Lena wants to be "the teacher that everyone respects" not because she is "mean and strict" but because she intends to treat learners "with respect and love." She strives to "be the fun teacher who is never grumpy, always making jokes but still maintaining discipline in the class." Lena hopes that her class will be the one "learners are always looking forward to and always enjoy." She sees herself as "the person who gets the discovering going." She portrays herself as the "person who gives and explains the work, but the learners need to try and discover the work on their own as well…because there are many ways of solving a problem, you just need to find the method that suits you best." If they struggle, she says she will help them but thinks that "a good way of understanding mathematics is to try it on your own." Lena also views herself as "an elder in the classroom." She doesn't want learners to feel that she is totally "above them and unreachable" but she does want them to "have the necessary respect that they should have for someone older than themselves."

Lena depicts her role in the mathematics classroom as "firstly to give learners the self-confidence to believe that they can do mathematics." Her next important role is "to explain the work in such a way that everyone can understand it and then apply the work to their everyday life." She also subscribes to "the role to supply the learners with the necessary life skills to reach their full potential in this world." Lena would like her learners to "be excited about mathematics" and to "realise that everything in this world has some form of mathematics in it. She hopes learners will "not only do the mathematics because they are told to, but because they want to do it and enjoy it." She hopes learners will "feel the satisfaction of discovering the world of mathematics."

Lena wants her classroom to "have a friendly and relaxed atmosphere." She wants learners to respect her and to treat her accordingly. She hopes to establish a culture in her classroom of "openness and friendliness" and for the "learners to feel free to express themselves" and to feel "that they are special". She intends to accomplish this by getting to know the learners in her class and giving them "the respect they deserve and being a fair teacher with integrity." She will strive to live out her Christianity in the classroom by just being herself, "without discriminating against any other religion."

Lena chose the board game "Snakes and Ladders" as her metaphor for the portfolio. She says that as a little girl, this was one of her favourite board games. She enjoyed "how you can be slowed down by the snakes that take you back a few blocks but that you can also advance a few blocks when you land on a block with a ladder." Lena felt that this was exactly what had happened to her throughout her PGCE year. As she moved through the blocks of the year, there were times when she landed on a block that made her feel like she went backwards in her professional development. This helped her though to realise that there were aspects of facilitating learning that she still needed to work on and develop. She compares the positive experiences and feedback she received to blocks with ladders in them. These represented her development and how she moved forward as a facilitator of learning.

Peta (2007)

After school Peta completed a BSc degree in Medical Sciences in 2005. In the collage that she compiled at the beginning of the PGCE year, she included a picture of a stethoscope which she

said symbolised her parents' dream for her to become a medical doctor. In 2006 Peta enrolled for her Honours in Pharmacology which she did not complete. Instead she chose to do the PGCE course in 2007 with a focus on mathematics.

Peta wanted to become a teacher for as long as she can remember. She enjoys working with people and also doing mathematics. Peta believes that she is "naturally drawn to work with other people." She likes "helping others find their way in life, often inspiring them to grow as individuals and to fulfill their potential." She thinks that she will "be a teacher whose students can really depend on to be fair." She wants to "be consistent and balanced" in her approach. She does not want to raise her voice and intends to always "treat every student the same without any favouritism." She claims to "have high expectations", always following up with people she has helped.

Peta indicates her strengths in the classroom being that she is "a calm and relaxed person." When asked about her weaknesses, she noted that she does not like fighting because she says she has a tendency to hurt people with what she is saying. Peta summed up her values in one Zulu proverb: "Umuntu Ungumuntu Ngabantu." This means that a human being becomes human through other human beings. She also emphasizes that in our South African constitution every person has the right to be treated like a person.

Peta views herself "as someone who should be able to make progress easier. To convey content in such a way that it will be easy to interpret." She doesn't just want "to teach learners what to learn or master, but how to do it." She would like to "show the learners how they can use mathematics in everyday life so that their gained knowledge may be power." She hopes learners will be "inquisitive with an enthusiastic and curious attitude towards mathematics" and her learners will experience the fact that she loves mathematics through her teaching and "that they would also start to think positive about it." Peta states that she "won't like to have any disruptions" in her classes and wants "students to realise that they will be dealt with according to the rules but in a fair and consistent way."

Peta tells the story of herself and the heart of an eagle as her metaphor for the final portfolio. The story is told in seven phases each symbolizing a corresponding phase in her PGCE year.

The story begins with an eagle's chick hatching. The second phase describes a strong wind blowing the baby eagle out of the nest. Phase three tells how a farmer found the baby eagle on the ground and placed it in his chicken run at home amongst all the chickens. One day a nature conservationist came to the farmer's house and found the eagle in the chicken run. He was shocked to hear the farmer explain how he had reared the eagle as a chicken and how the eagle had taken on their habits. The nature conservationist stressed how wrong this was and felt sure that the eagle could still learn to fly. Phase four and five tell of the two men (the farmer and the nature conservationist) together embarking on teaching the eagle to fly. Phase six tells how on the third day the nature conservationist took the eagle to a high mountain, pointed her to the sun and instructed her to fly like an eagle. The scared eagle looked around her, gave a loud call, stretched out her wings and flew! Phase seven concludes with Peta foregrounding the excellent sight and courage that eagles are known for. She stresses one should not keep "your eyes on the ground like a chicken because you doubt your own competences." Eagles belong in the air.

Kapinda (2008)

Kapinda enrolled for BSecEd(Sci) in 2004. Therefore similarly to Lena, she had to complete the PGCE as her final year in order to graduate. Although she thought that the PGCE is a good course to open doors for future career opportunities, she did not plan to become a teacher after completing the PGCE. Her career goal was to rather go into ministry.

Kapinda tells in her portfolio how she was "born as a mentor and tutor and facilitator!!!!" Kapinda means "grace and favoured by God; sparkling". Her dominant intelligences are interpersonal and intrapersonal which makes sense to her as she has a deep love for people. She enjoys being around people and being actively involved in their lives. She is also a 'thinker' and often is introspective to analyse situations. According to Meyer-Briggs personality type indicator, she is extrovert, intuitive, feeler and thinker. She learns the best when movement is part of the learning environment and learning task. According to her brain profile she is very creative and very emotional with organizational skills not very dominant. She believes that her calling is to "help people discover and develop their potential. To be a mirror of truth."

Kapinda describes the PGCE as a life-changing experience. She admits that she really learned a lot about herself. She says she now realises how important this is, since if one doesn't know who one is, it is impossible to believe in oneself. Kapinda mentions that the PGCE equipped her to prepare for an unknown future. She says she was often confused about what tomorrow would hold, but realised that is what life is about: learning to prosper amidst uncertainty. Kapinda also shared the changes in her views on the education system and teaching paradigms. She realised that we are dealing with learners who have a post-modern mindset, and should meet them at the place where they are. This is why, she says, we cannot teach in the transmission paradigm any longer and should encourage discovery learning in the transcendental paradigm. She felt that during the PGCE she and her peers learned what they did through Authentic learning, and the PGCE really applied to the Practice-theory of Facilitating Learning.

Kapinda identifies herself in the classroom just as a person, as not being more important than the learners, but that she too is a life-long learner. She aspires to be open to learn new skills, more human knowledge and more about life and people while also facilitating the learners to learn more. She believes that one of her main roles in the mathematics classroom is to encourage learners. For Kapinda, helping learners to believe in themselves is of "utmost importance". She strives to "encourage learners to be positive and not to underestimate themselves". She also wants to "make them hungry to investigate mathematics, and not be afraid to try."

In addition she also sees her role as enabling learners to relate the theory they learn to their daily lives. She believes that "spoon feeding doesn't promote maximal learning" but that it is good to "give some form of guidance and structure and help learners towards solutions." She envisions a relaxed but focused attitude in her mathematics classroom. She wants learners to be active rather than passive and to encourage them to keep on searching for meaning. She describes her desired classroom culture as an "interactive culture". Her ideal is for learners to find meaning in the subject content of mathematics. She hopes that what they learn will make sense to the learners and "be relevant to real life". For Kapinda the best part of mathematics is "to find a solution after struggling for long." She wants to encourage learners "to keep on trying, in order to experience that satisfaction of finding the solution."

Kapinda used the Fish River Canyon hike in Namibia as her analogy to navigate her journey through the PGCE year. She says that "every hiking trail has its ups and downs" as was her experience during the year. Kapinda actually hiked this Fish River Canyon trail during the student recess in her PGCE year. This therefore made this metaphor particularly relevant for her. She starts by identifying herself as the hiker before providing the reader with a packing list for the canyon hike that she parallels to characteristics in herself she needed to "pack" for the PGCE. She then summarises the ups and downs of the PGCE year in terms of Phases.

Sophie (2008)

Sophie started a Bachelor of Arts (BA) degree at the University of Pretoria directly after completing school. She completed her BA degree in 2007 with an emphasis on educational subjects, including mathematics courses that our BEd students do as part of their degrees. In 2008 she enrolled for the PGCE course with the intention of spending some time teaching in the United Kingdom in 2009.

Sophie describes herself as a very confident person who has faith in herself. She views herself as "a person who loves children" and "someone who really communicates well with children." She expresses that she is "not shy and will say when and what is needed for a situation." Her personality test indicated that she is dominantly introvert with intuition, feeling and judging scores being the same.

Sophie lists her strengths as "love easily and care about others", "strong bond with children" and that people get on well with her as she understands people and sees herself as someone that "anyone can talk to." She also feels that an advantage for her in the classroom is that she can "speak loud and clear to learners and people" and that she can do something and not let others interfere with her work. Her weaknesses she professes are that she sometimes gets despondent, especially when she is stressed. She adds that she then also gets "a bit confused with the things" she has to do. She admits to buying too many shoes, being mad about watching television, loves food and overeats and finally that she loves her sleep and is not friendly if someone wakes her up.

In the classroom Sophie sees herself as the facilitator and the children are her learners. She feels that in the classroom she cannot be a friend to learners like she is "with other children." The context of the classroom is different and she views herself as a "different person" there. She wants learners to see her "as their superior and facilitator" and she expects them to respect her. Her role is "to educate learners, especially in maths and to maximize their potential for their own futures and lives." She wants to strive for "equity in the classroom" and "not have any favorites." Sophie states that she "will not discriminate against race, colour or culture" and intends to "be fair in everything" she does in the classroom and in the school. She intends to tell her learners "to keep their cultural beliefs outside the classroom" if it disturbs her facilitating and insists that "all learners must also be considerate towards other learners' cultures."

Sophie hopes learners will be themselves in her classroom and "participate in all the activities" she does. She doesn't want them to be afraid of her so "that they don't want to ask questions" but she also doesn't want them to see her as their friend. She expects learners to "ask questions when they don't understand, and if they don't and they also don't understand" she states that "the rest of their problems are not my responsibility." She aspires to "plan fun and interesting activities and be organized" so that learners can see that she knows what she is doing.

Regarding mathematics, Sophie would like "learners to experience the learning area/subject of maths … as interesting, fun and challenging" in her class. She says learners must "want to come to class" and she will do her "best so that all the learners understand the work, therefore all of them will not find it frustrating." Her aim is to "connect the work with real-life situations and careers so that learners will want to do mathematics and "find it interesting, because they then know that they will make use of the information, somewhere in the future."

Sophie ran the Comrades Marathon (87km) for the first time in 2008, while also completing her PGCE course. She used the analogy of running the Comrades in describing her PGCE "marathon". She admits that both undertakings were strenuous and "had a lot of uphills and difficult times." She adds that at least "there is a downhill on the other side of every uphill." She enjoyed the downhills very much and the supporters made the marathons pleasant and

worth the effort. Sophie divides her portfolio into 14 sections that parallel sections of the Comrades marathon.

Anabella (2008)

Anabella, like Lena and Kapinda also completed a BSecEd (Natural Sciences) which has the PGCE course as the fourth year. She admits that initially she did not want to consider teaching as a career. Both her parents are involved in education. Her mother is the principal of one of the largest pre-primary schools of the South African Women's Federation and her father is both the principal of a school for physically disabled children and a counsellor at the South African Council for Education. She claims that she therefore knew "exactly what education entails" and subsequently made herself believe that she is not a teacher and that she is meant to do something different with her life. In retrospect she admits that the only reason for this self-indoctrination was because she didn't want to do what her parents did; she thought this would be a mediocre and uncreative decision.

She remembers though, sitting in a mathematics learning period in Grade 11, when she suddenly became aware that she was critically assessing the educator teaching them. She tells how in her head she thought of everything that she would have done and said differently if it were her teaching. When she realized this, she immediately forced the thought out of her head! She subsequently started studying BSc, Biological Sciences to become a vet and after a year it "hit" her that she was busy lying to herself and if she was not going to be honest with herself that she would eventually miss her "calling from GOD!" She now says that she was always "born a teacher" and recalls how everybody told her this, but that she just "always stayed hard headed and stubborn about the issue."

That is how it came about that she enrolled for the BSecEd (Natural Sciences) degree in her second year and for the PGCE. She feels that the PGCE is not only part of her degree but "also the most important course" that will eventually contribute to her "fulfilling her purpose in life!" She admits how disappointed she was after realising that the PGCE year wasn't what she expected it to be and that she, "kind of, had the wrong perception of teaching." She knew she had to "build new knowledge and get equipped with the foundation, the rhythm, the melody of facilitating learning" before actually applying it in her practice-theory.

Anabella believes that "mathematics is one subject that the average learner fears and avoids practising because it's a complex concept subject and the fear of getting a problem and to not know how to solve it is a terrifying feeling". That's why she believes that her "role as mathematics facilitator is to really kill that fear and to help the learners understand and enjoy mathematics" like she did. She wants to strive to be 100% herself in the classroom and by doing so to get the maximum fulfilment out of each day whilst teaching her favourite subject and "working one on one with children."

Anabella expects to work "with learners that want to learn, work hard and grow through struggling and failing." She wants to see "perseverance, discovery, relief, satisfaction, focused and ambitious learners with a zest for life and mathematics." She believes that mathematics is the subject that can really teach one all of this. She hopes that her learners will "have the courage to continuously ask questions if they don't understand, to participate in class discussions and to always question the work by using their critical thinking."

She plans to share her own mathematics history with learners in her class to "highlight that nothing is impossible and that our goals are always reachable with the right mindset and attitude." She intends to give learners "control over their own learning, so they feel responsible for their own growth and development in the subject, that they also feel undependable [independent] and get to experience a little bit of adult-life in the mathematics classroom." Her demeanour in the classroom will be "strict but approachable and will influence the difficult/stubborn learners' thoughts/minds to try and give mathematics a chance."

Anabella predicts that her classroom culture will "definitely be positive, to always strive for higher, better and faster in every way possible. No learner must be afraid of not knowing, and they must see challenges as an opportunity to grow." She wants learners to walk out of class "with a smile and something to think about" and she wants them "to fall in love with the subject and as a result also with life." She hopes learners will "go out and live life to the fullest by using their maximum potential." Anabella believes that "through mathematics, [learners] can experience the important life skills that's needed for life."

Anabella begins her portfolio with the following quote by Sergei Prokofiev:

"It is the duty of the composer to serve his fellow man, to beautify human life and point the way to a radiant future. Such is the immutable code of the artist as I see it." She chose the composition of music and the listening thereof as the metaphor that she felt really describes her and also represents her professional development as a facilitator of learning. She describes in her portfolio how she cannot imagine living without music as it is such a part of her life. It allows her to escape from the busyness and stress of the world, in order to "get refreshed and ready to face the struggles". She quotes Martin Luther saying: "Beautiful music is the art of the prophets that can calm the agitations of the soul; it is one of the most magnificent and delightful presents God has given us." She presents and uses 11 steps in composing music that link with her own personal high or low points in her professional development. Anabella also uses the colour green throughout her portfolio as she sees the green as being representative of the growth and development that she experienced throughout the year.

Toni (2008)

Toni (the only male in the sample) came to the PGCE with a different background from the other students. He is a BSc Financial Actuarial mathematics graduate from the University of Pretoria. He says that he realised during his high school education that he has "a calling to be an educator." He admits that he did not want to accept this and that "the financial gains and status in the corporate world are much higher."

Toni views himself as having "exceptional mathematics ability." This is shared with a great love for mathematics. He wanted to use this skill to the utmost of his ability and is the reason he enrolled for "arguably the toughest mathematics course at varsity." He never had any real dreams of becoming an actuary. When he was nearing the end of undergraduate studies he realised that he needed to pursue his "dream and calling of becoming an educator." He started to inquire about the possibility of enrolling for a PGCE in education. He did not do this immediately since there was strong opposition from his parents. He says he felt as if he would not make them proud if he became an educator. He admits to struggline with things that did not interest him anymore, trying to complete an honours degree in Actuarial Science. Finally during December 2007 Toni decided to pursue his dream "at all costs" and enrolled, albeit late, for the PGCE course.

In the classroom Toni intends "to be involved in mathematics education." This means that he will "be the facilitator but also a student of the subject." He describes himself as having "a positive attitude towards life", being "a confident person and … a good speaker." He believes that he will be able to use these attributes to his advantage in the classroom. He feels he has "a responsibility to be a positive role model" in the lives of his learners who will be "teenagers who are busy constructing their own identities."

Toni believes his role in the classroom is "to create opportunities for students to experience the richness and wonders of the world of mathematics. This includes creating and generating learning tasks and experiences focused on the wonder of the mathematical world." He reflects on his recent introduction to the "idea that education is mainly an emotional activity." In relation to this, Toni mentions that "many students experience a feeling of failure when they are confronted with mathematics." He believes that he "will need to provide students with the emotional support they require to master the subject." He confesses that this will be a challenge for him because he does "not respond well to people who are emotional" and does "not know how to provide them with emotional support when they need it."

Toni cites "openness and trust" between himself and the learners as important in order to "create an environment where I [he] can identify students who experience difficulties with the subject much faster. If these difficulties are identified at an early stage it will be much more effective … to try remedy the problem." Toni believes that "the role of the facilitator is not just to provide learners with the opportunities to engage in a mathematical problem." As a facilitator he states that he "will have to create opportunities for learners to develop their fundamental life skills as well."

His ideal of a student is one who is "inquisitive, enthusiastic and willing to persevere while confronted with a problem. Problem solving is fundamental to grasping concepts and discovering mathematics. Only through perseverance will the learner solve a problem and create an 'AHA' effect. Once this effect is reached it can become an addiction and mathematics will no longer be a burden but enjoyable." Toni believes that the best way to get students interested in the subject "is to be enthusiastic about the subject that you facilitate. A positive

attitude towards a subject will influence the learners in that class. If students are exposed to the greatness of their mathematical abilities when it is put into real life context they will enjoy the subject. It is important to ask the students to try and link everything they learn to real life. Mathematics is not just a set of rules to manipulate numbers. It is science that is used to discover, analyse and describe all natural phenomena around us."

Toni hopes to create a positive culture in his classroom, "one where students can feel free to share ideas and information about topics related to mathematics and things in general." He states that "the greatest level of achievement and construction of knowledge will be when every person in the classroom can contribute to the process of learning." He confesses that he does "not know everything about the subject" and that he can "still learn from students in the class." He believes his learners "should experience mathematics in a practical real world problem. Seeing and realising the impact that mathematics has on the world around us is the only way to get students involved in the subject." He would like to "incorporate some of the other intelligences of the MI [Multiple Intelligences] theory" into his classroom. He cautions that because he will be "facilitating the study of mathematics it is easy to forget about the other intelligences and only focus on the mathematical intelligence." Finally Toni believes that learners "should not experience mathematics as being separate from other learning areas." He would like to "create learning tasks that involve the learner in a holistic way" but he admits to not being sure how to succeed in doing this.

Toni tells his story of professional development with the analogy of "a farmer who had a dream to create a new cultivar of grape and use it to create an extraordinary wine." The perfect grape represents the way he changed during the year while "perfect wine represents the quality of learning that took place" because of his transformation. After the introduction the nine sections in the portfolio guide the reader through a series of learning tasks that he developed and uses to show his development.

3.5.3 Data collection

As the final portfolio comprises a large part of the summative evaluation of the PGCE students, there is a module within the course known as Professional Portfolio Development

(Slabbert, 2004). Students are guided from the beginning of the year on how to prepare for and what documents and evidence to collect as part of their professional development throughout the year (see Appendix B). They are required to keep daily reflections, learning task designs, video recordings of some of their lessons as well as their practice-theories to include as evidence in the final portfolio. Following the stipulated guidelines, students decide what documents and artefacts from the duration of the year to include in their final portfolios.

During the course of the year the PGCE students develop three portfolios prior to the final portfolio that they submit for examination. Students are given feedback and further guidance on these interim portfolios by the lecturers responsible for the Professional Portfolio Development module. As the specialisation lecturer, I only receive the final portfolio at the end of the academic year to assess. Once the portfolios had been assessed and the students had also completed an oral presentation and defence of their professional development, I sought their permission to use their portfolios as the source of data for this study. Students have the option to collect and keep their portfolios once they have been assessed but most students leave them at the university, as was the case with these participants. Once I had ethical clearance and permission from the participants, I retrieved their *portfolios* from the storeroom as well as other relevant documents I had stored from their PGCE year. These relevant documents included a *mathematics baseline assessment* students complete on selecting mathematics as their area of specialisation and any *assessment reports* issued to students on lessons I have observed them teaching during classroom visits. These documents are elaborated on below.

Portfolios

The professional portfolios that PGCE students submit as part of their summative evaluation for the course are the main source of data for the case study. The portfolios are extensive and contain reflections, learning task designs, video data from school-based practice periods, brain profiles, graphical representations of their emotional journeys, their changing mission and vision for teaching and education, the concept maps that are a representation of their practice-theories as well as any artefacts or documents they choose to include to demonstrate their professional development. Each student is required to choose a metaphor or analogy that they think best describes their journey through their PGCE year. The portfolio needs to be

organised in such a way that the analogy portrays the storyline that guides the examiner or reader of the portfolio through the students' professional development.

For the purpose of this study, in describing the mathematics profiles and instructional behaviour of the participants, I include the following data from students' portfolios (an example of each can be found in Appendix G):

- Their vision and mission statements on education from their portfolios or their initial and later views of education
- Their learning task designs (comprising a series of lesson plans)
- Their reflections from their portfolios as well as class-based tasks
- Video recordings of a selection of lessons during their school-based education periods that students chose to include in their portfolios

At the beginning and again at the end of the year, students are required to write a *vision and a mission statement* on education or their *initial views on education*. Students include these statements in their portfolios as evidence of how their views on education have developed and changed during the year. Students do a *written lesson preparation* for each lesson that they teach during the course of the year. These are known as Learning Task Designs (LTD's) and there are guidelines students need to follow in developing these LTD's. This written preparation also needs to be available for mentor teachers at the school who are assisting the students during their school-based education as well as for the specialisation lecturer when they attend a lesson for assessment purposes. Students include a selection of LTD's in their final portfolios to demonstrate their professional development, especially with regard to teaching in the four different paradigms mentioned in Section 3.4.1. The PGCE course also requires students to keep *daily reflections* during their school-based education periods, reflecting on the lessons and LTD's they planned, how they worked out in practice and what literature they have read or what they need to do to improve on or change in their practice-theories. At the beginning of the year, students are made aware of the responsibility they have to make and keep *video-recordings* of a selection of the lessons they present during their two school-based education periods. For their final portfolios, students select the recordings that they have identified as most representative of their development. These are included on DVD's in the portfolio for the examiner to view. Students also show clips from these video-

recordings during their oral presentation and portfolio defence that also forms part of their summative evaluation. I therefore did not decide which lessons to record for data purposes. I used the video-recordings that students included in their final portfolios.

Mathematics baseline assessment

The *baseline assessment of students' mathematics content knowledge* is a "traditional" assessment (see Appendix D) that I developed and introduced into the course in 2005. Although this baseline assessment is in the form of a traditional assessment, I do not use it as a measurement tool. Instead I perform a deductive content analysis of the assessment, specifically with regard to the types of errors students make in completing the assessment. I code the errors into one of three categories, namely, fundamental errors, solutions omitted or incomplete and careless errors. The content analysis provides me with some insight into the students' mathematical thinking and pre-empts the personal and individual consultations I subsequently carry out with each student on aspects of their understanding of school mathematics. Students are given the baseline assessment and asked as mathematics teachers to set up a memorandum for this particular instrument (test) that covers work included in the curriculum up to a Grade 9 level. The memorandum needs to show how students would expect learners to solve the questions posed and also needs to indicate how marks would be allocated in the marking of the questions. This may seem to contradict the reform ideology suggested in chapter 2. However, traditional test instruments still dominate the assessment in most mathematics classrooms. I believe these test instruments can still be a valuable part of the reform ideology depending on how they are used.

If students are encouraged to show their thinking in the tests and teachers use the tests to gain more insight into the mathematical processes and understanding of learners, then the tests become an important diagnostic tool. If teachers focus predominantly on learners' answers and how learners apply memorised facts and algorithms in the test, then the test instrument remains supportive of the more traditional ideology. I therefore use this baseline assessment task for a dual purpose: as the departure point to addressing this aspect of assessment in mathematics and as a tool that offers me insight into the PGCE students' mathematical thinking and their understanding of some basic mathematical concepts. In this study I used the content analysis of the baseline assessment as one of the indicators of the subject matter

knowledge of participants within their mathematics profiles. This is further explained in chapter 6.

Assessment reports

In addition to the portfolios, another aspect of the students' summative assessment is the evaluation of their school based education periods by their specialisation lecturer. The lecturer is required to visit each student within their particular subject domain at least twice during each of the two terms (the duration of each being approximately six weeks) that the students spend based in the schools. Students usually invite lecturers to attend a specific lesson or the lecturer may choose to indicate a specific day or week during which they will visit the student. For the mathematics specialisation module I try to make at least three visits to each student during each school based education period. For the first lesson I attend, I ask the students to invite me to a particular lesson. For the second visit, I request their teaching timetable and indicate a week during which I plan to visit. For the third visit, I leave it open-ended and visit at any time unless they have a particular concern or indicate a lesson they require assistance with.

During the course of the lessons I observe, I write down any comments. At the end of the lesson, I usually have a short debriefing with the student (if their timetable permits this) and then email them a comprehensive report during the following 24 hours (see Appendix H). In this assessment report I include questions that I require students to reflect on in their response to my assessment. They are required to submit this response back to me via email within a week of receiving their assessment report. In observing subsequent lessons of the student, I try to focus on aspects within their classroom practice that they have improved on and those that still need attention. Students often use these assessment reports as part of their final portfolios in demonstrating their professional development. I keep a database of the assessment reports so I was able to draw reports from this database as required even where students did not include the reports in their portfolios.

3.5.4 Data analysis

For the data analysis I used the guidelines from Miles and Huberman (1994) as my main reference source. Their flow model of data reduction, data displays and conclusion drawing/verification represents an outline of the components of data analysis as I applied them. According to Miles and Huberman (1994) *data reduction* entails the process of selecting, focusing, simplifying, abstracting, and transforming the data from their original format in which they were presented. For this study, this involved a number of phases. First I worked through each of the portfolio collections for each student. This included reading through all the reflections, metaphors, personal accounts, learning task designs, brain profiles and commentary, concept maps of practice-theories, reports and assessment from the lecturer (myself), the mentor, their self as well as peer assessment. At this stage, data were also sorted according to where they fit into the conceptual framework.

The video data included in each portfolio were also transcribed and coded during this stage of the data reduction using Transana[16]. The software allows one to separate the data into different series, episodes and finally clips, which become the unit of analysis. In this study, each participant is represented as an individual series. The videos of different lessons during their SBE periods that they provided in their portfolios were entered as episodes in their particular series. Each episode was transcribed and analysed visually through the identification, coding and categorizing of clips. Clips can be grouped into categories (that have been inductively or deductively constituted) but they can also be allocated descriptive keywords and later regrouped or organised according to common keywords. This conceptual process is iterative and multi-layered, continually forcing one to challenge and raise the level of analysis. I started off by allocating the clips descriptive keywords and later grouped them into categories. For example, if a participant was teaching a lesson and made a mathematical error, I would allocate the keywords "mathematical error" to that clip. Later the clip was organised into the category of subject matter knowledge for the purpose of reporting on this component of the mathematics profile.

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[16] This is a video data software analysis tool available from the Wisconsin Centre for Educational Research. For more information see www.transana.org.

The text and video analysis represented the first level of inductive analysis (to see what possible codes might emerge from the data) as I read and sorted the data for any emergent patterns or themes. It was during this phase that I started to notice varying degrees of discrepancies between the way the participants viewed and represented themselves and their practice and how I (or the other specialisation lecturer)[17] and their peers or mentors perceived them. The main theme that I inductively established in this phase therefore related to what Skemp (1971, 1989) calls "reflective intelligence". This is further expanded on in chapter 7. Other less dominant themes that were induced related to depth of reflections, mathematical errors, level of mathematical ability, type of mathematics (e.g. process versus conceptual), teaching and learning approach, usefulness of planning, autonomous versus democratic classroom culture continuum and traditional practice versus reform practice.

Having noticed the theme of reflective intelligence emerging from the initial data reduction, I decided to provide three *data displays* for this report in order to enhance the credibility of the data. These included: introductory reflections of how the participants portray themselves (in Section 3.5.2), participant reflections written in the voice of the participant (chapter 4) and a researcher reflection written by myself on each of the participants' mathematics profile and instructional behaviour (chapter 5). Each of these data displays in turn provided another phase and level of data reduction and simultaneous inductive analysis. This therefore created a multi-stage process of organising, categorising, synthesising, interpreting and reporting on the available data (Gay & Airasian, 2003). This process is further outlined in chapter 6.

During this time I was also continuing to review additional literature for the study in further developing the conceptual framework. Additional themes and categories started emerging there too. I therefore constructed a more detailed (pre-determined) analytical framework within the conceptual framework to apply to the participant and researcher reflections (see chapter 6). This was done using the initial inductive themes with a view to again ensuring further credibility of the data and also in order to produce the profiles in a fourth data display

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[17] Another lecturer sometimes assisted me with presenting lectures or visiting students for assessment purposes during their school-based education periods. Some of the assessment reports of the students included as data are therefore written by the other lecturer.

(in addition to the three mentioned in the paragraph above), in a visual representation that would make case comparisons (within and cross-case) easier. Within-case analyses involved examining the relationship between each participant's mathematics profile and instructional behaviour. Participants were grouped together according to the similarity or differences in their mathematics profiles and cases compared before a broader cross-case analysis was carried out (Eisenhardt, 2002). The data reduction, display and verification process was therefore an iterative one involving both inductive and deductive coding techniques (Miles & Huberman, 1994; Creswell, 2003; Gay & Airasian, 2003) or what Tashakkori and Teddlie (1998) refer to respectively as latent and manifest content analysis.

For the purpose of the case comparisons I developed the format of the visual representation of the mathematics profiles and instructional behaviour profiles in consultation with a friend who is an architect who was able to assist me with the drawings. Using his technical and critical input and the conceptual framework I constructed the four categories and visual representations for each of the components of the mathematics profile. It was important to me that the visual representation is simple yet symbolic of the data it represents. While engaging with the literature in order to develop a suitable framework for the instructional behaviour construct, I decided that the most appropriate way to represent it in the visual presentation would be on a Cartesian plane. The Cartesian plane allowed me to position the instructional behaviour of participants on two axes rather than in one linear dimension. The two axes I chose to make up the Cartesian plane are denoted by continuums: on the x-axis is the traditional to reform (see section 2.3.5) continuum and on the y-axis the endpoints are authoritarian versus democratic (see section 2.3.6). This is further discussed in chapter 6.

3.6 Methodological norms

In qualitative research it has become acceptable to use alternative terms for validation standards of research (Creswell, 2007) such as credibility, transferability, dependability, confirmability and authenticity (Lincoln & Guba, 1985).

In my opinion the credibility and dependability of the study are the two most important features in validating the accuracy of the study (Creswell, 2007). *Credibility* is usually equated

in quantitative terms to internal validity and deals with whether the results are an accurate interpretation of the participants' meaning (Creswell, 2007). In this study an attempt to ensure high credibility was made through prolonged and sustained engagement with the participants (a year worth of data for each case), progressive subjectivity through a careful monitoring of the developing constructions (through an audit trail, as well as my continual iterative data reduction and display process) and triangulation of multiple data from the participants' portfolios (Guba & Lincoln, 1989). I also included the analytical process of compiling the data tables (see chapter 6) for each participant according to the conceptual framework. These tables guided the compilation of each participant's mathematics profile and instructional behaviour profile.

As the data was taken from what the students presented in their portfolios to the public, formal member checking was excluded as a validation process. This decision was taken as some of the participants compiled their portfolios three years before the narratives and profiles were compiled. With most of the participants already being in the field of teaching, it seemed futile to ask them to read through it now three years later to see if it represented what they then believed (and was in any case written in their portfolios). However, as there was another lecturer who assisted me at times with the mathematics specialisation module, I sent my analyses of the mathematics profiles and instructional behaviour to her as a form of member checking.

The four data displays alluded to in the data analysis section were also intentionally included as a means of increasing the credibility of the study. These varying data displays also allow for a more explicit *dependability* trail showing the progressive analysis of each step of the process and providing some chain of evidence (Yin, 2003). According to Whittemore, Chase and Mandle (2001), by including the data of how the participants present themselves in their portfolios (through their personal reflections) as well as how others assessed them (reports from mentors, peers and lecturers) the *authenticity* of the report is also enhanced as "different voices are heard" (p. 206).

While *transferability* has been considered through the use of multiple case studies and including a rich description of each case, the intention is not to generalize or directly transfer

the results of this study. Where a micro theory has been suggested, it is reserved for these participants in this context. This was intended as an exploratory study to understand any relationship between the mathematics profiles and practice-theories of the participants, but not to establish causal assertions (Yin, 2003).

3.7 Conclusion

This chapter has outlined the research methodology used in this study. A retrospective or post-hoc case study involving seven single cases was used. The study is situated within a social constructivist worldview. The context of the study, namely that of the Post Graduate Certificate of Education course was described as a backdrop for the reader for the chapters that follow. The participants were introduced as they depict themselves in the portfolios that they handed in at the end of their PGCE year. The data collection, analyses and quality control procedures were also discussed. The following chapter presents the participant reflections written in the voices of the participants.

CHAPTER FOUR   PARTICIPANT REFLECTIONS

4.1 Introduction

This chapter presents reflections in the voice of each of the participants. Data were all collected during the PGCE year of the participants and selected from their final professional portfolios. Each participant reflection here is a compilation (in chronological order) of portfolio entries I selected from their final portfolios. These are narrated by the participants [18]and the entries included were chosen as representative of the full extent of entries appearing in the participant's portfolio. These reflections are intended to highlight information, experiences and beliefs of the participants relating to their mathematics profiles and instructional behaviour profiles.

After completing the initial literature review, I decided that the four most important components that I would focus on in depicting and analysing the *mathematics profiles* of the participants would be: subject matter knowledge, pedagogical content knowledge, conceptions of mathematics and beliefs about the teaching and learning of mathematics. In terms of *instructional behaviour*, I differentiated between traditional and reform practices on one continuum and authoritarian versus democratic experiences of teaching and learning mathematics on the other continuum. Each of these components was defined and described in chapter 2.

For the participant reflections in this chapter I have opted not to explicitly demarcate between the various components of the mathematics or instructional behaviour profiles, although they strongly guided my selection of what data to include from the portfolios. A more analytical view, drawing on these reflections and distinguishing between the components within each construct is provided in the researcher reflections in chapter 5. The basic outline of these

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[18] Grammatical corrections to these reflections were only made when meaning was adversely affected. Respondents were not first language English speakers.

participant reflections presents each participant's initial and subsequent views on education (at the beginning and then the end of the course), lesson reflections and notes from their Learning Task Designs (LTD's) and experiences during the PGCE course. Although the dates of the portfolio entries are not always included, I have worked these entries into the participant reflections in chronological order and chosen at least one learning task from each of the two school-based experiences that each participant experienced. The changed font in the text is intended to mark the participants' own voices.

4.2 Marge

After a period of more than 20 years during which I often and intensely hankered to study further, I could finally do it at the start of 2006. Although I was very positive and excited about studying, I was not at all prepared for what facilitating of learning implies. My portfolio describes the self-examination that I went through. I was freed from a number of "bravade" on which my self-image and self-confidence was based at that stage. This is also explained in my portfolio.

At the start of the course, I had strong convictions about what mathematics and mathematics teaching are. I held fast to what Ernst describes as an instrumentalist view which could perhaps bend towards a plaTonic nature. I saw mathematics as a rigid body of facts, rules, laws and skills and myself as the authority and source of knowledge. I viewed mathematics teaching as the process within which solutions are explained with the single goal of being imitated.

From the moment I was confronted with having to follow a problem-centred approach in mathematics specialisation, I was sceptical and tense about it. I could not imagine how learners can construct their own mathematics. I could also not see how the greatest part of the curriculum could be presented in a problem-centred manner.

I had two strong convictions that were not in line with constructivism. I could not see how a learner could be confronted with errors. I went as far as to state that a learner should rather not do mathematics at all, rather than make mistakes. I could also not believe that learners could construct their own mathematics. In my opinion mathematics was a rigid body that must be meaningful.

After this morning's session, I know that, like I admitted the day before yesterday, I am guilty of a suffocating love in an inappropriate manner. I assume the responsibility for others. I am inclined to nurture dependence. I now realise that I denied my own children and learners the opportunity to develop their intra-personal skills. … I will have to believe in learners' potential….I really want to change but I do not know how to. I cannot see, but first I have to believe. … I will have to renew my thoughts and get advice about how to develop my right brain. I will also have to believe in my own potential…

I understand my role in the classroom still in terms of transmission and transaction paradigms. In those terms I understand my role as being to motivate learners to have a passion for mathematics, to build self-confidence in learners, to explain concepts in mathematics to learners…and to prepare learners for the examination. I see my role as making mathematics accessible and logical; to always convey everything with reasons.

I doubt very much whether negative learners taking a compulsory subject like mathematical literacy, are capable of constructing their own, CORRECT knowledge….I am always under pressure not to waste too much time. I feel concerned about letting them [learners] construct wrong ideas and then have it demolished again. I have always thought that it is more harmful to construct wrong ideas than no ideas at all. My idea has always been to show the way with clear explanations, embedded in theory and have the learners exploring with those examples as analogy.

I am shocked at how I totally missed the point with the planning of my specialisation presentation (learning task design). I commenced with theory and disciplined knowledge and ended with the application of problem-solving: exactly back to front!! The choice was further hopeless in the sense that the content did not form part of the new lesson plan. It has only been presented for the last two years and has no place in the reality of the real-world. It was impossible to use the transcendental paradigm for this content.

At Hoerskool [Highschool] Gold I was confronted with a lack of discipline, respect and motivation in the learners. My mentor also reacted at times negatively to a problem-centred approach by, for example, making the comment that everything takes twice as long. I was under pressure to teach conventionally and the first time I was assessed by Hayley, I got a very bad report. This coincides with lesson planning 3. This was a painful blow for me as I have always boasted of an excellent academic prestige.

At Hoerskool [Highschool] Gold, it started going better with me. A turning point was the operationalising of a combined self-study exercise of lesson 6, 7 and 8. I generated this problem myself. The learners had previously learnt the social knowledge and heuristic for this. The learners could solve the problem graphically with very little sophisticated mathematics, therefore on the horizontal level as described by the theory of Realistic Mathematics Education. To get the learners working self-actively was a personal victory for me. I cannot claim that this was facilitating learning, but the learners and I went through a learning curve and growth process. I can describe the nature of the learning experience as a type of tutorial class within which the learners were self-active. There was very little to no formal teaching.

My second SBE was at a high school only for girls. I can compare it to Paul's experience in Athens which he describes as: Athens was naturally a city of new

things. All inhabitants and visitors to the city wanted to know what the newest philosophy was. I had expectations of the learners. I was under the impression that this the one school where a problem-centred learner-centred approach would be welcomed with open arms. While I developed learning tasks for this SBE, I included the concept of solving or deduction in my personal practice-theory as an end-product outcome. Out of the nature of my learning area, I developed a need for this concept.

As part of the learning task design, I also began to reflect on how the lesson of an operationalised learning task might pan out and using that I planned questions that I could use during the learning task comments to effect reflection and meta-learning. It was also clear that the classroom culture that I wanted at Gold was focussed on discipline. Meantime I began to realise that it includes more than discipline. I discuss this in more detail in the following reflections.

I wrote a list of core concepts on the board and gave co-operative groups an opportunity use these to consolidate the concepts. Some of these concepts were new, but the learners could understand them in context and shape because it was constructed knowledge. This was a successful example of the heuristic of horizontal mathematics which then gets formalised vertically.

After the successful operationalising of LTD 1 and 2, my mentor was openly positively surprised…I could apply my personal practice-theory during the operationalising of LTD 2. … In LTD 2…the problem was not really high. The problem was a story. In retrospect I also know that I did not effectively facilitate co-operative learning effectively. I am, however, of the opinion that the operationalising of this problem still contributed to the learning quality of the learners. Meaningful and comprehensive content was generated during the process of solving. In the classroom culture this was a meaningful breakthrough. Learners have been conditioned through transmission and here had valuable experience with meta-learning strategies.

During learning task 5 I encountered the hurdle of incomplete social knowledge that Murray, Olivier and Human refer to. The learners were not confident with function notation. At this stage I worked social knowledge and heuristic into my personal practice-theory….This problem can be done in Grade 12 with sophisticated mathematics at a vertical level. It also lent itself though to a less sophisticated solution on the horizontal level. It was a meaningful way to let the learners construct knowledge and then to teach the quadratic function in a more "naked" way through transmission teaching.

I feel positive about the extent to which I succeeded in holding myself back from teaching learners and thereby robbing them of an opportunity to what they are able to do. Still I feel under pressure to finish the learning task in the shortest possible time. This makes me sometimes change over to transmission too quickly. I believe they feel unhelped and confused about this strange experience.

It was difficult for me to handle more than 30 learners at a time on my own: to let them go outside; to let them take the measurements and to facilitate. Many learners were helpless and did not have a good grasp. Many of them, for example, did the diagrammatic representation correctly. They struggled a lot to understand that the problem can be solved in two ways. An atmosphere of dependence was present. Learners do not read the written presentation. They are accustomed to not thinking for themselves. Claxton's description of a lack of common sense could clearly be seen here. The phases that Bruner describes, do not apply to these learners at all. They are used to fragmentation and struggle to integrate.

There were two more learning tasks that I operationalised at [the second school] that made learners excited and interested during the learning task presentation. The one was a problem about saving options and the other was a game with a prize. I chose LTD 16 as my most successful learning task presentation. I attribute the girls' involvement to the fact that everyone can identify with crime. When I told them that

my car had been broken into twice, some of the learners wanted to immediately know if this was the truth, and it was. There was definitely less resistance toward problem-solving. The learners all tried to solve the problem and the general atmosphere favoured meta-learning.

The operationalisation of learning task 16 was successful. To avoid conversations and subsequent dependence and to keep the atmosphere one favouring meta-learning, I included another concept in my personal practice-theory: that of Vygotskian scaffolding or hints in the form of questions that would force learners towards reflection and meta-learning. The girls wrote cards to bid me farewell and the report from the mentor was very positive.

4.3 Lena

At the start of this course I thought of teaching as being a job like any other. Now I know that to become a teacher is a calling, you need to have passion for teaching and for children. I thought that the aim of education is to give learners the knowledge that they need to be successful. I have learnt that that is not the only aim of teaching, but that you also need to give the learners the life skills they need.

In the classroom itself it is always important to earn the respect of the learners by showing them respect and treating them in a fair way. It is also important to build good relationships with your learners so that they will feel relaxed and confident in your classroom. Every learning task will have a different order. In some you will first give/explain the new work and in others you will first let the learners explore and try on their own. It is a good idea to start the LT [learning task] by getting the learners attention with something unusual or interesting. Then give a quick recap of the work done in the previous period and determine the learners' prior knowledge. In mathematics it is important to never use words like: difficult, stupid, wrong. Always motivate and encourage the learners and try to understand the reasoning of the learners

On the 23rd April I presented my first learning task to a Gr. 10 class at Höerskool [Highschool] F. This was my poorest learning task of the year. It had a lot that I could improve on. Firstly the Learning Task Design (LTD) did not contain the theme of the learning task. This makes it difficult for someone else to use/read my LTD. I presented this learning task in a totally teacher-centred manner. The whole period was direct teaching where I explained the new information and then did an example.

In my reflection on this learning task I wrote that the learners did not understand the concepts immediately. I was not prepared enough to explain it to them in a different way because I didn't think about that when I prepared the learning task. I also prepared too much work for one period and was not able to finish all the work. This caused me to rush through the work and not giving the learners time to discover the work on their own. This learning task made me realize how much work still lay ahead of me. I felt like I was back at square one. As stated in the article "Freedom versus Control" by Steven Wolk, it is important to let the learners be active in their own learning. In my next learning task I should try to involve the learners more and make the presentation learner-centred. I should prepare better by thinking of different ways in which the same concept or problem can be explained. This is because the learners do not always understand straight away and I need to be able to take a different approach. In my next preparation I will also prepare a little less work for a period so that I will not need to rush through everything.

At the end of the learning period I had no proof that the learners achieved the Learning outcomes I had set for that period. This is portrayed in my second Practice-theory – it does not contain anything about Learning outcomes or Assessment standards. When I designed my third Practice-theory I put both Learning outcomes and Assessment standards in. This helped me to think about the certain outcomes when I design a learning task.

After a slippery start, I took my newly designed practice-theory and tried to design a better learning task. On the 2nd of May I put a learning task into action which brought about both a snake and a ladder. In this learning task I asked the learners to see if they can find a pattern in the different examples. This was my way of involving the learners more and making the learning task more learner-centred. At the end of the learning period I asked the learners to do a quick journal entry about the work that we had done in that period. This was to determine if the set learning outcomes were achieved (showing how I used my new practice-theory).

Although this learning task was presented in a more learner-centred manner, I could still have involved the learners more by asking specific learners to explain how they understood a concept or problem or by leading them to discover the work on their own. This learning task was not exciting enough. After this learning task I moved up a few blocks, but my learning task still had aspects that brought me down.

I still need to make my learning tasks more learner-centred. In the article 'Toward meaningful learning' by Steven Wolk, he says that significant learning takes place when the subject is perceived by the student as having relevance to his/her own life. That is why I will design my next learning tasks around something that is relevant to the learners' own lives, something they will be interested in. I will also concentrate on the learning task presentation because if I can get the learners' attention straight away they will be more interested in what we are doing.

By asking the learners if they can find a pattern in the examples I forced them to use higher order of thinking skills. I added this in my fourth Practice-theory because it is important to develop the higher order thinking skills of the learners as much as possible. I also added that the learners need to discover the work on their own to make the learning tasks more learner centred and to improve the quality of learning

*By the end of my first School-based Education I felt that I got the hang of things. Then I started with my second School-based Education at Höerskool [Highschool] G and did my first learning task that was based on a real life problem (*ladder*). Unfortunately I also stumbled over another* snake. *In this learning task the learners had to do cooperative learning in pairs. This did not work as well as it could have if I divided them into groups of 3 or 4 (which according to* Cooperative learning in the classroom *is the optimal group size for cooperative learning). They did not have enough ideas and opinions to ensure optimal quality. In this learning task I focused on making the work relevant to the learners' everyday lives. I concentrated on the learning task presentation by giving them a problem that they want to solve immediately and discover the work on their own, instead of direct teaching. I also improved the learning task feedback (LTF) by thinking of questions I could ask the learners to lead them to discover the work on their own, in my preparation. This worked well and the learners were able to come to the correct conclusion after cooperative learning. This learning task proved that I was on the right track to becoming a real facilitator of learning, using everyday life situations in mathematics.*

As stated in Cooperative learning in the classroom *the optimal group size for cooperative learning is 3 / 4 learners per group. In my next learning task I will divide the learners into groups of 3 and see whether the outcome of the cooperative learning is a higher quality of learning. I need to think about my learning task feedback when I am preparing my learning task. As stated in* Facilitating learning: what is it really? *'feedback is inevitable for flow, growth and the improvement'. That is why it is important to me to prepare questions I can ask the learners to lead them to discovering the work on their own.*

As I moved on through my game of Snakes and Ladders I kept on improving as facilitator of learning. On the 6th of August I presented my best designed learning task in the transcendental paradigm. Firstly I asked the learners if they have ever thought of an idea to change our world. I got a few ideas from the learners and then

I showed them clips from the movie 'Pay it forward''. This immediately got their attention because they knew the movie and wanted to work out whether the boy's idea could really work.

In this learning task I divided the learners into cooperative learning groups of 3. Even though this gave a better result than working in pairs the cooperative learning still didn't go as well as I wanted it to. This was because I divided the learners into their groups and they had to immediately move into those groups. The class was restless and everyone was moving around. In the future I will divide them into their groups beforehand.

In my preparation I concentrated on the learning task feedback. I anticipated how I think the learners will react to the learning task and also prepared questions I could ask them to help them discover the work on their own. At the end of the learning period the learners formulated the formula in their groups and realized that they can do it own their own. This became clear in the learning task consolidation showing that the quality of learning was very high. Even though this learning task did bring forth a snake *that I need to improve on, it showed a lot of aspects of my facilitation of learning that has improved tremendously.*

A part of my vision at the beginning of the year was 'to foster a love for mathematics in all my learners' and 'to change the negativity/hostility most learners have toward mathematics'. In the first week of second School-based Education at Hoërskool [Highschool] G I asked my whole class to write down what their mark for mathematics was at the end of the previous term and then also the mark they would like to get for mathematics (target mark). Throughout the 2 months that I worked with the learners I constantly reminded them about their target marks and motivated them to work harder. In my final week at the school they wrote a term test on the work that they had done. In the class of 35 learners there were 9 learners who reached their target mark and 8 learners who improved with 10% or more from the

previous term. When I asked the learner who improved with 35%, why she thinks she has improved, she said it is because she started to enjoy mathematics more and because I motivated her to study and figure the work out on her own. On the day I handed out the learners tests, I gave a chocolate as reward to the ten learners who improved most (and not the ten learners with the highest marks). The learners who had improved felt good because they were acknowledged. I believe this will motivate them to work even harder and it will also help them to enjoy mathematics more because they understand it.

4.4 Peta

I think that to educate someone is almost like informed consent, you give the person all the information and make sure he/she understands it so that he will make informed decisions in his life from this point in time onwards. Education is like drawing a picture; you have to start on nice clean page - usually the people you teach/educate don't know about the specific subject; so you start drawing the trees, the clouds, the sun, the house, the flowers etc. At the end they can see the "bigger" picture and understand.

In the beginning I was very scared and unsure. When I stood in front of the class I was afraid to perhaps be wrong or to make a mistake or that I could not do the calculation. I was very stressed and I know that when I feel stressed I cannot think. I was worried about almost everything, if I would be able to write the calculations on the board, and I stood with the book in my hand the whole time to see if I was still correct. I did not facilitate learning at all and did not even teach. It felt like I was holding a debate. Sometimes I could see on the faces of the learners that they did not understand what I was saying or that I was speaking too fast. When I spoke to them, the communication was not what I wanted it to be, it felt like we totally did not understand each other.

Discipline in my class was ok. I again just struggled with pedagogical knowledge. Some of the children frowned while I was explaining content and I got so frustrated with myself because I could not explain the work in such a way that they could grab on to this knowledge. I will work on this problem with Miss Barnes to ensure that by the time I come back @ 18 April 2007 that I will have improved in such a way that I can confidently say I think the children/learner understand. Every time I have to give a class, I am very confident and enthusiastic. The moment someone asks me why or they do not understand, I am confused and struggle to answer them in a pedagogical way = steps so they can follow.

On the 11 May I did a transcendental learning task with Grade 10 learners. I first gave learners an activity that introduced them to multiplication and division of algebraic fractions in terms of the number zero. Learners were busy for the whole period with this activity. I planned another learning task for the learners to also complete. I did the "senseless value" activity because I realised that most of the learners do not understand the concept of multiplication and division of algebraic fractions in terms of the number zero. I was very frustrated during this learning task. The learners controlled me. The learners determined what should happen when in the class and with what tempo we work. In a certain part of the class, I ask learners if we can go on with other work.

This learning task is representative of my whole first SBE. I was frustrated, unhappy and always behind with the work. During a certain time I went to see Prof S to tell him that I was behind in my reflections, that I don't know what I am doing and that I am struggling!! Prof S suggested I write a reflection about why I think I feel like I felt at that moment. I never even worked out myself the process that learners should follow to solve a problem and did not establish or plan the end product. I mentioned in my reflection that I do not carry over quality information to learners and that I do not know if they achieved the learning outcomes. I think the above-mentioned was my biggest problem, If I knew what I wanted the learners to achieve and if I planned

how they should get there, I would have been much more in control of the classes and less frustrated.

During my second SBE in a lesson on 31 July Grade 10 learners are shown the task in which they are asked to graphically represent data about a vegetable garden. Learners are offered the formulae and calculations that must be used to get to the end product. Learners needed a lot of guidance to get to the end product. The facilitator of learning had to help a lot to get the process of learning to start and to keep it going. After I had explained what to do, learners just looked at me and said they do not understand. I would really have liked to leave them so that they could think about it, but time is an important factor, especially because the learning task needs to be completed by the end of the double period. I am already behind with the Grade 10 planning. Learners must work together well and support each other. Learners drew the graph through the origin and we discussed why they should not do this. Learners derived the definition of domain and range and symmetrical axis from the parabolas that they drew themselves. In the future I will try to make the authentic real life problem easier so that I as the facilitator of learning need give less guidance, so that learners can work independently.

Learners benefited from having to think for themselves for the first time and trying to get the solution. This was the start of them learning a new thinking process because they are accustomed to only transmission learning. Many of the learners really enjoyed the challenge and some came and thanked me later for all the trouble I had taken. I think learners enjoy mathematics more because it is a challenge. I think it was a good learning experience for the learners but I could perhaps have asked more questions and said less so that they could think more. Sometimes I still feel "forced" to help them get the answer, rather than calmly leaving them to struggle a bit themselves. It is still difficult for me to not show learners how. I wish I had said less because I felt at the end as if I had spoilt the "moment". Next time I will try to say

less and be ready with better questions so that learners can struggle a bit themselves and wonder about how to get going. I definitely want to improve my questioning.

Today in class [8 August] I asked the [Grade 11] learners how a person works out the x and y intercepts. One of the learners mentioned that you use the dual intercept method. I forgot that it is the same and asked them really honestly what the dual intercept method is. One of the learners shouted to me: "Oh no. Get out of the class. Just get out." I was very upset. I have already had trouble with this learner before and I don't know how to handle the situation. The learner makes no secret of the fact that he thinks that as the student teacher I am absolutely not competent to teach him. Overall I also have discipline, concentration and respect problems with the learners. I am well aware that respect gets earned. It is also bad for me that the relationship between myself and the learners is like this, because the Grade 10 class and I have an excellent relationship, where a conversation like this would never have taken place.

Grade 11 learners have a transcendental task [11 – 25 August] in which they have to plot their cinema ticket cost against the number of sales. Learners were finished very quickly because I had to help them a lot. I wish I hadn't. I then began to explain the hyperbola to the Grade 11 learners. First I explained the part of the work where the hyperbola does not translate at all. Only then did I explain horizontal and vertical translation. Learners are very lazy to read. Learners blame the fact that they do not understand on the teacher. SO…on Friday I spoke to them about their poor cooperation and that it is difficult for me to help them to understand the mathematics if they will not cooperate. They must also work a bit from their side. Learners then began to cooperate.

I wish I could get learners in some way to do more themselves. They expect the facilitator to perform miracles. I get the feeling that they think the facilitator should enable them to understand what is going on in the syllabus rather than that they

should try themselves. I am going to give them a worksheet on Monday to work through with problems as well as all the answers and tell them that it is self-study. I want to just test and see what happens.

They [learners] came with the attitude that when a student teacher teaches them, they never do well or understand…I closed the door and told the class that if they would prefer that Mrs Coertze give them class, that they must please say so now. It is my choice to teach them, and I don't have to teach them if I don't want to. I also told them that it is difficult for me to effectively convey the mathematics to them if someone walks out the class ever so often or if no-one is prepared to give their cooperation. I asked the learners what they expect from each day's mathematics lesson. I also asked them if they were going to start giving their cooperation, otherwise I refuse to help them any further. I told them that I am prepared to give them my best, they are prepared to do it for themselves. I hope that my little sermon helped and that I will see how effective it was in the next class.

My final learning task was with Grade 10 learners. I started this learning task by asking learners to take a deep breath and to calm down and to close their eyes. I started by telling the learners the tale of a very rich Chinese king who had a beautiful daughter. Then I told learners that they should depict what I told them graphically and try to determine a general formula. I think that by first giving them an oral presentation and then the written presentation helped the learners in that they had more clarity about what was expected from them. During this learning task I gave a lot of attention to the end product/solution of the problem. I think I am starting to better understand the thought processes of learners and to appreciate them although there is still a lot of room for improvement. Having knowledge of the final product/solution and the thought processes of learners makes it easier to facilitate. My learning task design was therefore an good improvement on any of my previous learning tasks.

The learning task execution existing of an oral and a written learning task was better because I differentiated between them as two different concepts. My spes lecturer (Marge) noted in her feedback that she experienced that I created a favoured learning environment. During this learning task I asked questions like: "Why do you think this is the answer? Or "How can you do it differently?" These are definitely more higher order thought process questions and I would very much like to still improve on this, because I think learners benefit from it.

From my first SBE I have definitely learnt to not be so conservative in my thoughts with regard to learning task design. I experienced first hand that learners definitely understand more if they solve the problems themselves and that it is important that the problem is well-organised and must be worked out so that learners can optimally solve problems in the shortest possible time. Horizontal mathematisation should definitely precede vertical mathematisation.

At the end of the PGCE I think that the aim of education according to the article 'Facilitating learning what is it really?' is to maximize and fully utilize human potential towards a safe, sustainable and prosperous universe for all. 'Umuntu Ungumuntu Ngabantu' is a Zulu proverb meaning 'A human being becomes human through other human beings'. If these above-mentioned concepts are taken into account, in reference to education the most important is not for me to ensure that learners understand mathematical concepts but that I handle learners as valued adult people and behave and facilitate learning as such so that above all the learners will learn important life skills.

4.5 Kapinda

In January 2008 I believed that education lays a foundation of general knowledge, basic manners, academic literacy and qualities. Learners absorb information. Education is the transfer of knowledge and wisdom. Education is important to enrich

people, and the community. It promotes development of civilization. Therefore the aim of education is to lay building blocks to build a stable strong house.

Graphs were my first learning task which I designed but not presented or executed. The learning task design is disorganized and too lengthy. I should also have been divided into micro learning tasks instead of all types of graphs included in the same learning task (which spreads over six periods). I was unfamiliar with the correct terminology, I referred to lesson *instead of* learning task, *and did not understand what is requested in the Product Outcome. The learning task does not contain a real life challenge.*

Assessment was not effective. No assessment rubrics or memorandums included in learning task package. Methods of assessment included educator assessment (marking of worksheets) and self-assessment (marking of homework).

The learning task on volume was my worst learning task which has been executed. The real life challenge was neither urgent nor was it a realistic challenge since none of the learners work in fabric where ham jars are made. I did not plan media well (posters was written too small). I did not understand the terms of assessment standards and learning content. No assessment rubrics or memorandum included. The following was not included in the learning task design:

1. learning task sequence number

2. number of learning tasks presented in each paradigm

3. integration with other learning areas

4. supportive resources

5. learning task categories

6. learning product (homework assignment)

The history of volumes is irrelevant to learners. Presentation was unclear and disorganised, there was no chronological flow during the learning task presentation. Learning was not authentic since no real meta-learning took place. Learners

immediately worked in cooperative learning groups. It was ineffective since learners could not individually contribute to the group. Interaction between facilitator and learners was poor; tables were moved too far to the back. Facilitator also did not give enough chance for learners to answer questions and to interact. All the learners did not participate since meta-learning did not take place, therefore not all learners attempted to contribute. Only the stronger mathematical learners did the work.

Learning task feedback was not at all effective. I did give acknowledgement to learners by my presence and interest on how they solved the problem of discovering which cylinder had biggest volume. I did not give any resilience because I did not really encourage anyone who seemed to be disappointed for not finding a solution. I did ask clarifying questions to determine where the learners are, but did not use the information I gained to encourage meta-learning actions. When I saw that learners were on the wrong track (for example not knowing what the radius means), I did not guide the learner in realizing he was on the wrong track. I did not require resourcefulness since I did not suggest to any learner to find resources or advise auto-education. I provided edutainment only after the learning task was completed. No consolidation took place at the end of the learning period: therefore I did not evaluate the rate of progress or quality of learning, and although I gave homework, I did not really provide an effective continued challenge.

The real life challenge of my first LTD at Hoerskool [Highschool] G was realistic and urgent. The week before the learning task was presented, all the busses were on strike and since a large amount of learners travel with bus to school it affected them and they did not have transport to school. Although the learning task was presented in the transcendental paradigm, I think the learning task guided the learners more than necessary regarding the procedures learners should follow. I did give learning task feedback when I moved between the tables during cooperative learning. I did give acknowledgement and recognition to learners who were on the right track. I provided resilience where needed and tried to answer learner's questions with self-

answering questions. I do however feel that I tend to lead the learners more than what is necessary, and I become the resource in stead of encouraging the learners to consult other resources.

I think the second last learning task at [Highschool] G was successful. I should just work on discipline in terms of not allowing the learners to be in control of the time. We lost a lot of time because I did not stick to the time limit. I let learners be in control of the time. I will also expand the rubric to assess learners' body language, facing the audience, eye contact, and communication skills. When the learners reported back to the other groups, the rest of the class did not always understand the solution (although the proof was correct), since the learners did not communicate clearly.

The challenge was to discover why certain theorems in Mathematics are true. Often teachers give theorems to learners who memorise it without understanding it. the learners enjoyed the challenge and found it interesting. A few learners had an "aha" moment.

The learners enjoyed the video clip of Casper de Vries. In a humouristic way Casper de Vries revealed some truth about the paradigm in which learners only learn through rote learning, and memorise theorems without understanding it. The learning task presentation wakened the question WHY inside learners heads. This is important since one should never stop asking questions. By asking questions one learns.

Learners firstly learned through meta-learning. Learners completed individual worksheets in which they applied many theorems. The aim of this worksheet was to remind them of what the theorems were and to solve problems by using these theorems. This made the climax bigger regarding the fact that learners would be more eager to understand it once they realize that they do use it without knowing WHY. After meta-learning was completed learners worked in heterogeneous

cooperative groups. Each cooperative group had a different theorem to prove. Learners were allowed to use their solutions from the meta-learning worksheet to contribute to the discovery.

At the end of the learning period a representative from each group reported their discoveries to the rest of the class. Other groups assessed the representative and the whole group received the mark. It was therefore very important for the group members to ensure everyone understands the discovery. This encourages learners to support each other and prevents learners from copying work.

My most successful learning task concerning a real life challenge was LTD 8 on kites. The challenge was clear and the learners understood what was request from them. The learners were interested and put a lot of effort into this project. Kites are fund and everyone from young and old can be captured by a kite. The learning task presentation had clear instructions on the procedures of making a kite. Learners also needed to calculate the cost of the kite as well as the surface area. Learners firstly learned through meta-learning where they individually completed worksheets. It was crucial to first learn through meta-learning, to discover the characteristics of a kite. Without knowing the characteristics of a kite (the lengths of the sides, angles, etc.) one will not be able to make a kite. After meta-learning, learners divided into cooperative learning groups to discuss the project. Learners had a week to make the kite at home. Learners were very creative. Some learners even worked out a motto for their kite. Their interpersonal skills were most definitely developed.

During the week learners asked me questions if they had any uncertainty. The kites were assessed on the rugby field. I did give acknowledgement to learners by complementing their effort and creativity they put into the making of the kites. I showed interested in their discoveries and inventions. I provided resilience where needed during the week, and when learners came to ask me questions about the design of the kite I tried to answer learner's questions with self-answering questions.

I encouraged learners to think about what they are doing. I guided some learners in telling them they should consult their discoveries from the meta-learning worksheet in order to find remember what the characteristics of a kite is, but not give the characteristics on a spoon to them.

Learning task consolidation was done at the end of the learning period by interviewing learners, finding more out about their kites, what they struggled with, their feelings or any uncertainties. I asked learners how they divided the work between themselves.

At Garsfontein, my main "challenges/downs" was finding real life challenges in Mathematics. At Pro Arte, it was easier since the Mathematics Literacy curriculum is already in a real life context. [Highschool] G is very competitive and performance orientated. I experienced some pressure to perform. The teachers were not very welcoming towards the students and we were never treated as part of the teacher team. During staff meetings we sat against the wall and were not allowed to sit around the tables with the rest of the teachers.

My greatest "success/up" at [Highschool] G was the Grade 9 learners! It was a privilege to journey with them and to invest in their lives. I have also learned a lot from them. It was amazing to every day get to know the learners personally. The second SBL period gave me the opportunity of a new start compared to Pro Arte. I experienced that is easier to establish class principles (for example the way I treat disciplinary situations in the class, launching group projects), when one starts with a group than to try and establish it after teaching for a period. It is good to be consequent throughout a period. Therefore it is difficult to create a classroom culture halfway through the term. At Pro Arte I still focused on finding my feet therefore did not immediately focus on creating classroom culture. At [Highschool] G I had much more confidence therefore could focus on classroom culture and principles from day one. One day I dressed as Spongebob Squarepants. The learners really enjoyed the

Maths class and I think it motivated them to do their work. I had freedom to do what I want. Every week I played motivational video clips, including Facing the Giants and teachings of Rob Bell. I also gave the learners Brain Teasers which they really enjoyed and captured their attention. Another highlight was a three week "Romans project". Cooperative learning groups competed against each other when completing projects, doing extra work, and attending extra class.

Every single day was a confirmation that I am on the walking on the road to my own purpose, because I went to school in a bad mood and got home in a good mood. I did not know it is possible to experience that level of job satisfaction. Every day I was even more passionate. it was such a privilege to spend time with the learners each day (especially the grade 9s).

During the year my views on the education system and teaching paradigms shifted. I realised that we are dealing with learners who have a post-modern mindset, and should meet them at the place where they are. This is why we cannot teach in the transmission paradigm any longer and should encourage discovery learning in the transcendental paradigm.

4.6 Anabella

The aim of teaching I believe is successful education of children to adults. We play a very important role in every child's development and growth, so that we have mature South African citizens in the end who can add value to our country on various domains. Teaching helps the child to form their perceptions of the world as well as their personality and interests. How to work with people and how to successfully integrate into the society. Education is like a garden. A garden consists of different types of plants just like teaching consists of different aspects: learners, teachers, to learn, to teach, using teaching tools etc.

In one of our first classes in spes [specialisation] we got a certain concept that we had to teach for the group and we got half an hour to prepare. I had a very simple concept, and when I stood in front of that group I realized that I don't have a clue how to explain the concept in the correct way. I was struggling to find the right words, and to talk and write, through me of my point the whole time. When I walked back to my seat, I felt stupid, humiliated and just dumb, and then Haley also gave us a test to do where she tested our mathematical thinking and background. She then called me in and said that my maths is not where it is supposed to be and that I must work on exponents etc. We also got our brain profiles back, and there it also states that my mathematical, analytical left brain is the least developed.

*I knew then that I needed a lot of work and that my maths background must be sharper and clearer. I know I want to become a maths teacher, but when I got home that day I started doubting if I will be able to do this or was I just kidding myself. I sat with that thought in my head for quite a while but then I decided to change my mindset. It was only my first time and experience that I had in teaching and I made peace with the fact that I can't always do everything 100% right the first time and that this is a learning experience where I can better myself everyday. **I will be a maths teacher, and I will be good at what I do,** and even if I get critique now I can get go and work on it, and I will prepare and teach in the best way possible for me.*

And I know that a right brain person makes wonderful teachers and with my right brain I can make class interesting. Although I'm not so strong in my left brain I will do everything in my power to develop that area and to get the best out of myself to really know my subject and the end and to one day also be called a professional in my field.

With my first attempts in teaching, I started educating in the transmission and in the transaction paradigm. With my first class I went through in incident where the

children said that they don't understand the way I was explaining the work. This was a low point for me and I decided to take this low point and change it into a positive experience. That night I planned my lesson very carefully and after practicing my verbal presentation in front of the mirror and with my friends I went in with a lot more self confidence the next morning. I decided that I will show them, and I could see the difference in their faces and they even started asking questions. This was a good sign and after class a girl came up to me and said that, for the first time she actually understood was going on in class. THIS WAS AN EXLARATED FEELING!

*I did my first Learning task at [Highschool] C and it went well, although originality and creativity still lacked. I didn't really yet understood how to correctly give Learning task feedback and what my role was in the classroom. This was a high point because for my first attempt I felt confident that this was a good start and it was in this learning task that it actually dawned on me that facilitating learning can work. I also started to "play my individual notes randomly", meaning that I thought of various ideas that could work for my second LT [learning task] and eventually I came up with an idea that I really thought would work and I was excited to operationalize the LT. My SPEC lecturers came to assess me and **the LT was a total disaster!!***

My learning task was definitely unsuccessful and I didn't even come near to reaching my specific outcomes. My original plan was to give each learner a different graph to investigate and find consequences of the q and a changes in the different graphs. I wanted all the learners who had the same graph to group and decide on an effect. Then all the different graphs will be drawn on the board with the effects of a and q under each graph and a summary could then be seen on the board. It was seen as only an introduction and a revision exercise or them to refresh their memories of grade 10.

My learning task failed completely because I overestimated their knowledge on graphs. I didn't realize that they still couldn't plot graphs and that most of them didn't

even know how to use the table method to plot points and draw the graphs. It took them 2 whole periods and they weren't even finished after that. I realized that in the future I must first determine what they know, even if it is just one easy graph, I could have tested if they do know how to plot. I also could have given them the drawn graphs without them having to plot it, because my main aim was actually for them to see what a and q does, plotting will only take unnecessary time where they could have already worked and concentrated on the outcome.

I also know that transcendental means for them to be challenged with a realistic life problem. I could have presented my learning task much better, through making it urgent for them and for them to get excited to see whet the effect is and if they can find the reason for something happening. Overall the report that I received was mostly remarks made on my mathematical language use. I know that I still don't talk perfectly and that my words can give misconceptions but that is just the consequences that I'm willing too accept because I know that my mathematical English won't be perfect in a year's time and that it takes experience to teach in another language than my own.

I also did a bit research on the concepts of horizontal, vertical and realistic mathematics, and came to the conclusion that the focal point should not be on mathematics as a closed system but on the activity, on the process of mathematization. Looking at horizontal mathematics, the learners should come up with mathematical tools which can help to organize and solve a problem located in real life situations. Furthermore I deduced that vertical mathematics can be deemed a re-organizational tool within the mathematical system itself for finding shortcuts and discovering connections between concepts and strategies and then applying these discoveries themselves.

Facilitators should give the learners the opportunity to re-invent mathematics by practicing it. It allows them to develop informal strategies for dealing with

mathematical problems under the assumption that with guidance these informal strategies can progress to more formal applications without limiting them to a certain set of rules.

I will also concentrate on making mathematics a real world mathematics education. Through this I hope to make learners perceive mathematics as an authentic and real experience within their minds. For the problems to be presented to the learners, this means that the context can be a real world context, but this is not always necessary. The fantasy world of fairy-tales and the formal world of mathematics can be suitable for a problem, as long as they are regarded as real I the learners' minds, context problems and real life situations can be used to constitute and to apply mathematical concepts.

In my learning task 2.2 I made a mistake with my calculations with the final end product outcome. All the learners struggled to find the right answer and it was because of me that they didn't reach the correct end product outcome. I felt incompetent, dumb and stupid! I went home and worked the problem out thoroughly and asked colleagues to check my answers. I had to go back to class and apologise for my mistake and I immediately handed them a copy of all the right answers. I learned that I must make sure of answers before I go into class and before operationalising an LT, to also ask for advice/help from colleagues to check that my work is liable and correct. I

My last LT operationalised at my second SBE was my best learning task. They [the learners] stepped in class greeted me and sat down. I handed out their already worked out homework problems which they had to do for today and then I also gave out their written presentation of my learning task. I told them they should keep quiet, sit back and enjoy! I then showed them a clip of Mission impossible, where the guy worked out the math and physics behind a jump that he was going to attempt from the one building to the other and he made it and was alive. After I showed them the

video clip, I told them they are now going to use this clip and find the answers and calculations for him to successfully have made the jump. I gave them all the info on the written presentation. I told them that they can ask me questions but that they were not allowed to talk with the others around them. I also told them that they only have 20 minutes whereafter I am going to take in their worksheets for marks.

What was very interesting is that the kids that always do very well academically were the kids that are hands went up first. They couldn't handle it that I don't tell them exactly what to do. There was one girl that got so frustrated that she almost started crying because she didn't catch the problem at all. They are so used to be told exactly what to do that this freaked them out completely.

I told them that the challenge is to actually solve the problem on their own without asking the whole time what to do. They would ask me the silliest questions, and then I would read the info on the written presentation with them and they would immediately catch it. I came to the conclusion that these kids are lazy and that they don't ever make efforts to read questions or interpret info given in the word form.

The kids that never really shined in class actually came up and took the lead with this learning task. Although there was no cooperative learning planned, the kids that got really frustrated began to seek for clarity and started asking the less clever kids who were on the right path on what to do. I could see that confidence their confidence was really boosted and I was proud to see that they could figure the problem out without anyone's help.

I felt great! It was exciting learning task and I could see that the video really inspired them to start working. The learning task was successfully operationalised, and the quality of leaning was constantly on a high level. I felt confident and in control. The learning task worked well and finally I could see the implications and consequences of the transcendental paradigm work positively for them.

With this learning task I tried to incorporate both scaffolding skills as well as learning task feedback strategies. It worked well and I could see that the kids really got terribly frustrated with how I was applying the theory and just these reactions told me that I was on the right path. This was actually my last LT operationalized at my second school-based learning period and after this LT I finally mastered the paradigm and theory. I know that I will never be perfect and that I can still grow at all levels but at least now I know exactly what to build on in future and how to think and design LT that can work.

Although my initial views of education are not wrong, I definitely came to a deeper insight, that education is not just a teacher telling kids what to do, or transferring knowledge like a computer, but it's about a lot more than that. It is about directing the child to take control of their own learning by motivating and inspiring them to eventually take responsibility for their own quality of learning and to at the end develop self-directive, independent life long learners that can not only adapt to the real world out there but make noticeable differences in society where ever they may find themselves. Maximise their potential on a continuous basis!!!

4.7 Sophie

I see teaching as the manner, way and technique that information (new information) and content is explained to people (learners), shown and how examples or experiments are visualised for them to make it understandable and clear and to make them wise with their new knowledge.

I began as an unexperienced, unmotivated, unconfident student. My first 3 weeks were the most difficult, because it felt I didn't do so well as the other student were doing. Also because in our student group at the school, I felt I were less experienced with senior learners in High School. I struggled with the work and getting through to the learners, because my mentor teacher were present in all my classes and the

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learners preferred to ask her questions, instead of asking me. After my spec teacher visited me for the first time, I was obliged to ask my mentor teacher for some space and I asked her for a class that I can do anything with, on my own. She gave me her Grade 10 [mathematical] literacy classes and her Grade 9 class. Some days I facilitated 5 of the 6 periods. I had 90% of her classes and the work load were quiet a bit. After my spec teacher's 2nd visit, I had an accident the following day. After my accident my mentor teacher thought it was better to just give me the maths lit classes. She also wrote me a "personal report" and said how much I improved. Now I am more organised, motivated, confident and I make better choices. I also know now that I need to be more organised and I musn't postpone my work until later…

I didn't have enough confidence in my class while my mentor teacher were there. She observed every class of mine and I felt that the learners don't bound [bond] with me. During break I, Diane and Kimberly talked about it. Kimberly called Mrs J and started to talk to her and told her about the problems I were experiencing. Looking back, I were first really uncomfortable in my classes and had a lack of confidence. After I talked to Mrs J, I felt better and in the first class I suddenly had confidence and I talked to the learners and facilitated the way I want to. The other PGCE students really helped me and they also felt good by helping me solve the problem. I didn't have enough confidence and were uncomfortable in my classes because Mrs J watched the whole time and when the learners struggled with some of the questions they didn't ask me and they couldn't get used to me teaching them, because they asked her the answers they didn't know. The learners also felt uncomfortable with me at first, because I look maybe 2 – 5 years older than them and also because they were used to Mrs J way of teaching and handling things.

My weakest learning task was at my first SBE at [Highschool] W. My outcomes were: I wanted to make the learners understand the work they need to know for the exams. I also wanted to see if they can remember they work I did with them, and whether my practice on them improved their maths skills. My outcomes for the

learners: I wanted them to renew their knowledge of number and number relationships (substitution and factorization) and data handling and space, shape and measurement (the last activities I did with them). I also motivated them to use their knowledge of data handling with their own problems and to help them to learn about each other. Unfortunately the work I did with them that day – I didn't do with them while I was practicing at [Highschool W] – It was the work their teacher did with them just before I arrived. The learners handed in assignments that I marked for their Portfolios, about the activities and lessons I did with them 26 and 27 May. So I know my outcomes were reached.

These are some decisions that I think didn't work during that lesson. I first did the work the teacher gave me with the Grade 9 and 10's. I didn't facilitate the learners – I TAUGHT them. It didn't work, because I couldn't accommodate my own personality and own style of teaching in the classroom. It also caused confusion, because the learners were used to their own teacher's way and style of teaching. I weren't organized in my crit lesson, which I will always regret. I really improved, and I know I have, but the last lesson I had to show it – I didn't and couldn't because I weren't prepared enough.

These are the decisions that I thought did work during this lesson. I talked to my mentor teacher about having my own class for a while without her observing the whole time. I didn't give attention to any comments in the class. I handled all the problems of the learners in the same way. I started to give my learning tasks to the other PGCE students and asked them if my spelling were correct and whether or not they themselves understand the learning task. Before I designed my learning task, I asked my mentor teacher for some ideas and after I produced the learning task I talked to her about it. I divided the learners in to Cooperative Learning groups and I divided them so that all the "groups" like friends, the smart learners and races were mingled. It really worked. I asked the learners during my practice to help me to

explain to the person next to them, because I can't go to each one individually. I can personally say that this was my worst lesson ever and I really made a mess out it.

We discussed the discipline in the classroom and talked about what I as facilitator need to do to establish it. Today I was even more unsure about myself as facilitator than yesterday. But I know that one day I will be the best facilitator ever. I was told by people that I am not a good facilitator and that I cannot apply my learning theory, instead of that I recognised myself, it made me feel inferior about myself and as a facilitator. I was unsure about how I would apply consolidation in the class and what must be done to ensure that the end product outcomes are achieved. I can show people that they are not always right. I can just get better and better everyday and prepare my work and consult many people and lecturers about my whole learning task and practice-theory and how I must consolidate, as much as possible. As facilitator I am going to prove people wrong. I am going to give learners recognition, motivate them and explain my reaction to learners. Will ensure a continuation and give them another question/problem. I will maintain the level of discipline and continually give them a challenge and ensure that it is interesting and make sure that they do not get other things to busy themselves with in class. I will establish a relationship of trust and recognise them as people and motivate them through telling them everyone is in a position to do good things. I will reward them for the problems that they must solve. I will ensure that my attitude is constant so that learners know my norms. I will ensure that I know the rules and the consequences and that I am part of the interaction. I will warn learners if they continually do something wrong and I will react on the action that is taken. I will execute rules, the learners must know what these are and that they must pay attention in my class. The others also have a right to learn.

In my lesson on the 28th August, the learners were excited and worked hard. It was something different and especially because I changed the groups again, it made a huge difference. The learners encouraged EACH OTHER which elicited a big reaction.

The video camera naturally also played a big role. Because it was something different and some learners do not have a feeling of acceptance/love, the groups co-operation worked very well. The stickers and sweets also brought a lot of joy.

These were the things that I changed about myself during the second SBE. I planned my lessons each time and asked my mentor for help, if I was unsure about what to do. I filed all my work and began to get organised. I treated all the learners the same, as difficult as this was. I changed the whole classroom atmosphere, when I implemented the sticker system. According to this the learners got stickers if they did their homework and when they got full marks for a test. The classes and groups in each class also competed against each other. The learners started looking up to me, started listening and keeping quiet in the class. Their view of me as a role model (action research) began to take place and I am proud to say that I also presented 5 transcendental learning tasks, the last 4 were very good and consolidation showed that the learners learnt a lot and that the quality thereof was deep and good. I gained more self confidence, I began to know the names of the learners and I did my reflections regularly. I also made time for an extra mural activity, where I got to know some of the learners well. I acted professionally in all of my classes and I established rules in my class (no cellphones), that the learners listened to. The assessments that were done by my mentor and my lecturer, showed my improvement....

I now see education as the facilitation of learning. It is the way we help learners to optimise their potential to become active, interdependent lifelong learners. I as the facilitator help them to shape the future. I have to let learners experience, in order for them to learn. I have to ensure that the organisation of the subject proceeds smoothly. I have to facilitate the chosen subject with maximum effectiveness. In education I have to ensure a successful learning product and outcome and I have to facilitate learners in that way to maximise their potential as humans.

4.8 Toni

The aim of teaching is to successfully prepare the learner for challenges in the future. Through teaching the learner should develop skills to identify and successfully conquer these challenges. Teaching is also a method to stimulate the development of the learner on an emotional, intellectual and social level.

I confronted peer students of the PGCE programme with the firs learning task I designed. The real life problem was to calculate the perimeter of a chicken farm in the Lichtenburg area. For this they will need to develop the distance formula used in analytical geometry. This was supposed to be a learning curve for me as facilitator, providing me an idea of the possible responses that I can get from the learners in my classroom. The students quickly got involved in the learning process. It felt like they forgot it was only a trial learning task and actively tried to solve the problem. It was as if they were in a real classroom situation.

I did not use the scaffolding as successfully as I did in this learning task during the rest of the year. I still believe that the scaffolding used in this example was of critical importance and I want to use similar scaffolding in my practice one day. This learning task required learners to construct their own knowledge. I classify the method of instruction used in this learning task as dialectical constructivist approach as discussed in the Good strategy instructors article (number 1 in the bibliography). I tried an endogenous constructivist approach in learning task number 4. I feel most comfortable with the dialectical constructivist approach (tried in this learning task and learning task number 7) and believe that when I facilitate learning with the approach the learners achieve the best quality of learning at the optimal rate of progress.

The worst learning task I believe I implemented was with Grade 10's with the critical outcomes that I aimed to achieve being problem solving, team work and effective communication. The learners were divided into five rows each containing five learners. A paper with five word sums was handed to each row. Row 1 to five

received paper one while row 4 and five received paper 2. The desks were number 1 to 5 from front to back. Each learner received a word sum to try and solve. I thought 15 minutes would be enough for this, after this they will try discussing their solution/ attempt with the other learners who had the same problem, then they will return to their base group and discuss the solution of all 5 questions.

I believe that students should be autonomous. They should be able to discover solutions individually and share this with their peers. This is associated with a natural process of meta-learning and cooperative learning. I did not give any guidance to the learners on how to solve the problem. I thought the lesson erupted into chaos and trying to establish control again I reverted back to traditional methods of teaching. My anticipation of what was going to happen was wrong. The learners are still dependant on the educator as source of information. This should have been expected taking the current education and classroom culture into account. The learners had a lot of questions. This is supposed to be a good thing since questioning is where learning starts. I tried to answer or meet all questions of learners. I started to spin because I could not listen to all the learner's questions at the same time and while they were waiting for me to provide feedback on their questions no learning was taking part on their behalf. I should take the time to listen to a learner's question thoroughly without trying to run to the next learner.

I know that I possess a great skill for mathematics and that I have a wide knowledge of the subject. I am confident that I can solve any problem in the current curriculum. This resulted in me not completing the end product outcome myself and when I reverted back to traditional methods I made a mistake on the board. What I can learn from constructing the end product in myself is:

- Possible misconceptions
- The though process needed to sole the problem
- Possible questions that will be asked by the learners

- *Questions that should be asked by the facilitator to improve the quality of learning*

- *Prior exercises needed and ideas for scaffolding*

The important lesson for me is to identify the skills we use without noticing that the learners may not yet have acquired these skills. An example is the translation of words into equations. I believe this is where assessment of prior knowledge and scaffolding will be useful. The scaffolding will also aid in dealing with multiple questions at the same time.

I also approached this learning task from an endogenous constructive viewpoint. Since I was not successful I did not want to use this approach again although it seems that the facilitation of learning paradigm is built on this approach. In learning task number 9 I again tried the endogenous constructive approach and achieved tremendous success with it. It gave me the opportunity to view the approach of the learners and thus establish the knowledge that they have and what still needs to be learned.

The greatest lesson that is to be learned from this learning task is that there should be a thorough analysis of all the aspects of a learning task whether it is successful or not. I should not think that everything is a failure when I am not successful.

My best learning task put into operation was the last learning period I met with the grade 10 learners during my second school-based learning. During this learning period we started with a new topic. I tried something new for this period. Learners had already identified and constructed graphs of:

$y = a\sin\theta + q$; $y = a\cos\theta + q$ and $y = a\tan\theta + q$

$y = c/x + q$

$y = ax^2 + q$

They are able to state and interpret the effect that the parameters a and q have on the graphs. They are also able to determine the expression of an equation from a given graph with the coordinates of certain points given. They have not seen an exceptional graph together with equation y = ab..+ q. What I expected from them was to determine the genera shape of an exponential graph and the effect that the parameters a and q have on the graph through the construction of multiple graphs. This is the exact same procedure they followed for the previous graphs with the exception that they were guided step by step. I did not give them any specifics.

Each learner received a written instruction with the problem. I did not read the problem to them. They had to identify what needed to be done themselves. After learners read the question some started to work while others asked questions and did not now what to do. After a while I asked some of the learners who started working on the problem to explain to the class what needed to be done. Some learners spontaneously started to work together. At the end of the period most learners only finished one graph. During the consolidation I asked a learner to present his work on the board to the entire class. The class then had the opportunity to question him.

The learners used the table method to construct the graph of the exponential function. This is the same method that they initially use to draw all other graphs. The first problem was that there were only unknown values in the equation. The concept if variables (x and y) and parameters had to be discussed first. After this most learners chose a value for the parameter b (2 was the popular choice). The learners then constructed a table for the equation y = 2x, thus b = 2; a = 1 and q = 0.

Usually learners will choose positive and negative integers for the independent variable. For this table they only used natural numbers. This was a surprise for me. It might be because x is the exponent. I realized that exponents is a difficult topic for grade 10 learners. They may not all be comfortable with a negative exponent and

questions usually ask them to give answers with positive exponents. This is a clear demonstration of how prior knowledge influences the learning experience.

Some of the learners constructed a table with values for the independent and dependant variable of the equation y = 2x, I asked them what the values of the parameters a, b and q are. They stated that the value of b is 2 but many different answers for the values of a and q were given. For example was when a learner identified that the value of q is 0 since it is not present in the equation, he automatically assumed that the value of a is 0 as well because it is not present in the equation. This is a lack of understanding of the notation that is used. I try to help learners overcome this difficulty by having them describe an equation verbally to me. I encourage them to use the correct terminology and to distinguish between constants and coefficients. They need to explain the effect of coefficient (multiplying a value) and a constant (increasing/decreasing a value by a constant amount),

At the end of the learning period learners only identified the shape of the graph of an exponential function. They did not draw enough graphs to determine the influence of the parameters a and q.

I enjoyed this learning period very much. At the start learners were uncertain of how to approach the problem. Once they identified a strategy of solving the problem they started to work vigorously on their own and in groups. The need to solve the problem was substituted with desire to solve the problem. This was the first time I really experienced this.

When learners are not given specific instructions the mathematics they use can be observed more clearly. They do not just mimic the example of the educator but rely on their own mathematical ability. I believe this is the best way to identify flaws in the conceptual understanding of mathematics of the learners. It is also possible to

observe the understanding of a variety of themes and not just the topic that the class is busy with during the learning period.

I was surprised by a specific learner in the class. He is a weaker learner in the math classroom. He took leadership of a group in the class and explained to them how the problem will be solved. he also demonstrated a good understanding of what values should be chosen for the parameters to solve the problem. After the learning period he asked me for a copy of the written instruction because he wanted to complete the entire problem at home. This was significant for me because it was my last period, he did not have to submit anything to me, and it was a Friday. He is not a strong mathematics learner but wants to do a mathematics problem during the weekend.

This was the final task that designed for my school-based education. I implemented this learning task on the last day of my school-based education. I was frustrated with the way things were during my second school-based education. My mentor was a person an educator who believed that the educator should provide the learners with an exhaustive example of the problems and the way in which it should be approached by the learners. This is contradictory to my view of education. This learning task was a form of rebellion. I deliberately moved into an endogenous approach. Learners were confronted with a problem that was not divided into any smaller parts. They had to identify for themselves how they would approach and solve the problem. An amazing experience for me was when the class moved into cooperative learning spontaneously and I only facilitated this process.

The consolidation I did during this learning task was also a breakthrough for me. I made use of an individual learner to present his solution on the board to the entire class. I gave other learners the opportunity to question his approach although they did not make full use of this opportunity. The consolidation provided learners with an idea of what is expected from them during the next learning period to establish the influence of the parameters in the

My view of education changed greatly during this year. I previously held the opinion that the teacher is the most important factor for learning to take place and that the teacher's action will influence the quality of learning. This is not true. The focus should be on the actions of the learner and how these actions will improve their quality of learning and how learners will crave further knowledge.

The main aim of education is develop learners who will become citizens that can be responsible for their own learning. This is done through facilitating meta-learning which creates active, effective, collaborative, independent life long learners and facilitating cooperative learning which creates active, effective collaborative inter dependant lifelong learners. Focusing on the highest level of cognitive skills identified in Bloom's taxonomy will create the opportunities for learners to develop and improve their own learning experience. This can be associated with real life challenge.

4.9 Conclusion

This chapter has presented the reflections of each participant narrated through their own voice. The compiling of each reflection was done by using entries in chronological order, taken from their final professional portfolios. As the researcher, I chose the entries to include those which were most representative and descriptive of the participant's progress and experience during the course of the year relating specifically to their mathematics profiles and instructional behaviour. Chapter 5 now presents my researcher reflections on each of the participants with regard to the two constructs being studied in this investigation.

CHAPTER FIVE   RESEARCHER REFLECTIONS

5.1 Introduction

In the previous chapter, a compilation of participants' reflections and experiences from their final portfolios was presented. This participant reflection described how each participant viewed the aim of education, their experiences of teaching and learning mathematics within the PGCE course, their insights during their two school-based education periods and their progress and development over the course of the year with regard to developing and implementing learning task designs. The reflections were written in the voice of the participants as they represented themselves in their final portfolios, in defending their professional development. The purpose of including these participant reflections was to give the reader insight into the participants through the eyes of the participants themselves, before presenting the researcher reflections in this chapter.

These researcher reflections are my experiences, views and assessments (and some assessments from the lecturer who assisted me) of each participant during their PGCE year. The approach I used in writing these reflections was to include comments on how the participant represented themselves in comparison to how I viewed them. In the mathematics profiles I then expound each participant's subject matter knowledge, pedagogical content knowledge, conceptions of mathematics and beliefs on the teaching and learning of mathematics through my own observations, conversations and encounters with the participants. Finally, the instructional behaviour profiles are outlined according to each participants' position on the continuum of reform versus traditional approaches to the teaching and learning of mathematics and the second continuum of providing learners with either autocratic versus democratic experiences of learning. I draw on the literature referenced in chapter 2 in guiding the development of these narratives.

My main sources of data for this chapter came from the learning task designs and video-recordings of lessons included in each participant's portfolio. I also draw on my reports of

their observed lessons and the baseline assessments (see Appendix D) they wrote on entering the mathematics specialisation module of the PGCE. This baseline assessment covers a variety of topics and learning outcomes up to a Grade 9 level (from the South African curriculum) and is made up of a number of TIMSS items that were released on their website for public distribution as well as other items taken from Grade 8 or 9 school assessments. The PGCE students are instructed to draw up a memo for the baseline assessment without consulting anyone else or their textbooks. The assessments help me as the specialisation lecturer to gain some insight into the level of conceptual understanding of basic mathematical principles with which students enter the course. While I do not wish to argue or prove the scientific validity and reliability of these baseline assessments, they have proved over the last four years to be a very good indicator of the level of mathematical conceptual understanding that students demonstrate in their teaching and learning of mathematics during the PGCE course.

5.2 Marge

5.2.1 Mathematics profile narrative

The way Marge has represented herself and reflected on her approach to the teaching and learning of mathematics is significantly in line with how I experienced Marge's growth and development throughout the year. Marge always displayed strong subject matter knowledge, with conceptual depth and an ability to think relationally. When she wrote the baseline mathematics assessment that I require all students to write on entering the course, Marge found some solutions that I had not even included in my memorandum. This strong subject matter knowledge and her passion for the subject appeared to put her in a position to develop her own mathematical problems for learners that were later presented in an appropriate and authentic context in her LTD's.

The first lesson of Marge's that I assessed was conventional, as she mentions. She initially expressed a deep concern of how she could not understand how things could be any different. However, Marge has an ability to persevere and she began reading, widely! Evidence of this is apparent in her portfolio and in the quotes from her assessment reports below. Marge especially enjoyed the literature on Realistic Mathematics Education to which I introduce all

the students as part of the course. She also did her own research and found the work of researchers at Stellenbosch University (Olivier, Human and Murray) on the problem-centred approach very helpful.

Marge began finding ideas on the internet, in textbooks and by looking for mathematics in her everyday life and working them into mathematical problems that could facilitate the construction of mathematical principles in her LTD's. She tried various forms of assessment in her learning tasks and worked exceptionally hard at changing her approach to and view of teaching and learning mathematics. She started viewing learners' errors as potential learning opportunities and began answering questions by asking another question to encourage learners to become more independent thinkers. Marge also successfully started using scaffolding in her lessons where she gave questions or hints to learners who were struggling while still trying to encourage them to think for themselves. The progress in her pedagogical content knowledge was evident throughout the year and is illustrated by the following quotes from assessment reports I sent her during the course of the year.

> *I experienced the lesson as very teacher-centred, with the learners doing very little thinking of their own…The learners' role was to respond on occasion when requested and to copy the examples. It is difficult to see this then as facilitating of learning but rather as "copying" of the teacher's notes and thinking. Statements such as "Ek gaan vir julle wys hoe werk dit, en dan [I am going to show you how it works, and then….]" re-inforce for me a very teacher-led and teacher-centred style of teaching. (24 April 2006)*

> *Think about what the learners gained mathematically from this lesson – they followed the rules given and the examples on the board but how has this enabled them to be more mathematically literate or to understand the concept of a mathematical function? One runs the risk of making mathematics out to be a set of rules that need to be memorized and applied at the right times or you can't do it. (24 April 2006)*

> *Your passion for the subject and perseverance with challenging students are to be commended. (5 May 2006)*

There was definitely a noticeable attempt at shifting to a more learner-centred approach in this lesson. (5 May 2006)

It was good to see that you "entertained" the incorrect answer of the learner about B + C – 180, by writing out exactly what she said and allowing her to realize her own mistake. This is a definite improvement in your pedagogy – keep it up! (1 June 2006)

Your questioning skills are certainly improving all the time. I experience that you are pushing the learners more and trying to make them more independent in their thinking – well done. (1 June 2006)

Your LTD's are of a high standard – both in design and execution. You have also maintained a good balance between context and mathematics. Continue to ensure that learners are given sufficient opportunities to practise and demonstrate their understanding. (7 August 2006)

By the end of the course Marge had progressed from a predominantly instrumentalist view of mathematics to a Platonist view and eventually a problem-solving view. She successfully made the transition from a content-orientated approach to a more process-orientated one where she managed to explicitly demonstrate her changing beliefs through her attempts and ability to take on the role of explainer rather than that of instructor. She was able to design effective LTD's (up to a Level 5 of Mason's levels) that she had thought up herself, to monitor that actual learning was taking place through appropriate assessment and to reflect on ways to improve her classroom culture and pedagogical content knowledge. In my opinion her strong subject matter knowledge, her ability to reflect on herself and her lessons with critical insight and accuracy, the literature she read, tried and her own experiences during her school-based practice periods are the factors that enabled the positive changes that occurred in her conceptions, beliefs and practice.

5.2.2 Instructional behaviour narrative

Initially I would classify Marge's instructional behaviour as very traditional. Her first few classes were characterised by a dominance of expository teaching, a focus on correct answers and correct mathematical methods as well as the efficient mastering of rules and algorithms.

As Marge began to engage more with the literature and review her own conceptions and beliefs with regard to mathematics and the teaching and learning thereof, her approach in the classroom began to change.

Marge started to value communication in the mathematics class more highly, design and implement learning tasks that reduced the emphasis on routine arithmetic computation and encouraged more guided (scaffolded) discovery methods, exploration and modelling. She began making more frequent use of alternative assessment methods such as journal entries and encouraged learners to compare and discuss their mathematical techniques. Marge's learning tasks became more problem-solving orientated and engaged learners in real-life, contextual problems where learners were first required to attempt their own informal solutions before seeking a more formal approach.

On commencing her first school-based experience, Marge displayed (and expressed) a need to always be in control of the learning and management of the classroom. She would tell the learners what they would be dealing with for the day, show them a few examples, explain the steps and get the learners to try some calculations themselves. Her approach was therefore formal, expository and did not allow for a lot of communication between the teacher and the learner, except for the odd question to ensure that learners "understood" or to see if they had any queries they wanted to express. Marge's listening was also more evaluative initially where she was focused on listening for the correct answer or mathematical explanation.

Late in her first school-based experience and into her second school-based experience, Marge began to become more aware of the classroom culture she was creating through her authoritative actions. She began to encourage learners to share their reasoning first, before she provided them with her formal, stylised approach. More group work was undertaken in her classes, while individual meta-learning was not disregarded. During this phase her listening also moved towards a more interpretive listening where the correct answer no longer became the focus. Marge asked learners to elaborate on their thinking and explanations behind incorrect answers and stimulated further discussions using these errors. Communication, especially relating to mathematical issues therefore became more of an integral part of her lessons, although Marge never reached a hermeneutic level of listening where the teacher and

learner become equal partners in jointly exploring mathematics. By the end of the year, Marge's instructional behaviour had therefore shifted from a traditional to a more reform approach and from a very autocratic to slightly more democratic position on the two continuums.

5.3 Lena

5.3.1 Mathematics profile narrative

In the baseline assessment Lena performed well, only making one or two careless omissions and one general solution where she could not find the specific values required. She never made any overt fundamental errors during the lessons I observed her teach or in her learning task designs. While I would not regard her subject matter knowledge as strong as that of Marge or Toni, I am of the opinion that it was still conceptually sound.

Lena was given a Grade 12 class to teach at her first school-based experience and right from the start she confidently presented the content to them without faltering. As she explains in her reflections, what she struggled with initially was finding more ways to try and explain to learners when they did not initially understand. This was more a feature of her pedagogical content knowledge which was also often highlighted in my comments in reports sent to Lena during her first school-based experience. Another focus was on trying to encourage Lena to make more use of contextual problems, rather than her preferred model of showing examples to the learners before getting them to try some calculations of their own. A few quotes are provided below from a range of reports during the first semester that illustrate these comments.

> Think of ways to move your teaching towards a more learner-centred approach. Remember that this has to do with the amount of thinking and learning they are doing, rather than whether they are just active in the lesson. (24 April 2007)

Listening to the answers learners propose and investigating their correct as well as incorrect responses can be very helpful in identifying for you what they understand, rather than simply what they can do. Actually asking learners whether or not they understand is not as useful. (24 April 2007)

I think these learners are afraid of making mistakes. This is probably due to many years of mathematics experience for them where mathematics has been about getting the right answer. They therefore begin to think that if they can't get the right answer, they shouldn't even bother. This is something for you to consider in your own practice-theory and how you can change this in your classroom culture once you have your own class. (10 May 2007)

Although your lesson involved the learners, I want to challenge you to consider how you could have more engaged and challenged them with this particular content. Try to think of where this applies in real life (for example painting versus filling a swimming pool) and how an actual box of ice-cream cones is packed. Beyond just the pure mathematics embedded in this learning outcome, I think there is a lot of scope for more use of context. (30 May 2007)

During the second school-based experience, Lena started showing more creativity in designing her learning tasks and making effective use of challenging learners with problems in authentic contexts. She was able to design learning tasks that I would classify as Level 5 on Mason's levels. She was continually working at and reworking her personal practice-theory on the teaching and learning of mathematics, especially in terms of working in the use of urgent problems that would engage learners on a horizontal and then vertical mathematisation level. During this time Lena also showed good development in terms of her pedagogical content knowledge specifically with reference to her planning, ideas, posing of questions and use of scaffolding. The comments below from reports issued to Lena (by the lecturer who relieved me) during the second school-based experience substantiate this.

The problem about the homework was relevant to learners' lives and their context. Learners had the opportunity to solve the problem in an informal manner (horizontal level). Some of the learners generalised the solution to a formal, vertical level. (24 July 2007)

The idea to show snippets of a film to learners was outstanding. This put the problem that they needed to solve into context and I believe you were successful in immediately getting the attention of the learners. (6 August 2007)

Your use of questions such as, "Are you sure?" and "what do you think?" are effective questions during learning task feedback. (6 August 2007)

Your reference to the sketch of the hyperbola was a good way to make use of scaffolding for the learners. (6 August 2007)

I was excited about the consensus that some of the learners reached. One group was convinced that the formula was $y = 3^a$ while another group reckoned that it was $y = 3 \times a$. The resulting discussion was educationally very beneficial. (6 August 2007)

Similar to Marge and Toni, Lena took a methodical approach to writing her reflections and to developing her practice-theory. Lena's reflections mostly foreground what she thought had worked and what could be done to improve her practice. With regard to her conceptions of mathematics, she demonstrated an instrumentalist view of mathematics throughout the year. During her expository teaching she conveyed mathematics as a bounded system of rules and algorithms. Lena had creative ideas and made effective use of media and context. Although she did design problems that encouraged learners to think about and engage with the mathematics, her focus remained largely on mathematics content and the mastering thereof. Initially she did not indicate that she required the learners to be anything more than passive receivers of her teaching. Later in the year though she began to ask more questions that encouraged communication from the learners.

My perception of Lena throughout the PGCE was that she will always strive to improve her practice. This appears to be part of her nature. However, I did see the conflict she continually seemed to be experiencing between the way she was taught mathematics and how she was being challenged to teach it. Initially she battled to see any fault with the traditional approach to the teaching and learning of mathematics. It was only when she started to successfully apply

a more constructivist approach that she became excited about the prospect of working this into her practice. While students make some radical changes to their beliefs during the PGCE year, Lena appeared to be one of those students who took time to reflect and internalise change in her practice. I suspect though that when she does, the change is deep and sustaining.

5.3.2 Instructional behaviour narrative

The most striking characteristic in all of the observation and recorded lessons of Lena is what I have called "the teacher pause". As I commented in one of her reports,

> *Think about your questions and the pauses you allow. If it is not really a case of you requiring an answer from them, then rather make a statement. Otherwise it is good to wait for them to provide an answer to avoid encouraging a classroom culture where they know you will answer if they just wait long enough. (25 April 2007)*

Lena had a tendency from the beginning to start a sentence (not necessarily a question) and then pause for the learners to "fill in the blank". For example, she would say, "…and the third term is……four". She did not necessarily wait for an answer to come from the class. After approximately a second she would fill in the blank herself. Unfortunately she tended to also do this with questions that she posed to the class. If the correct answer was not forthcoming from a learner very quickly, she would immediately proceed with her expository explanation. This is an important aspect of Lena's instructional behaviour. This was one of the influential factors that kept her lessons predominantly authoritative for the entire year.

The learners seemed to quickly pick up on this culture of not having to answer too quickly as the answer would then come from the teacher anyway. This therefore did not encourage a lot of mathematical discussions or communication in the classroom. When Lena did start her expository explanations, they required little more than surface involvement from the learners with questions such as, "…who joined the points?" or "what was the value for *a* that you got?" However, in the actual learning tasks that Lena designed she managed to make use of problem solving and effective scaffolding within the tasks. Towards the end, the problems were also real-life and in context. During such a lesson though, her standard approach was to introduce

the problem to the learners (either verbally or with assistance from media such as video clips). Lena would then distribute the written problems and instruct the learners to work on their own before moving them into groups for further discussion between themselves. After some time in their groups, Lena would move to the front of the class and begin going through the problem in her usual expository approach. I could not find any examples of where she invited learners to share their solutions to the problems or where she facilitated a class discussion on the problem. Her listening skills also remained evaluative, rather than interpretive although she did towards the end start asking individual learners higher level thinking questions as she moved about the class.

In terms of instructional behaviour, this meant more of a movement occurred for Lena on the traditional/reform continuum than on the autocratic/democratic continuum.

5.4 Peta

5.4.1 Mathematics profile narrative

Peta's reflections are accurately representative of her frustrations and challenges throughout her PGCE year. Peta is a soft-spoken and gentle individual and discipline issues feature often in her reflections. I suspect, however, that Peta's personality is not the only factor that may have aggravated her negative experience of discipline issues with learners. As Peta mentions in her reflections, she initially lacked confidence, was very nervous she would make a mistake and struggled to explain the content to learners. She was also overtly aware of potential weaknesses in her pedagogical content knowledge. Much of this was due to the gaps in Peta's subject matter knowledge, some of which became evident in her baseline assessment through fundamental errors as demonstrated in the examples below.
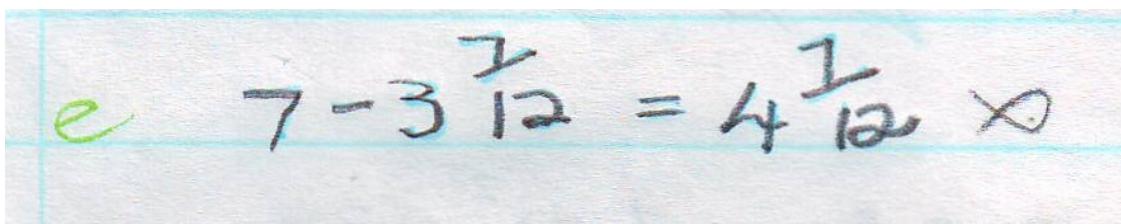
Figure 5.1 Example of a fundamental error from Peta's baseline assessment

This first error is particularly disconcerting with regard to Peta's conceptual understanding of fractions and working with rational numbers. This is further confirmed by the errors in Figure 5.2 below where she appears to incorrectly apply exponential laws. When students are doing this assessment, they will often complain that they have "forgotten" the exponential laws after not having used them for a few years. My response is always that if one understands the notation and has a conceptual understanding of the concept of an exponent, that there is no need to have any memory of the laws. The notational and conceptual understanding should be sufficient to allow one to find the answer without applying any laws, although this may make one's calculation slightly longer. Peta's responses to the questions below indicate her inability to demonstrate either a notational or conceptual understanding of exponents.

Question 2b

(4) $10^4 + 10^4 + 10^4 + 10^4 + 10^4$ (2)

(5) $2^3 \times 2^2$ (1)
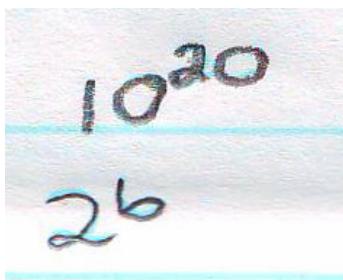
Figure 5.2 Further examples of fundamental errors from Peta's baseline assessment

Even after a few difficult incidences exposing some gaps in her subject matter knowledge, Peta continued to persevere in working at designing learning tasks that were more learner-centred and constructivist in their approach. The following quotes are taken from reports I sent Peta.

> *Consider in your practice-theory the effects on your classroom culture of showing learners how to do the first one. Does this help you see who understands? Who ends up doing the thinking? Is this more learner or teacher-centred? What are (if there are) the benefits of telling and showing learners how to*

do the mathematics? These are questions that you will need to think about as you reflect on your practice. (11 May 2007)

You are still telling too much, rather than getting the learners to think. You need to work more on designing questions you can ask learners when interacting with them. These can be written down in your planning already.(11 May 2007)

I am still concerned that your teaching is still too teacher-led and that you make too much use of whole-class teaching. On this video it again looked like groups already finished had to wait for you to finish attending to other groups, and your next instruction, before they could continue. I wasn't sure why you had chosen this above a self-led worksheet. Perhaps this is in your reflections, or feel free to comment on it in your reflections to me. (30 May 2007)

Although this improved as the lesson progressed, learners did not seem to be engaged for parts of the lesson, although they were involved. My next challenge to you is to get them solving problems that challenge and engage them to think as mathematicians. There is a difference between them being mathematically engaged and them supplying answers on demand or following your instructions. Remember that we can involve learners and still not have a learner-centred lesson. I am sure that you will take up the challenge in the second semester to work on this, now that you are more confident in front of the class. (30 May 2007)

During her second school-based experience, Peta did take up the challenge by applying herself to improve her planning. Her pedagogical content knowledge appeared to improve despite the deficits in her subject matter knowledge. Her planning, assessment and classroom management advanced to a sufficient proficiency in my opinion over the course of the year. She made use of hints to try and get learners to think more independently and her questioning technique improved. This is substantiated by the following quotes taken from the assessment reports written by the specialisation lecturer relieving me while I was on study leave during the second SBE of the students.

It is very positive that you introduced the new topic with an example in an authentic context…The problem in a real context was solved by learners on a horizontal level. This was a good decision. You could have made the learning experience even more learner-centred by asking the learners to do a journal entry about their observations. (31 July 2007)

Your skill in setting questions has developed well. (31 July 2007)

I enjoyed it very much that some of the learners do not want hints from you anymore. This is a positive change in the classroom culture. (14 August 2007)

The Chinese proverb that you used to present the learning task was a lovely idea, something different and definitely effective…I liked the fact that you asked the learners to "tell the proverb graphically…" (29 August 2007)

The final task that Peta reflects on in her participant narrative is also indicative of the highest level she achieved in designing a learning task according to Mason's (1989) differentiation. This was a level 3 in my opinion. Her conception of mathematics appeared to remain rigid and bounded by rules and formulae throughout the course of the year. I make this deduction mainly from the way she portrayed the mathematics in her learning task designs and from her low frequency of engaging with the actual mathematics content in her reflections. Peta definitely felt more secure when dealing with mathematics as a set of rules and algorithms, therefore predominantly teaching in a content-orientated manner. This may again be a function of the gaps in her subject matter knowledge, which possibly also led to her mostly taking on the role of instructor in the classroom, where her strongest focus was on mastery and correct performance.

5.4.2 Instructional behaviour narrative

All the lessons I observed Peta teaching and the videos she included in her portfolio follow much the same order of events. A worksheet was handed out to learners at the start of the lesson. On one occasion, the learners immediately just started working on the worksheet but the other times Peta either read through and explained the instructions or problem to the

learners or presented a verbal presentation of the problem. Peta would then move between the learners and respond to questions as requested while the learners worked on the problem or calculations. If a question seemed to be repeated by a few learners Peta would go to the front of the class and present an explanation to the class. The learners would then continue with their work, which they would either hand in to be marked or mark themselves from an explanation presented by Peta.

There were some positive changes though within this order of events. The quality of the worksheets improved from a set of calculations to more contextual type problems, although there was never actually a problem I would deem as relevant to the real life of the learners. Initially Peta would read through the problem and instructions of the written presentation with the learners and explain to them what they needed to do. In one of the lessons she showed them how to construct the table they would need to complete in order to draw the graph they were being required to draw. However, in her final learning task design, Peta presented the verbal presentation (of a Chinese proverb) to introduce the problem (rather than reading through the problem and instructions with the learners) and then turned the learners' attention to the problem of representing the Chinese proverb graphically.

During expository explanations, Peta mostly focused on the explanation and the correctness of the learners' responses. Towards the end of her second school-based experience, Peta did begin to ask more questions in response to learners' answers and questions, but these did not necessarily elicit high level mathematical reasoning processes. I suggest that, even by the end of the year, Peta was still more comfortable with a step by step development of ideas and following rules and algorithms. Her discussions with the class did not encourage them to find patterns of thinking or make connections between various concepts, but rather to guide them to the correct solution of the problem. She also seldom made use of authentic or alternative assessment. I would therefore classify Peta's instructional behaviour as dominantly traditional throughout the year.

The issue of an autocratic versus democratic learning experience for the learners is an interesting one in Peta's case. Unlike many of the other students, Peta never started off trying to be in "control" of the class. At times we actually commented on how much say the learners

had in her classes, to the extent that she would ask them when she could carry on with the next worksheet or problem. However, at times she would feel that the discipline was getting out of control, get very angry with learners and attempt to then "take control" from a discipline point of view. Mostly though, Peta learnt to move around the class and interact with the learners working on their problems individually or in groups. In this interaction she appeared to show signs of somewhat more interpretive listening rather than the evaluative listening she demonstrated during the whole class teaching discussions.

5.5 Kapinda

5.5.1 Mathematics profile narrative

As I worked through Kapinda's portfolio again, analysing her learning task designs and reflections, the aspect that stood out most was Kapinda's tremendous creativity in designing learning task designs. From the beginning of the year Kapinda seemed to enjoy this part of the training and worked hard at continually improving her learning task designs. She did not seem to struggle with any sort of cognitive or belief conflict regarding the new paradigm of thinking she was confronted with in the PGCE course in comparison to the way she was taught as a learner. She never showed any resistance towards a more problem-based approach and seemed to embrace the challenge with great enthusiasm. Her learning task designs always actively engaged the learners and learners appeared to enjoy Kapinda's lessons very much. The following quotes from assessment reports we sent to her illustrate this.

> *Again I want to compliment you on a lovely idea and a more learner-centred lesson. I think it could have been even more real-life though if you considered an everyday context such as packaging for supermarkets, and how companies try to optimise volume and minimise cost in order to produce better profits. (6 May 2008)*

> *I liked the way you engaged the learners in a short discussion on personal appearance, weight issues and peer expectations as part of the verbal presentation. The topic ensured natural integration with other learning areas like Life Orientation. (27 May 2008)*

Although the learning did not take place with a central problem as focus, the issue was exceptionally relevant to the particular group. (27 May 2008)

All learners were involved and actively engaged. (27 May 2008)

This was a good way to handle the test. It made good use of differentiation and engaged learners far more than going through the whole test with the whole class would have. (18 August 2008)

A great video clip and introduction to this lesson. Really appropriate and this would be a good tool to use at the start of year when setting classroom culture. (11 September 2008)

Overall I would classify Kapinda's subject matter knowledge as good. There was no evidence of any overt fundamental errors in her learning task designs or observed lessons. In the baseline assessment Kapinda made one careless error and did not find complete solutions to two of the problems. What I did observe though was that Kapinda seldom, if ever, approached the teaching and learning mathematics in ways that demonstrated a deeper relational understanding of general principles of the domain as shown by Marge for example. During the course of the year, she learnt to design and present interesting and engaging problems to the learners. However, the mathematically focused class discussions, feedback and consolidation of her lessons lacked evidence that she was aware of or intent on facilitating the learners' understanding of the mathematical processes involved. She seldom, if ever in the lessons I observed, questioned or delved deeper into learners' errors or thinking and appeared to remain more content orientated in her enacted beliefs towards the teaching and learning of mathematics. The following quotes from a range of assessment reports to Kapinda support the above claims.

Be careful not to enforce narrow perceptions learners may have, e.g. that the perpendicular height of a right-angled triangle will be the vertical dimension and the base the horizontal dimension! Any of the perpendicular sides can be regarded as the base and vice versa. (24 April 2008)

Be careful not to respond to wrong answers too quickly. Probe into wrong answers in order to get clarity on learners' thinking. Instead of answering that the AREA of the circle was subtracted from the

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area of the square, a learner answered that the CIRCUMFERENCE was subtracted from the area. She did, however, get the correct answer. She understood the solution, but only used the wrong TERMINOLOGY. Your response was to say "You cannot do that". (24 April 2008)

I am concerned about your decision to order the BMI [body mass index] ratio's in the table from smallest to largest. This can lead to the misconception that the median will always be in the middle of any list, or that all given lists of observations will necessarily be ordered. It is my opinion that learners should have the responsibility to order the observations. The group of learners close to me blindly found the middle number without first checking whether the list was in fact in ascending order. (27 May 2008)

To counteract apparent narrow understandings like the one mentioned under the previous point, assess their understanding of the formulas or strategies for median, average, mode, etc. by asking the learners to explain in words, in writing what the formulas or strategies entail. Another strategy they need to apply is to determine whether there is an even or an uneven number of observations. That is impacting on the approach in finding the median. The learners close to me did not take that into consideration. (27 May 2008)

I think you could have a bit more of a discussion (asking the learners) why it is important, especially in mathematics, to understand why we do certain procedures and apply certain laws. (11 September 2008)

Investigating numbers helps us to see and establish patterns which we think may be true (called conjectures). In order to prove the conjectures so that we can accept them as rules, laws and theorems, we use algebraic proofs to test and prove their generalisability. These proofs are based on the conjectures we established in the patterns. (11 September 2008)

The presentation on why dividing by 0 is undefined was too long and also not clear or correct. But you didn't make any comments. Be careful of letting such mistakes go without clarifying them or asking the class about them. (11 September 2008)

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Kapinda's reflections are accurately aligned with how I experienced her lessons. Her focus in the reflections was mostly on pedagogical issues though, such as her planning, ordering groups, handing out worksheets, interaction with the learners, assessment, questioning and discipline. She seldom made any reference to the actual mathematics processes or understanding learners should gain from the lesson. Kapinda never made any reference to literature in the mathematics domain or to articles they had been given to read in class. However, she did demonstrate an outstanding knowledge of the context of her learners and this enabled her to select and design learning tasks with authentic contexts to which the learners could easily relate. Although, as mentioned, her ideas were very creative and the problems she set engaged the learners, in my opinion she elicited up to a Level 2 from her learners according to Mason's (1989) levels.

Kapinda's conceptions of mathematics are not as obvious from her portfolio as some of the other participants. Her lack of identifying mathematical processes, the nature of the worksheets she compiled and her continued focus on mastering content led me (in consultation with the lecturer who sometimes assisted with lesson observations) to conclude that her view of mathematics remained instrumentalist during the year. Based on the above-mentioned reasons I would also define the role she mostly played in the classroom as that of an instructor.

Kapinda displayed a very natural tendency to design creative learning tasks, interact well with her learners and to get their attention. She also seemed to agree with (verbally) and embrace the shift to a more constructivist paradigm. She was clearly passionate about her relationship with the learners, about encouraging and motivating them and about her chosen profession. The "silence" that comes through in her portfolio though relates to the actual subject of mathematics. When I asked her later about this, she made the comment that although she sees the value in teaching mathematics using a more problem-solving approach, she could not envision how this is possible considering her own experience of school and university mathematics.

5.5.2 Instructional behaviour narrative

Kapinda's observed lessons were always enjoyable; both from a learner and observer perspective. She embraced group work in her first school-based experience and made extensive use of this type of collaborative learning where possible, sometimes allowing individual learning first, followed by groups then collaborating on the same problem. Kapinda varied her selection of groups well in terms of the number of learners per group and how they were organised into groups. Learners seldom had any part in this selection though and the group organisation was usually already written up on the board when learners entered the classroom.

Most of the observed or video-recorded lessons of Kapinda show her giving a verbal presentation of the problem and creating some context before handing out the problem or worksheet to the learners to work on individually or in their groups. Kapinda moved very effectively between groups, answering questions learners had and checking what they had done. She mostly answered learners' questions by posing another question to assist them in reaching the answer. However, even at the end of the year, the level of questions she was posing to them focused more on eliciting the correct response rather than investigating the learners' thinking processes. Her listening therefore remained evaluative throughout the year.

Kapinda made more use during the course of the year of alternative assessment methods such as journal entries, presentations and the use of rubrics to guide learners to be more independent. Her lesson task designs encouraged hands-on, guided discovery rather than expository teaching, but high level reasoning processes were not foregrounded. I never once observed her leading a discussion with the class where Kapinda required learners to verbalise their mathematical thinking or understanding or where investigative exploration and modelling were discussed. The problems given to learners were mainly designed to achieve the immediate curriculum outcomes and mathematical mastery required rather than afford the learners a more relational understanding of the domain.

5.6 Anabella

5.6.1 Mathematics profile narrative

Anabella's reflections are often refreshingly personal and honest. They are also mostly accurate with regard to the lessons I observed her teaching. I use the term "mostly" because there is one exception and that relates to the lesson she describes in chapter 4 as a "total disaster" where she was looking at the effects of the parameters of a and q on graphs with Grade 11 learners. The lesson was not a total disaster. The learners were not really proficient at drawing graphs though, so her lesson could not work out as planned. Relating to this I mainly gave her some pointers on how to consider achieving the desired outcomes differently. The main critique, however, in both my report as well as the colleague assisting me, related to her subject matter knowledge in relation to how she spoke about the mathematics content. The quotes below provide examples of this from more than one lesson.

> *Start to react to learners each time they refer to "take a term over to the other side" and "the sign changes". This is not mathematically correct and is definitely not what happens! They should understand the principles of the inverse for addition and the identity for addition. They do not have to write this down each time, but should quickly say e.g. +3x LHS and RHS. (23 April 2008)*

> *Instead of saying "get x or y alone on the LHS", you can say "change the subject to x or to y". Keep in mind that the subject does not have to be on the LHS! (23 April 2008)*

> *Be careful to always balance equations. In other words, do not change an equation to an expression. If your equation is 2x² + x − 3 = 0, do not suddenly write (2x + 3)(x − 1). It is essential for learners to understand that the solution to a quadratic equation is the roots which are those x-values for which the function values will be zero. (23 April 2008)*

> *Be careful of how you phrase mathematical ideas/concepts, e.g. "put a minus before the x"; a minus does not have meaning on its own – the term has a coefficient of -2 and not of +2; "the x-axis shifts", the <u>graph</u> has a vertical shift; "the slope moves down"; it is the gradient that is negative and the function that is decreasing; "plot graphs"; one plots points and joins the points to draw the graph; "a*

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and q differ"; a and q change or take on different values; "how does the tan-graph differ from the other two?"; the tangent function does not only differ from the other two functions in terms of the asymptotes – there are other differences too, e.g. the fact that one cannot refer to an amplitude, the range differs, the period differs, the fact that one cannot identify a maximum or a minimum value, etc. You understand what you are trying to convey, but the learners hear these in a way that results in the construction of incorrect knowledge and misconceptions. (12 May 2008)

Anabella viewed this very much as an issue relating to her use of the English language rather than the conceptual understanding issues we were trying to highlight regarding her use of terminology. For example, in mathematics an axis on the Cartesian plane is fixed. A graph can shift if its equation changes but the x–axis does not move. If one talks about "shifting the x-axis" this demonstrates a lack of conceptual understanding regarding the properties of the Cartesian plane, rather than an incorrect use of the English language.

As Anabella correctly stated, I was concerned about her level of subject matter knowledge as displayed in the baseline assessment students wrote on entering the course. She omitted a few answers, made a range of careless errors as well as two fundamental errors. One of these fundamental errors is included as an example in the figure below. Here Anabella seems to get somewhat confused with her application of the exponential laws. I note this as a fundamental error because of her inability to see that 50^4 cannot possibly equal 50 000 and that there is a huge difference between 5.10^4 and $(5.10)^4$. This can also be argued as just an incorrect application of mathematical notation but a student with a strong conceptual understanding of the subject would have noted this discrepancy even if they had forgotten how to apply the exponential law.
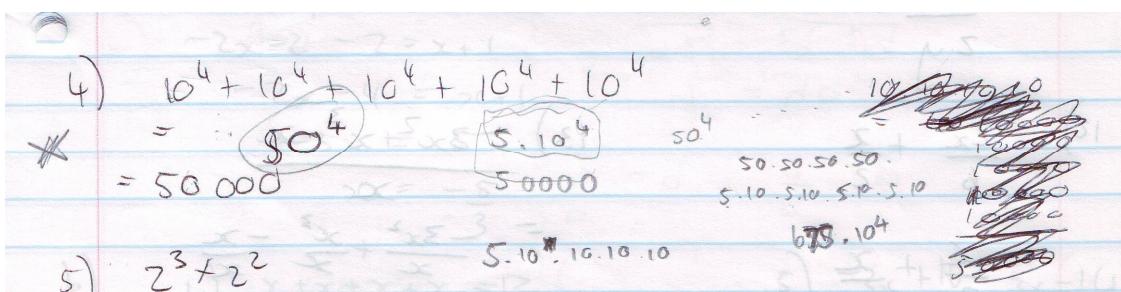
Figure 5.3 Example of fundamental error made by Anabella in her baseline assessment

During the course of her school-based experiences, the gaps in Anabella's conceptual understanding of mathematics were also evident, for example, in the mistake she mentions in her reflections. Unlike the careless error that Toni made while doing a calculation on the board, Anabella had included a solution in her lesson plan that she had worked out prior to teaching the lesson and the errors were in my opinion not careless but of a conceptual nature. This is one aspect of her practice that I believe Anabella was unable to be honest with herself about. She noted my comments on her level of mathematics knowledge, the results of the brain profile, her mistake and an intention to work hard to improve this in her reflections, but she never actually acknowledged that the gaps in her subject matter knowledge could be what hampered her ability to design and operationalise LTD's in the FET phase.

On the other hand, Anabella did improve in the design of her lessons throughout the year. She was creative, made appropriate use of media and started to use scaffolding at a basic level in her lessons. She did not often engage with learners' errors, which I suspect is also due to her level of subject matter knowledge. Similar to Sophie, Anabella's reflections seldom provided insight into the mathematical content. The scaffolding questions she prepared for many of her lessons indicated that her pedagogical content knowledge was, in my opinion, of a higher level than her subject matter knowledge. Perhaps the deficit within her conceptual understanding enabled her to work at making the subject more accessible to the learners. Anabella also worked very hard at improving this aspect of her teaching. She engaged with the literature on Realistic Mathematics Education and attempted to use horizontal and vertical mathematisation at times.

Reflecting on the reading Anabella had done, she agreed that in the teaching and learning of mathematics "the focal point should not be on mathematics as a closed system but on the activity, on the process of mathematisation." During her second SBE Anabella had more success in actually making this belief noticeable in her learning task designs when she was given a Grade 8 class to teach. It was only when she was teaching at this level that I noticed Anabella was able to design tasks that indicated that she held a less rigid and limiting view of mathematics. This could have been due to the fact that her conception of mathematics had shifted during the course of the year, or that her subject matter knowledge had constrained her

view when she was required to teach mathematics at a higher level. A few examples of quotes from assessment reports are provided below depicting the changes discussed.

> *Rather not teach learners a set of "steps" to solve certain kinds of problems. The status quo of regarding mathematics as a set of rules and algorithms is maintained by such practices. You can facilitate the development and recognition of certain strategies the learners can apply. (23 April 2008)*

> *Your use of questions as scaffolding was a good pedagogical decision. I could see that you made an effort with your preparation. One needs to mentally go through the thought processes of the learners in order to effectively set up the questions one wants to use as scaffolding. (26 May 2008)*

> *Although the problem was not urgent and did not originate from the learners' personal context, it was realistic and the learning period was conducted in the transcendental paradigm. (26 May 2008)*

> *You presented the problem verbally and the use of technology contributed to creating a conducive learning atmosphere. The learners were curious and their attention was definitely captured. The written presentations were of a good quality, were clear and served the purpose. (26 May 2008)*

> *The fact that you prepared a second worksheet for learners, who needed less time to solve the problem, was a good strategy. (26 May 2008)*

> *That was a good introduction to get them excited. (8 August 2008)*

> *You seem more relaxed in front of the class - this is great! I am very happy to see the transition you are making to a more learner-centred approach. Well done. You also seem to be gaining confidence. (8 August 2008)*

I view Anabella's belief of teaching as initially content-orientated, with evidence of a shift toward a slightly more process-orientated approach during her last few learning task designs. I would therefore classify her enacted beliefs regarding her role as a teacher as that of an

instructor moving more towards an explainer in the lower grades but reverting to the role of instructor for the higher grades.

5.6.2 Instructional behaviour narrative

Anabella's lessons also reveal a common development trend. Initially her lessons were very traditional and teacher-centred with her showing the learners step by step examples on the board before giving them some calculations to try for themselves. During one of the lessons at her first school-based experience, Anabella began to move towards attempting a more problem-based approach in her lesson design. She showed the learners a problem using the data projector and required them to go about solving it. Learners were allowed to ask for hints if they were stuck and these were given in the form of a question to scaffold learners' thinking.

The three lessons at Anabella's second school-based experience all followed a similar sequence. She would hand out the written presentation of the problem, do the verbal introduction and then walk around the class tending to questions from learners. The problems were always an application of work already handled in the class during the previous few lessons. Where there were recordings of Anabella going through the problems with the learners, these would be very expository with low-level cognitive questions posed to the learners every now and again. Anabella's presentations and contextual problems improved but the focus in her instructional approach remained on the content, such as the formulae and algorithms and on the final solution. When she walked around the class while learners were working on the problems, she mainly responded to questions posed rather than engaging with learners' thinking processes. There was no evidence of her investigating or probing learners' errors or incorrect thinking. Her instructional behaviour therefore certainly remained on the traditional side of the continuum.

I classify Anabella's instructional behaviour as mostly authoritative from the lessons and videos I observed. Her listening remained evaluative in all the lessons. Although Anabella's lessons became more problem-orientated and learner-centred, the learners always worked as individuals and were seldom (if ever) encouraged to elaborate on their thinking processes and understanding. As mentioned above, where questions were posed to the learners, it was clear

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that the outcome of these was a solution. Anabella listened for the correct answer and when it was not forthcoming soon enough, she would provide it herself. Anabella also had the habit of using teacher pauses, but then inserting the answer if the class did not respond timeously.

Anabella's body language was also a fascinating aspect of her teaching that necessitates a mention. She often walked around the class engaging with individual learners with her hands in her pockets or her arms folded. This could have been due to the cold weather in some of the lessons, but others were taped during summer. In one of the lessons she walked around with and used a metre long ruler to point to answers on the board that she could have reached from where she was standing. Anabella appeared to "play out" the role of a traditional teacher exceptionally well. As I replayed her lessons, I could not help but think how stereotypical of the traditional view of teachers her actions were. She was definitely in control, even when the learners were working on the problems. While her instructional behaviour did make a slight shift on the authoritative/democratic continuum, it still remained on the authoritative side throughout the year.

5.7 Sophie

5.7.1 Mathematics profile narrative

In the mathematics content baseline assessment test that Sophie completed on entering the course, she made a number of fundamental mathematical errors. Three of these are included in the figures below as examples.
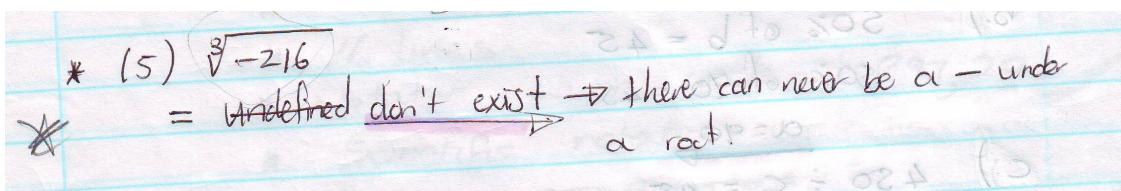
Figure 5.4 Fundamental error from Sophie's baseline assessment

The above example illustrates Sophie's dependency on rules and laws and her gap in being able to correctly apply conceptual understanding of the properties of numbers. Learners are often taught the "rule" that "you cannot have a minus under the square root sign" here she has

"applied" that rule even though it is the cube root that is being sought. Notice her use of the word "never". The following example below is one of the TIMSS released items and I include it in the baseline assessment to gain insight into students' understanding of gradient and interpretations of graphs. The conceptual gap in Sophie's subject matter knowledge in this regard is evident from her solution below.

Question 8

Kelly went for a drive in her car. During the drive a cat ran in front of the car. Kelly slammed on brakes and missed the cat. Slightly shaken, Kelly decided to return home by a shorter route. The graph below is a record of the car's speed during the drive.

Kelly's drive
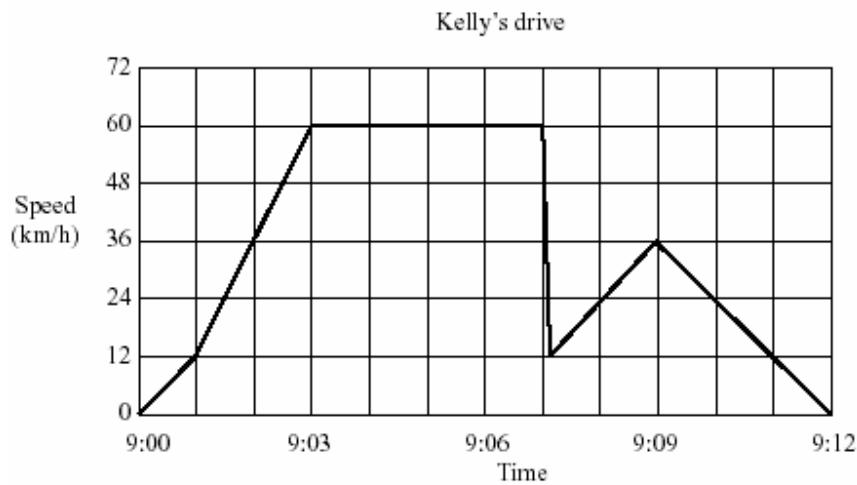
a)   *What time was it when Kelly slammed on the brakes to avoid the cat?*   (1)

a)   *Explain what you think was happening between 9:03 and 9:07*
       according to the graph.   (2)

       [3]
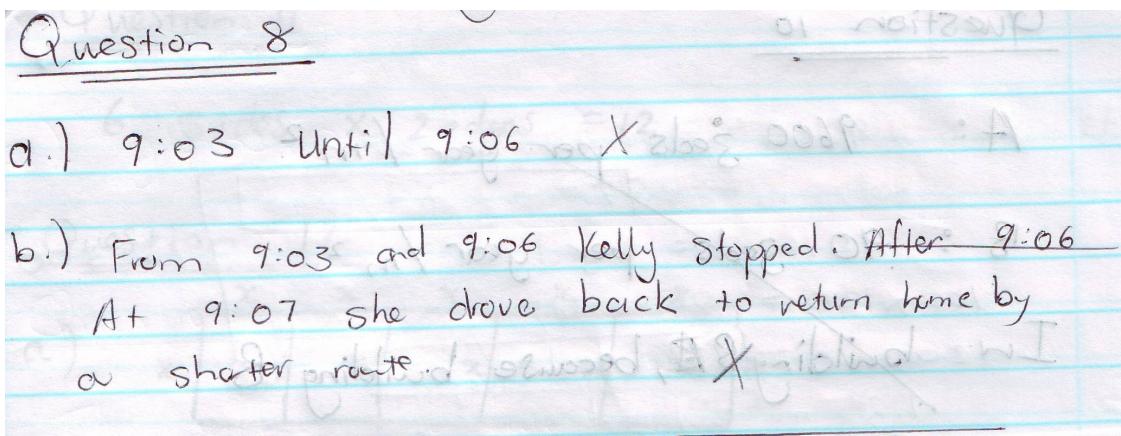
Figure 5.5 Second example of a fundamental error by Sophie

Figure 5.6 Third example of a fundamental error by Sophie

The error above is a common error that learners also make, mostly because they are applying an exponential law without understanding it. It can be argued that this was a careless error, but in the context of other similar errors, I would still classify this as a fundamental error which revealed further fundamental conceptual gaps in Sophie's subject matter knowledge.

As the lecturer of the mathematics specialisation module, I always have an individual meeting with each student concerning the results of their baseline tests. During the meeting with Sophie, I was honest with her about my concerns regarding the number of conceptual gaps in her subject matter knowledge of mathematics, especially in relation to her choice to teach at the FET phase. I indicated to her that she would have to work very hard at improving her own subject matter knowledge during the course of the year as this would impact heavily on her pedagogical content knowledge and the progress she would be required to demonstrate. On

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more than one occasion I suggested and tried to encourage her to rather teach in the Senior Phase where I thought she would cope better with the level of mathematics. But she insisted that she wanted to stay in the FET phase for her PGCE year although she may consider teaching in the Senior Phase once she had qualified. I could not prevent her from continuing in the FET phase as she satisfied the necessary regulations. The PGCE regulations require a student to have mathematics on a third year level in their degree in order to teach in the FET phase. Sophie completed a general BA degree but did her mathematics on the education campus where she completed the third year level of mathematics.

Sophie's reflections mostly focused on discipline, general engagement issues with the learners, getting her learning task design "correct" according to the requirements of the course and issues relating to her position in the classroom as she experienced it. Her reflections tended to be mostly emotive, and she seemed to struggle to be self critical of her actions. She readily provided extrinsic factors as reasons for her lesson or any element thereof not working out. I could not find any examples where she reflects on the mathematics, her beliefs or her approach to the teaching and learning of mathematics. The mathematical processes elicited from her learners through her learning task designs can mostly be classified according to level 1 of Mason's levels (1989). This includes doing specific calculations, functioning with practical apparatus and recalling specific aspects of a topic and specific technical terms.

The course of Sophie's pedagogical content knowledge is an interesting mapping. There were initially many general as well as subject-related pedagogical issues to deal with as the comments from her first assessment report (written by my colleague after observing a Grade 9 class) indicate.

> *Your voice is not clear and you are not always audible. Focus on pronouncing every word clearly. You are speaking too fast. Focus on speaking slower. If you start pronouncing every word clearly, it will slow you down. (25 April 2008)*

> *Maintain eye contact with the class while you are writing on the blackboard. Turn to the class often and never face the blackboard directly with your back to the learners. (25 April 2008)*

It is a good habit to give learners an opportunity to solve problems in class. Do not, however, become so involved with one learner that you isolate yourself from the rest of the class. While you were attending to one learner, the other learners had nothing to do. If you do need to pay individual attention to a learner, ensure that the other learners have work to do. (25 April 2008)

Questions per se do not elicit higher order thinking. There were two expressions: $a^2 - a$ and $a^2 - 1$. When referring to $a^2 - a$, you asked the learners "What is the highest common factor?". When referring to $a^2 - 1$, you asked the learners "How do we factorise this?" You literally gave them the solutions. They need to develop strategies, e.g. (a) look at how many terms are in the expression, (b) look at the highest exponent in the expression, (c) look at whether terms are positive or negative, (d) look for a common factor, etc. Even the terms in a quadratic trinomial can have a common factor. (25 April 2008)

Give learners an opportunity to experiment and to make mistakes. Let them do all these incorrect things they are uncertain of. Then ask them to substitute simple values like 1 or 2 into the expressions and ask them to test their answers. (25 April 2008)

The next learning task design that Sophie requested to be assessed was attended by both my colleague and I. The lesson was for a Grade 10 mathematical literacy class relating to representation of data. The nature of the content was such that it lent itself very well to an authentic context. Sophie made effective use of this opportunity and designed a creative problem with which the learners could identify (relating to their personal problems). This lesson engaged the learners far more than the previous lesson. However, my colleague and I still commented on a number of pedagogical issues that needed attention.

This was a lovely idea for a task. It is relevant to this age group and is a good example of cross-curriculum design (for example with Life Skills). Well done! The lesson was predominantly learner-centred and this is commendable. (7 May 2008)

In reflecting on your practice-theory, consider the value of an explanation from you versus self-discovery on their part. Although self-discovery is not always possible, or practical, it can be practsced in the mathematics classroom far more than it is. It does not mean that the learners are left alone to

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discover everything, but that you guide them to an understanding through various questions and prompts – called scaffolding. Scaffolding would be a good term for you to read up on in the literature (theory) on mathematics education, and to try out in your own practice in order to feed into your practice-theory. (7 May 2008)

Allow for and encourage different approaches to solving a problem. It is not necessary to first determine the percentages for each category. One can determine the angles at the centre of the pie chart circle by using the ratios from the frequency tables. The percentages can then be determined from the magnitudes of the angles. (7 May 2008)

While you are designing a learning task, you should take care to solve the problem in as many ways as possible and "reflect" in anticipation on how the learning period could develop. Not only will that enable you to develop a set of appropriate questions to use during learning task execution/learning task feedback, but you will also recognize possible errors in the written presentation. (7 May 2008)

Ensure that learners understand what they are doing. To learn recipes/methods/algorithms without understanding them does not help learners. In finding an angle at the circle centre, the one learner got confused and thought it to be x 100 ÷ 3,6 instead of ÷ 100 x 360, or x 3,6 as they probably learned the algorithm. She got confused between writing a ratio as a percentage and finding the percentage of something. When learners understand what they are doing, one can even encourage them to deduce quicker ways of calculating values, but they need to discover these themselves. The same group got an answer of 648º for one of the angles at the circle centre. (7 May 2008)

Sophie continued to teach mainly mathematical literacy classes and the comments above are representative of the rest of the assessment reports that were sent to Sophie during her first and second school-based experiences. Her ideas were usually relevant and creative. However, there often seemed to be an issue with either the memorandum or the written presentation of the problem given to the learners. I continually encouraged her to get her learning tasks checked by ourselves, her mentor or a colleague. We also consistently tried to motivate the

need to get learners to be more reflective and independent in their thinking. Examples from further assessment reports are included below.

To call learners to the blackboard to solve problems can be an excellent learning opportunity, provided that they share their thinking with the rest of the class. A learner, who merely writes down a solution, does not necessarily contribute to better learning quality. (28 May 2008)

You cannot risk not being excellently prepared and not being able to solve the problems yourself. The serious mistakes you made in the memorandum you set up are of great concern to me. (25 May 2008)

Give learners, who make mistakes, an opportunity to explain their thinking. This can elicit contributions from the rest of the class. You lose valuable learning opportunities when you wipe such attempts out and ask for another learner to come to the front. (28 May 2008)

This was an "oulike" [lovely] idea and I can see that you had prepared well for the lesson. It was a good idea to use "google earth" for the map. This is relevant and applicable. (18 August 2008)

I would like to have seen a learning product emerging from the lesson. While it is good to use rubrics, I would like to have seen a product (such as a journal entry) being required from the learners – and the quality of this being assessed by a rubric. Without a learning product it is hard to know that learning has taken place and that your outcome(s) have been achieved. Please try to address this in the next lesson. (18 August 2008)

This was a nice task you designed – a good exercise to make them aware of the cost of living. Using the newspapers was an excellent idea. (9 September 2008)

Consider the effects of a pedagogy where you give instructions to the learners and then read through these with them. This does not encourage independent learning. I suggest you rather give them the instructions and five minutes to read through them on their own and then allow time for questions. (9 September 2008)

You please need to still work on getting a colleague/mentor to check the tasks you set to ensure that they are clear. For example, in this task, you wrote: "Sê vir my watter vertrekke jy wil hê" [Tell me which rooms you want…]. But actually you wanted them to draw the rooms. Clear instructions and a well-defined rubric will really help to ensure learners become more independent learners. (9 September 2008)

My experience and assessments of Sophie's mathematics lessons led me to the opinion that she viewed her role as the teacher (or facilitator) mainly in terms of organisation, discipline, motivating learners and being a role-model. Her conceptions of mathematics as they evolved out of her learning task designs and approach to her lessons appeared to indicate that she continually viewed mathematics in a very rigid and rule-bound manner. Even when she presented the learners with a "real-life" problem, her reasons for why they were doing the work were:

"You are writing a test about this next Tuesday and you must experience the practical part of that."

"I can't help you because in the future and in your tests I also cannot help you and you need to experience this assignment personally so that you will learn from it."

"Those of you who want to become architects, engineers, builders, contractors, pilots or regional planners will use this one day."

"If you don't do it right now, you will not know what the surprise reward was."

"If you don't do this now, you will struggle in your test."

In my opinion, Sophie tried to follow the guidelines of the PGCE course in her learning task designs, but she never really understood or took hold of the constructivist approach. I could also not find evidence in her final portfolio of explicit beliefs she expressed on how to approach the teaching and learning of mathematics specifically. From the data I have on her and from the assessment reports, my opinion is that although she initially did not require any active participation and communication from the learners, she later began to ask low level questions of the learners in response to their questions. However, the intended outcome remained skill mastery with correct performance.

5.7.2 Instructional behaviour narrative

The instructional behaviour Sophie demonstrated during her whole first school-based experienced was very traditional. She would give the learners calculations to complete and then go through the solutions step by step with an expository explanation. Her explanation would usually proceed something along these lines: "So first you look for a common denominator. Then you take out the minus. The next step is to see if you can factorise further." One of her video-recorded lessons showed Sophie calling a learner up to the board to complete the answer to one of the "warm-up test" questions on the board. The learner endured a lot of jeering and mocking from his classmates who laughed at him while he did the calculation. Sophie did not make any attempt to intervene other than to tell the learners to be quiet and to check if his answer was correct. She then went through the learner's calculation step for step and failed to pick up an error. Various learners started shouting at her that there was still an error and she eventually invited a learner to come to the board to show her where it was. It was just a careless error in the final answer where the boy who originally did the calculation omitted a b^2.

Sophie then asked the class for the answers to the remaining six calculations and wrote them on the board herself owing to a lack of time. On completing the answer to question 4, one of the learners pointed out that the answer to question 3 ($a^8 - 1$) could still be factorised further as it was a difference of two squares. Sophie revisited question 3 and as the answer she wrote on the board was ($a^4 - 1$)($a^4 + 1$), it could actually be factorised again more than once to yield a final answer of ($a - 1$)($a + 1$)($a^2 + 1$)($a^4 + 1$)($a^8 + 1$). The point of this illustration above is to demonstrate an example of where Sophie seems to not to have engaged with the mathematics herself by evaluating the solutions from the learners. She never referred to any piece of paper or book to check on the answers and appeared to rely on and trust the learners for the correct answers. The answers and mastering of content were definitely her priority during this first school-based experienced but the conceptual gaps in her own subject matter knowledge seemed to be a disadvantage in assisting her with this. However, Sophie also elected to complete her first school-based experience at an English school while her first language is Afrikaans. This also seemed to make her less confident and less comfortable in front of the learners.

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During her second school-based experience Sophie began to show an ability to design more contextual learning tasks that attempted to engage the learners. However, mathematical reasoning was only required in one of these tasks where learners had to work out a distance between two points (using scale) on a google earth map of their school. Mostly the context seemed to dominate and the mathematics included was almost incidental at the end. For example, in one observed Grade 10 mathematical literacy lesson, the mathematical outcome was that learners learn how financial loans work. To achieve this outcome Sophie prepared a task where learners first individually had to draw a basic geometric design of a house (not to scale) for themselves and then get into groups and construct a big house for the whole group. Learners then had to calculate how much money they needed in order to build this house and what sort of loan they would need to apply for. The chosen context of drawing the houses took most of the time on this learning task, with the financial mathematics being a by-product at the end. The tasks can therefore not be classified as predominantly discovery type problems or ones that required higher levels of mathematical reasoning, exploration or modelling.

Sophie did make use of group work and mostly allowed the learners to select their own groups to work in. Something that stands out in all of her observed and video-recorded lessons is how she interacted with the groups and individuals while they were working on a task. She would usually stand in front of the class watching them work and responding to more social discussions, unless a learner called her over to ask a question. While communicating with one learner, she almost always re-directed her attention from the learner to another member or members of the class on a disciplining issue. Then she would turn back to the learner and usually tell them to just write down what they thought they should do. There were a few occasions where Sophie asked a learner a question in response to a question the learner posed. These were mainly very low level questions such as, "What is the formula for the area of a circle?" or "What is the value of the radius?" Sophie's listening remained strictly evaluative throughout the year and with the exception of the learners choosing their own groups, her approach to the learning remained very authoritative.

5.8 Toni

5.8.1 Mathematics profile narrative

Toni's relational mathematics subject matter knowledge was evident throughout the year in his baseline assessment, reflections and the level of mathematics problems he constructed. In designing lessons, Toni managed to engage his learners in a level 5 according to Mason's levels of mathematical processes, which includes describing in general terms how a technique is carried out to account for anomalies, special cases and particular aspects of the technique. An example of this is provided in his reflection in chapter 4 on a lesson for Grade 10 learners on graphs and the functions of certain parameters within the functions. It is also interesting to note Toni's extensive and correct use of mathematics terminology even though English is his second language.

Toni's reflections are self-critical and very much in line with how I experienced him in a teaching role. His continual attempt to methodically analyse each lesson and try to improve is evident from his reflections. A strong desire and attempt to improve his pedagogical content knowledge was also always forthcoming from Toni. But he seemed to continually struggle throughout the year with letting go of his instrumentalist view of mathematics. Initially he also tended to "do and tell" most of the mathematics himself without engaging the learners through higher order questioning or enquiring further about their thinking or errors. These aspects of his pedagogical content knowledge improved throughout the year as the following quotes from assessment reports demonstrate.

> I know you are probably aware that you are still telling too much, rather than getting the learners to think. You need to work more on designing higher-level questions you can ask learners when interacting with them. These can be written down in your planning. (31 July 2008)

> You handled the questions of the learner next to me well. You engaged well with her (and practised self restraint ☺) in answering her questions mostly with further questions. This aspect has certainly improved. (20 August 2008)

You dealt well with the errors in the whole class discussion. You encouraged learners, while still getting

them to explain and extend themselves. (20 August 2008)

Despite his natural tendency to think on his feet and design mathematics problems that encouraged relational understanding, Toni really struggled through the course of the year to make the transition from an absolutist to a more constructivist approach to his teaching. However, towards the end of his second school-based experience he was showing positive signs of competence in this regard. His early attempts to teach in a transcendental paradigm (see Section 3.4.1) found him feeling out of his comfort zone when the lesson did not work out as planned. In these circumstances, he would quickly revert to "taking control" and move to the front of the class where he would start explaining the mathematics.

The idea you had was good and the problems you encountered were probably due to incomplete prior

knowledge and to classroom culture. When you start reading up on something like classroom culture or

views and beliefs on mathematics, you will begin to understand the reactions of the learners as well as

your own. Understanding what happened is important in dealing with it. Do not be discouraged – rather

be pro-active and think of strategies you can apply in order to wean the learners from their dependence

on the educator. (9 May 2008)

When you decided to revert to a more traditional teacher-centred approach, I thought you could have

first asked which learners would liked to have written their solution on the board and explained their

thinking to the rest of the class. (9 May 2008)

Although Toni seemed to have both strong subject matter knowledge and pedagogical content knowledge, it was only in his last few lessons where he really had a breakthrough in managing to teach in a more problem-solving, process-orientated approach. In doing so, he also began to demonstrate his view of mathematics as a static but unified body of certain knowledge. This is in line with Ernest's (1988) Platonist view of mathematics. I have deduced this from his last few reflections where although he learnt to approach the lessons in a more problem-centred, process-orientated approach, the way he still talked about, used and interacted with the actual mathematics appeared to indicate that he still does not view the domain as a dynamic, continually evolving field of human creation, which is more in line with what Ernest (1988)

describes as the problem-solving view of mathematics. I suspect that this could have a lot to do with his background in studying mathematics through an actuarial science degree.

5.8.2 Instructional behaviour narrative

The aspect of Toni's instructional behaviour that caught my attention most in analysing his lessons was how he interacted with the individual learners and groups as they worked on their tasks. From the start of the course Toni demonstrated a passion for the subject of mathematics and this came through in his teaching. He clearly wanted all his learners to share this passion and made a concerted effort to engage with learners about their mathematical thinking and reasoning. He quickly learnt to respond to learners' questions with a further question in order to clarify their thinking. But he also always affirmed the learner for correct thinking or calculations when required. He never rushed from one learner to the next but gave each learner his full attention as he worked individually with them. He was the student that made the quickest transition from evaluative to more interpretive listening.

Toni was also the only other student (along with Marge) who managed to progress to the point of facilitating a few (albeit brief) discussions with the learners that elicited higher level mathematical reasoning. The questions he posed to the learners did not only focus on an answer but required the learners to enter into mathematical reasoning. Even the hints he would give the learners in the scaffolding process were not just a set of small steps that would guide the learners straight to the answer, but rather a suggested comparison in similar reasoning or thinking that would assist them in solving the problem. For example if a learner was asking a question about the effect of a particular parameter within a function he would encourage the learner to compare a few graphs of different functions in order to identify the effect. Most of the other students would simply ask the learner what they remember the role of that parameter to be in the standard form.

During his first school-based experience Toni was very traditional in his approach and displayed a lot of expository teaching. He seemed to be much more comfortable in this role. However, as the year progressed and the demands of the course required him to implement a transcendental lesson, he began to try a more problem-oriented approach. In doing so, Toni's

learning task designs were always of a high standard mathematically and encouraged exploration, the identification of patterns and modelling. The consolidation he did with the whole class on completion of a task was more representative of a reform and investigative approach to mathematical discussions than any of the other participants demonstrated (with the exception of Marge). Toni's instructional behaviour therefore in my opinion made a substantial shift on both the traditional/reform and authoritative/democratic continuums.

5.9 Conclusion

This chapter has presented my reflections on each of the participants in two parts; a reflection about their mathematics profiles and another foregrounding the trends in their instructional behaviour throughout the course of their PGCE year. The main function of these researcher reflections is to give the reader my view of each participant compared to the previous chapter where their own views about their experiences on the teaching and learning of mathematics were shared in their voices. The participant and researcher reflections provide the verbal view of the visual presentations depicted and compared in the following chapter. In chapter 6 each case is discussed individually before the cross-case comparison is presented.

CHAPTER SIX   ANALYSES OF DATA SETS

6.1 Introduction

This chapter draws on the reflections from chapters 4 and 5 in order to construct a visual representation of each participant's mathematics and instructional behaviour profiles. The visual representations were borne out of my need to be able to visualise what the textual reflections "looked like" in order to better facilitate within and cross-case comparisons. The mathematics profile is represented by a facial profile of each individual with parts of the face (such as the eye, the ear, the mouth and the head) each depicting one of the four components of the mathematics profile (subject matter knowledge, pedagogical content knowledge, conceptions of mathematics and beliefs regarding the teaching and learning of mathematics) respectively as identified and discussed in chapter 2. The instructional behaviour profile is presented on a landscape grid. The idea of the landscape grid has been adapted from the mathematical Cartesian plane, but without any intention of displaying values in order to demonstrate measurement. In this landscape the traditional to reform teaching continuum is represented on the horizontal axis and the autocratic to democratic learning continuum is presented on the vertical axis. These visual representations are then used as the basis for the cross-case comparison and discussion also included in this chapter.

6.2 Visual representations of profiles

As the narratives have been presented over two chapters, I wanted to find a way to simplify and optimize the cross-case comparison without continually drawing on quotes from the narratives. My quantitative mathematics background also found me wanting some sort of symbolic representation without getting into actual quantitative measurement, such as graphs or tables. These visual representations are the resulting output. Owing to the confidentiality of the participants that I wished to honour in this study, I could not include photographs of each participant. However, each participant is a person and when I introduced them in chapter 3, I wanted to also present a picture of them. A friend suggested I include caricatures of each participant and this developed into the idea of the visual mathematics profiles that are included

in this chapter. As explained in chapter 2, the word profile indicates a side view of a face. I therefore decided to make the mathematics profile a side view of each participant's 'mathematics' face according to the four components of subject matter knowledge, pedagogical content knowledge, conceptions of mathematics and beliefs regarding the teaching and learning of mathematics.

I have divided each of the components into four categories. I chose an even number of categories to avoid continually picking the "middle" option while still allowing for suitable differentiation between the participants. Each category is depicted by a particular icon on the continuum and the four components were then put together to form the initial and later the final mathematics profile of each participant. Each part of the face and the icons used to represent the categories was chosen with a metaphorical meaning in mind. The categories presented in this report are not intended to be absolute and I am using them for a pre-service context and what our PGCE course requires from the students leaving our programme with the expectation that they will still continually improve as they enter and gain experience in the teaching profession. For example, the fourth pedagogical content knowledge category shows the ear as "full" (see Figure 6.2) indicating more complete pedagogical content knowledge that the first category. However, this does not suggest that the participant's pedagogical content knowledge is totally complete but that it is at a high level in the pre-service context in order for the participant to enter the profession.

The *head* of the face represents the *subject matter knowledge*. Firstly this is due to my assumption that this is the "head" component. Without any knowledge of mathematics one cannot teach the subject. Secondly I view subject matter knowledge as something that one cannot easily see completely. We can see parts of it as the student begins to teach or do mathematical calculations but I do not think research is at a point yet where we can see or evaluate this component completely. In the visual representation, the category on the extreme left in Figure 6.1 below indicates obvious and fundamental conceptual gaps in the participant's subject matter knowledge. In the second category, less fundamental conceptual gaps were evident with some relational coherence of the content. The third category indicates that the subject matter knowledge appeared sufficient with no gaps evident in terms of errors or lack of mathematical understanding observed during the course of the year. The final category on the

right depicts subject matter knowledge that is not only relational but also able to extend into other learning areas where necessary.
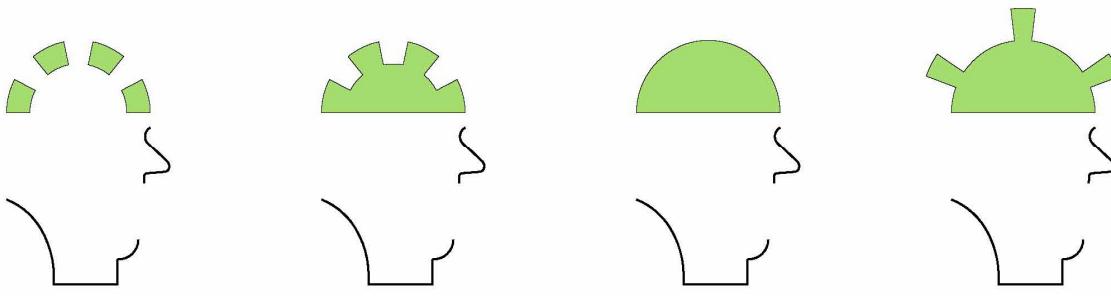
Instrumental   *Relational*

Figure 6.1 The four categories of the subject matter knowledge continuum

The category of subject matter knowledge for each participant was decided on by drawing on data from the baseline assessment the participant completed at the beginning of the year and conceptual gaps stated in the participant's reflections or observed in their lessons or learning task designs. These are summarised in Table 6-1 below. It was not possible to represent any change in the participants' subject matter knowledge as this is not in any way a focus of our PGCE course. As the course does not directly address this subject matter knowledge aspect, and due to the nature of how I chose to represent this component (focusing on the conceptual gaps as an indicator of their mathematical understanding), I viewed this component as more of a constant, rather than changing component of the profile.

Table 6-1 Summary of data analysis for the subject matter category in mathematics profile

Section 2.3.1	Subject matter knowledge
Baseline assessment	Careless or no errors, a few errors or solutions omitted, many errors, fundamental errors
Errors in LTD's	Errors made in calculations in learning task designs
Errors in observed lessons	Errors participant made in lessons observed or recorded

The *ear* depicts the pedagogical content knowledge. Reasons for this include that much of the pedagogical content knowledge of a student teacher is taken in by what they hear in class at university and what they heard at school. A large part of this in their own teaching practice is their ability to hear the learners, their errors, their thinking and where they are at in their thinking. The category on the far left indicates an incomplete pedagogical content knowledge for a pre-service teacher. The categories towards the right of the continuum show varying levels increased pedagogical content knowledge.
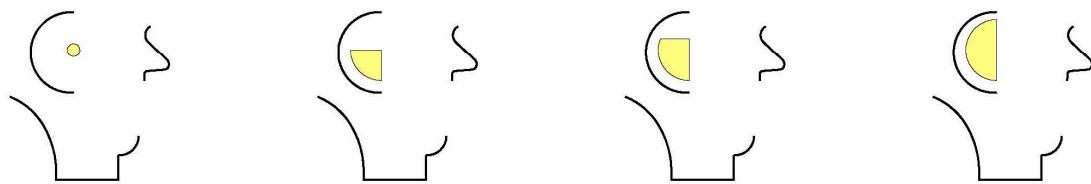
Less complete   **More complete**

Figure 6.2 The four categories of the pedagogical content knowledge continuum

Determining the *pedagogical content knowledge* category of each individual was slightly more complicated. The data I used came from the students' learning task designs, their reflections, assessment reports from the lecturer and observed or video-recorded lessons. As the students taught a range of different grades and mathematical topics during the year, it is only my intention to categorise their general pedagogical content knowledge and not refer at all to their domain or topic specific pedagogical content knowledge (Veal & MaKinster, 2001). The continuum used to determine the categories for this component is taken from Section 2.3.2.

Table 6-2 Summary of data analysis for pedagogical content knowledge category in mathematics profile

Section 2.3.2	Pedagogical content knowledge

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Mason's levels	See Table 2-1
Pedagogy	Participant's handling of learner errors/misconceptions
	Quality of planning
Assessment	Dominantly traditional or more alternative and authentic assessment and various forms thereof
Context	Participants' understanding of context of learners as viewed in LTD's and observed lessons
Curriculum	Knowledge of the curriculum according to LTD's and observed lessons
Classroom management	Issues such as discipline, handling classroom discussion, use of media, classroom culture

The *eye* illustrates each participant's view or conceptions of mathematics (for obvious reasons). The varying shape of the eye in the four categories indicates a movement from seeing mathematics in its absolutist form as a limited, rigid, structured and rule-bound subject on the far left category to a more dynamic, interrelated and continually evolving subject that is more in line with the constructivist/problem-solving view as expressed by Ernest (1991), in the category on the far right.
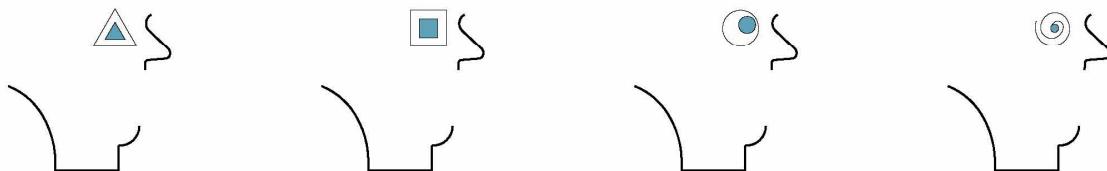
Absolutist   **Constructivist**

Figure 6.3 The four categories of the conceptions of mathematics continuum

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In order to decide on the category of the final two components (conceptions and beliefs), data from the reflections and observed and video-taped lessons of each participant were used. In differentiating between the categories for conceptions, I have drawn on Ernest's (1991) categories and added an additional category of absolutist (seeing the subject as even more limited and rigid than the instrumentalist view) to the conceptions of instrumentalist, Platonist and problem-solving views. These were determined from a summary of information as presented in Table 6-3 below taken from Section 2.3.3.

Table 6-3 Summary of data analysis for the conceptions of mathematics category in mathematics profile

Section 2.3.3	Conceptions of mathematics
Orientation *Thompson (1984)*	Content orientation or process orientation
Orientation *Thompson et al. (1994)*	Computational, calculational or conceptually orientated
Ernest (1991) categories	Absolutist, instrumentalist, Platonist or problem-solving

Finally, the *mouth* represents the beliefs about the teaching and learning of mathematics that each participant verbalised or expressed.

Transmitter   *Facilitator*

Figure 6.4 The four categories of the beliefs about teaching and learning mathematics continuum

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In differentiating between these belief categories, the role of the teacher can be either a transmitter on the far left, instructor, explainer or a facilitator on the far right of the continuum. A transmitter is a device that transmits specific information or signals to "passive receptors" or receivers that receive the signal but do not transmit back. When a transmitter sends out a signal to a transceiver though, the transceiver sends back information. In my view the teacher in the role of the transmitter believes the teacher is an expositor and although they are aware of the learners in the classroom, they talk to them as passive receptors without expecting input. The instructor and the explainer, however, both view the learner as a transceiver that they expect to be more active and communicate with them. The difference though is that the instructor demands a much lower level of input and response from the learner than the explainer, who tends to require responses that demonstrate understanding. Finally, the facilitator has the fuller, closed lips indicating that, similar to the explainer, they also expect learners to communicate their understanding and in my view, they see learners not only as transceivers but as decoders. Facilitators therefore tend to continually demand more high-level mathematical reasoning and facilitate discussions that elicit this. In such cases, the learners are supported to do more of the thinking and construction of knowledge with the facilitator guiding the process (hence the closed mouth in the visual representation). Table 6-4 below summarises the information used in determining each participant's category.

Table 6-4 Summary of data analysis for the beliefs category in mathematics profile

Section 2.3.4	*Beliefs regarding the teaching and learning of mathematics*
Role of teacher *(Ernest, 1988)*	Transmitter, instructor, explainer, facilitator
Role of learner *(Ernest, 1988)*	How the participant arranged learning experiences for the learners on a passive reception to active construction continuum

The instructional belief profiles were decided on using the reflections pertaining to instructional behaviour from chapters 4 and 5 and the video-recorded lessons participants included in their portfolios. Similarly to the approach applied above, each of the traditional/reform and authoritarian/democratic learning continuums (each forming an axis of the landscape grid in Figure 6.5) was divided into four equal divisions. However, these are not differentiated into categories, but rather form four smaller sub-quadrants in each of the four main quadrants of the grid. I have purposefully avoided using numbers on the landscape grid so that this remains a representation of their changing instructional behaviour, as I see it, without attaching a value or measurement to it. An initial and final quadrant for each participant was derived according to their position on each of the traditional/reform teaching and autocratic/democratic learning continuums, drawing on the criteria illustrated in Table 6.5 below.
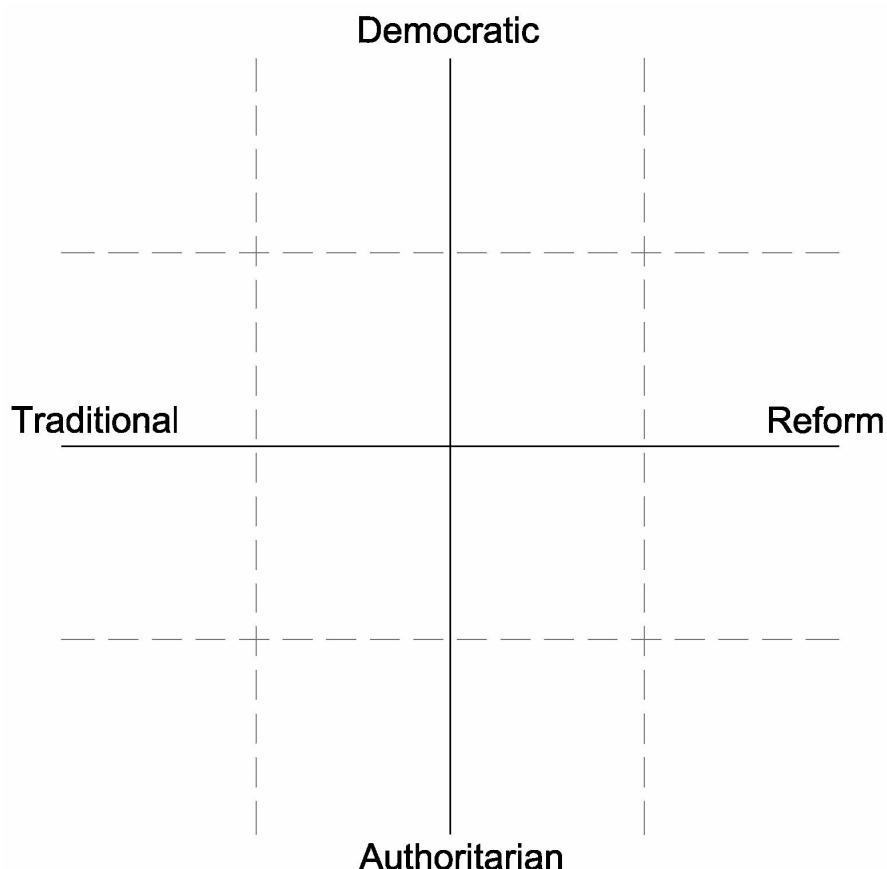
Figure 6.5 An example of the Cartesian plane depicting the instructional behaviour profile

Table 6-5 Summary of instructional behaviour landscape grid criteria

Democratic

Values content *Expository methods* *Algorithms focus* Informal methods encouraged and used Individual, collaborative and cooperative group work Heuristic listening	*Hands on discovery* *Finding patterns* *Methods important* Informal methods encouraged and used Individual, collaborative and cooperative group work Heuristic listening	*Making connections* *Exploration* *Problem solving* *Modelling* Informal methods encouraged and used Individual, collaborative and cooperative group work Heuristic listening	*Mathematical communication* *High level reasoning* Informal methods encouraged and used Individual, collaborative and cooperative group work Heuristic listening
Values content *Expository methods* *Algorithms focus* Cooperative group work Informal methods explicitly encouraged Dominantly interpretive	*Hands on discovery* *Finding patterns* *Methods important* Cooperative group work Informal methods explicitly encouraged Dominantly interpretive	*Making connections* *Exploration* *Problem solving* *Modelling* Cooperative group work Informal methods explicitly encouraged Dominantly interpretive	*Mathematical communication* *High level reasoning* Cooperative group work Informal methods explicitly encouraged Dominantly interpretive
Traditional *Values content* *Expository methods* *Algorithms focus* Less focus on steps Some group work Some informal learner methods but mostly still formal Some interpretive listening	*Hands on discovery* *Finding patterns* *Methods important* Less focus on steps Some collaborative group work Some informal learner methods Some interpretive listening	*Making connections* *Exploration* *Problem solving* *Modelling* Less focus on steps Some collaborative group work Some informal learner methods Some interpretive	**Reform** *Mathematical communication* *High level reasoning* Less focus on steps Some collaborative group work Some informal learner methods Some interpretive listening
Values content *Expository methods* *Algorithms focus* *Mostly individual* Official steps taught Formal algorithms Individual work Use of examples Evaluative listening	*Hands on discovery* *Use of groupwork* *Finding patterns* *Methods important* Official steps taught Formal algorithms Individual work Use of examples Evaluative listening	*Making connections* *Exploration* *Problem solving* *Modelling* Official steps taught Formal algorithms Individual work Use of examples Evaluative listening	*Mathematical communication* *High level reasoning* Official steps taught Formal algorithms Individual work Use of examples Evaluative listening

Authoritarian

The placing of each participant's initial and final instructional behaviour profile (to indicate the change that took place over the year) was determined by deductively analysing their teaching practice according to the following guidelines from the literature (see section 2.3.5).

Table 6-6 Summary of data analysis to determine the position of traditional/reform continuum of instructional behaviour profile

Section 2.3.5	Traditional versus reform practices
Values	Traditional – values content, correctness of learners' responses and mathematical validity of methods
	Reform – values finding patterns, making connections, communicating mathematically and problem-solving
Teaching methods	Traditional – expository, transmission, lots of drill and practice, step by step mastery of algorithms
	Reform – hands-on guided discovery methods, exploration, modelling. High level reasoning processes are central
Grouping learners	Traditional dominantly homogenous
	Reform dominantly heterogeneous

Table 6-7 Summary of data analysis to determine the position of authoritarian/democratic continuum of instructional behaviour profile

Section 2.3.5	Authority versus democracy
Algorithms/techniques	Official methods taught versus learners' methods

	encouraged. Intentionally differentiating between horizontal (informal learner methods) and vertical (more formal algorithms) mathematisation
Learner relations	Encourages individual competition or collaborative group work
Teaching style	Expository class teaching or also use of projects, group and invidualised work
Listening	Evaluative, interpretive or heuristic

The rest of this section shows a summary of the profiles of each participant based on a data analysis using the criteria shown in Tables 6-1 - 6-7. A verbal summary is provided, rather than the tables, but the actual tables can be found in Appendix F. A visual representation of each participant's mathematics and instructional behaviour profiles is then depicted: the initial one determined at the beginning of the year and the final one as displayed towards the end of the year. It is anticipated that these visual representations will highlight the changes that took place in participants during the course of the year and also facilitate the cross-case discussion in the section that follows.

6.2.1 Marge

Marge displayed strong subject matter knowledge throughout the year. She was able to draw on this to effectively design learning tasks of a high mathematical standard and ask questions that elicited a high level of thinking from the learners.

Instrumental   *Relational*
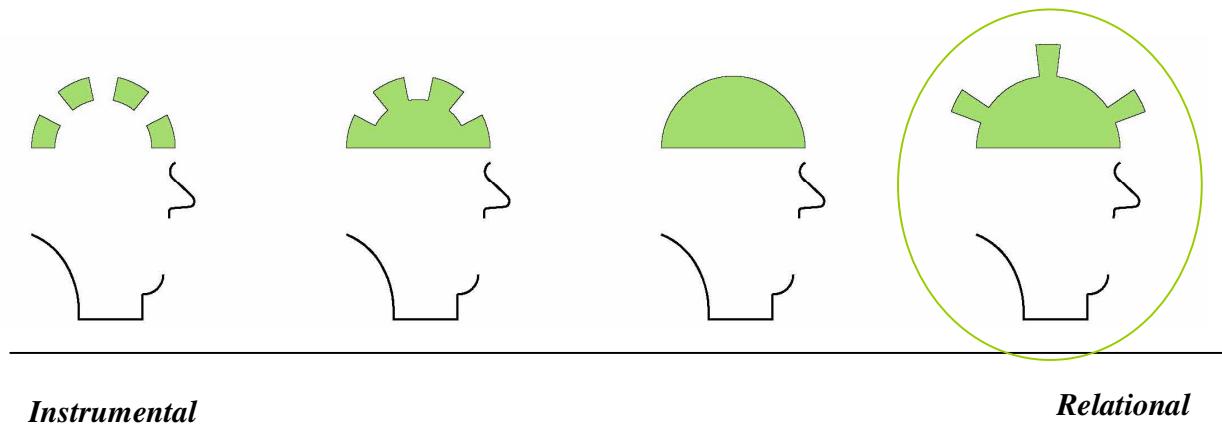
Figure 6.6 Visual representation of Marge's subject matter knowledge

Marge was the only student to progress to the 'more complete' category in terms of her pedagogical content knowledge. The main characteristic that finally put her into the more complete category was her ability and intent to explore learners' thinking, whether or not the answer was correct. Towards the end of the year, Marge appeared to understand how useful learners' errors and alternative conceptions could be, not only to her but as discussion points for the class in the construction of their mathematical thinking and reasoning.

Less complete   *More complete*
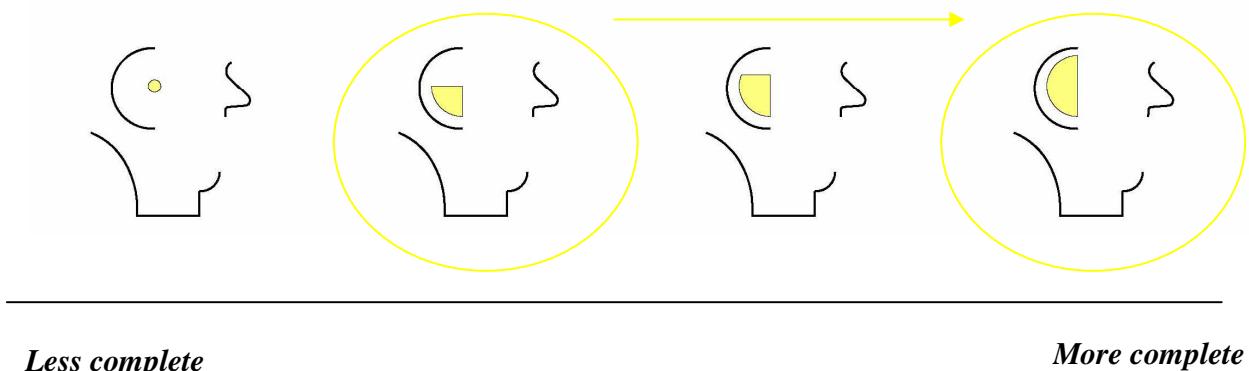
Figure 6.7 Visual representation of Marge's pedagogical content knowledge

Marge was also the only student whose conception of mathematics changed to a problem-solving view. By her own admission, she began the year with an instrumentalist view where she valued and foregrounded the structure, rules and algorithms. Marge took the challenges of the course very seriously and her perfectionist approach encouraged her to make every effort

to master a more constructivist approach to her teaching. Marge, however, was not satisfied with just mastering the approach superficially. She wanted to understand it and incorporate that understanding into her own practice-theory. She therefore began accessing and reading large volumes of literature relating to mathematics and the teaching thereof. Through this process and her school-based experiences, her reflections and learning task designs began to demonstrate her increased understanding and appreciation of the domain of mathematics and mathematics education. It was the combination of Marge's continued diligence in making positive changes in her view of mathematics as well as her extensive reading that enabled her to adopt the problem-solving view of mathematics.

Absolutist   **Constructivist**
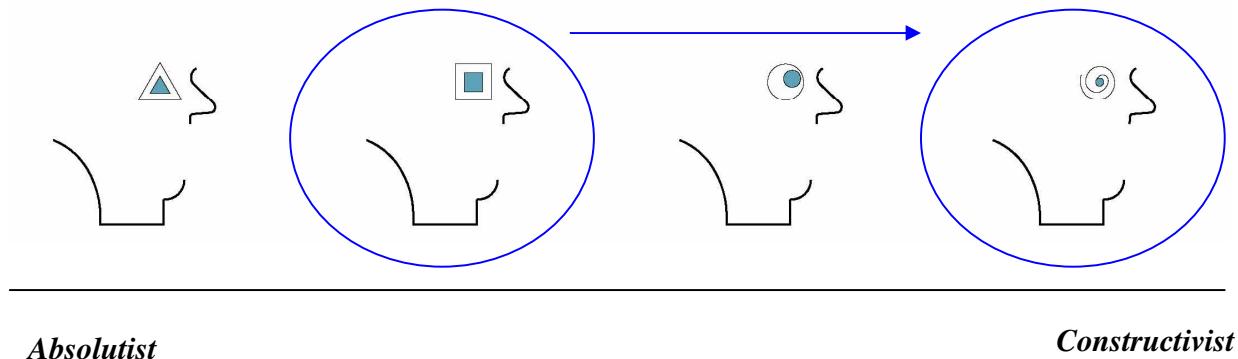
Figure 6.8 Visual representation of Marge's conceptions of mathematics

Marge treated the learners as 'transceivers' right from her first school-based education but initially her questions were limited to more low-level reasoning and fact recall. During the course of the year, she began to incorporate into her lesson plans the type of questions she planned to ask learners. This seemed to improve the level of questioning and required answers from the learners that demonstrated their mathematical understanding. Marge's final profile shows her as an explainer (rather than facilitator) as she did not demonstrate the ability to facilitate mathematical discussions on a continuous basis that required the learners to do most of the talking and use high-level reasoning and thinking.

Transmitter   Facilitator
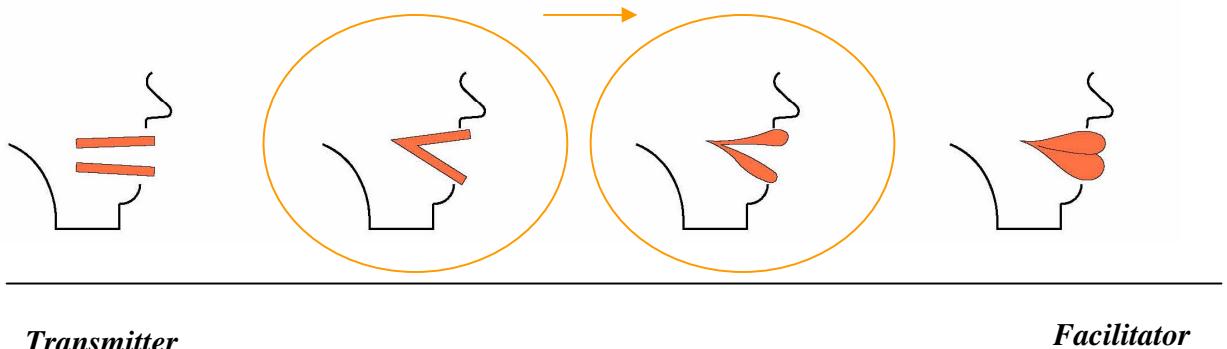
Figure 6.9 Visual representation of Marge's beliefs about the teaching and learning of mathematics

However, Marge's instructional behaviour changed significantly during the course of the year. As she began to take on the challenge of a more constructivist and problem-solving approach to the teaching and learning of mathematics, the design of her learning tasks began to change. She enjoyed setting problems that engaged the learners and began making more use of hands-on discovery, identification of patterns and modelling. As already indicated, high-level reasoning became more valued in her practice but not to the extent where it was being required often enough or with enough heuristic listening on Marge's part. It was clear that she was still always in control of the lesson and the class, rather than this being a negotiation and sharing of thinking between learner and facilitator. This is the reason her instructional behaviour profile made changes on both continuums but not to the optimal reform and democracy quadrants.
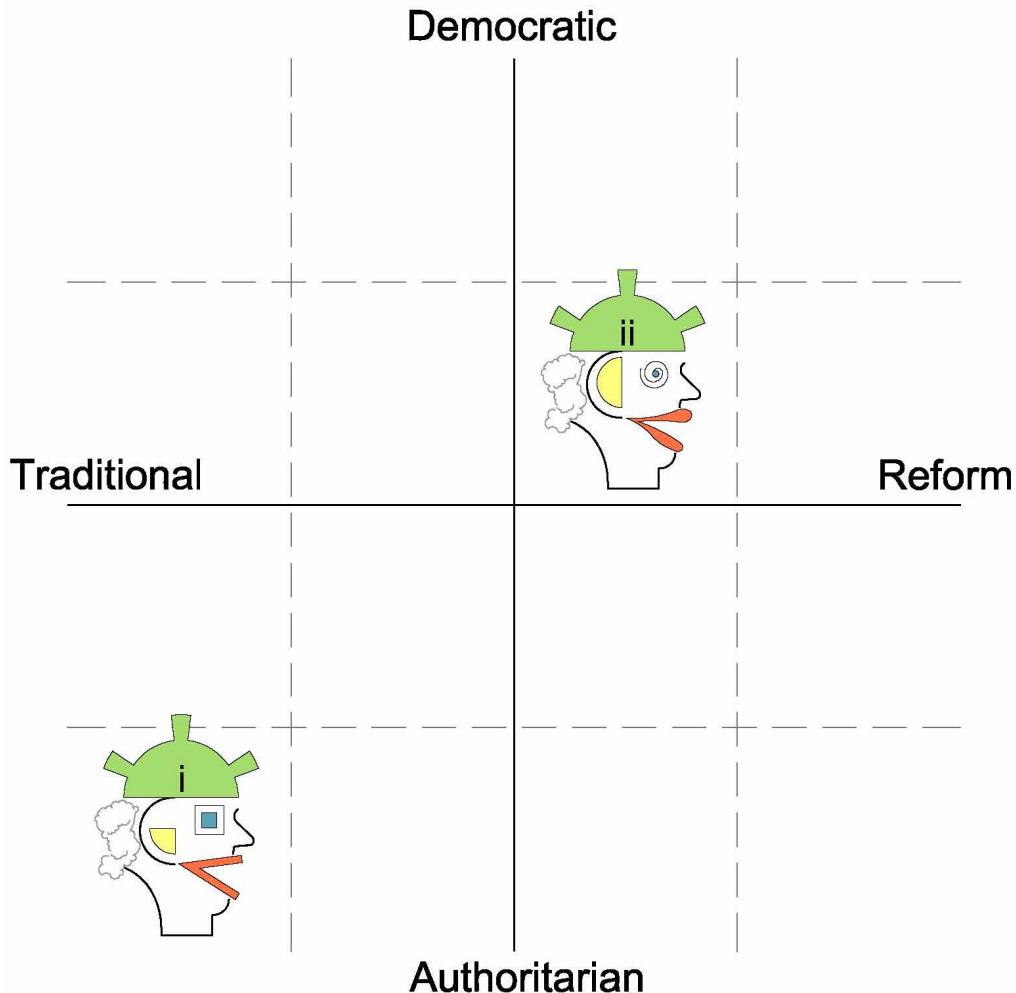
Figure 6.10 Mathematics and instructional behaviour profile changes of Marge from initial (i) to final (ii)

In her final mathematics profile, Marge demonstrates a well-rounded view of mathematics and the teaching thereof. On the solid foundation of her strong relational subject matter knowledge, her pedagogical content knowledge also improved. Marge's conceptions of mathematics changed from instrumentalist to problem-solving and from instructor to explainer. The changes in her instructional behaviour were also evident in the shift she made towards a more reform dominated practice tending towards more democracy in her classroom culture.

6.2.2 Lena

Lena showed no fundamental gaps in her subject matter knowledge throughout the year. She was able to draw on this effectively to design learning tasks of a high mathematical standard and teach Grade 12 learners with confidence right from the beginning of the year. However, her learning task designs and the lessons analysed did not show the depth of relational understanding that both Marge and Toni demonstrated.

Instrumental   **Relational**
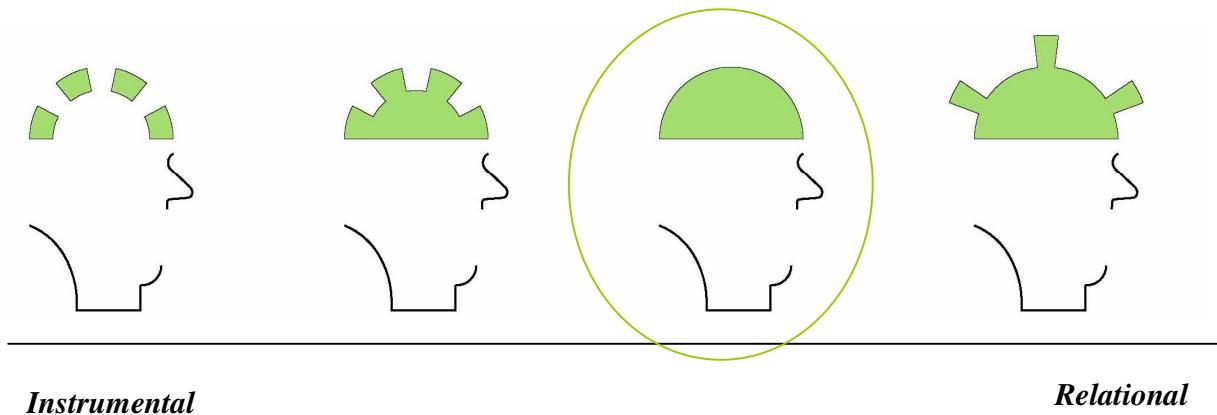
Figure 6.11 Visual representation of Lena's subject matter knowledge

Lena designed creative and well-thought-out learning task designs. She demonstrated some understanding of the learners' context in terms of designing problems in authentic contexts. Her knowledge of the curriculum was excellent and her classroom management was good throughout the year. However, Lena did not reach the point of investigating or valuing learners' errors and the learners' thinking behind these.

Less complete   **More complete**
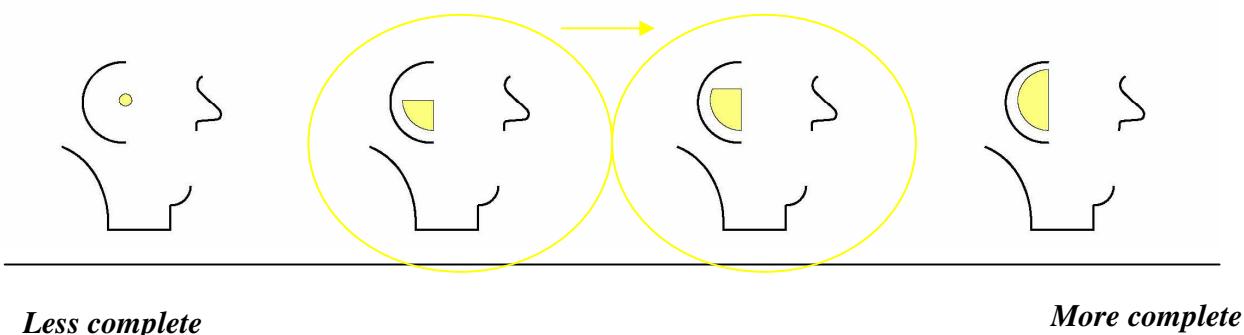
Figure 6.12 Visual representation of Lena's pedagogical content knowledge

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Lena's view of mathematics seemed to remain constant throughout the year. Although her teaching became more process-orientated, knowing and correctly applying the rules and algorithms appeared to remain her focus.

Absolutist   *Constructivist*
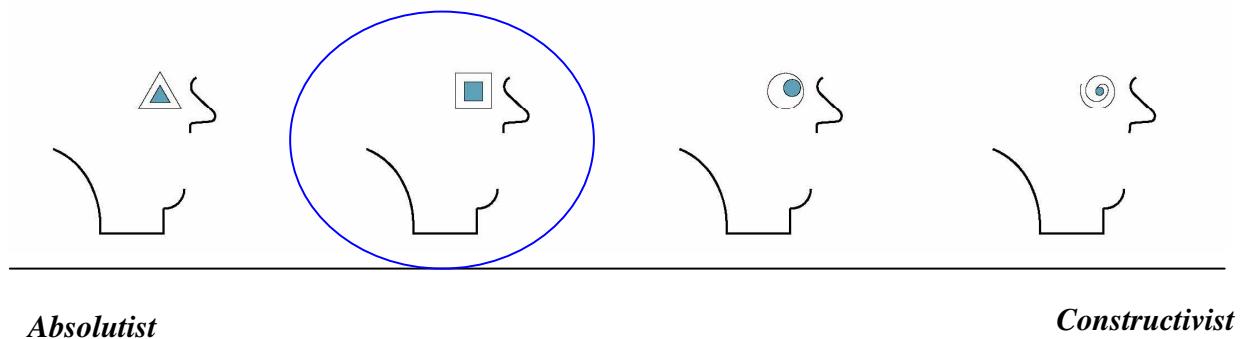
Figure 6.13 Visual representation of Lena's conceptions of mathematics

Initially Lena seemed to teach without requiring any response or communication from the learners. She made repeated use of teacher pauses (see Section 5.3.2) where she appeared to require a response from the learners, but would very rapidly provide the answer herself and continue with her explanation. Later Lena started to give slightly longer pauses and more opportunities for learners to respond, although her questions seldom elicited high-level mathematical reasoning from the learners.

Transmitter   *Facilitator*
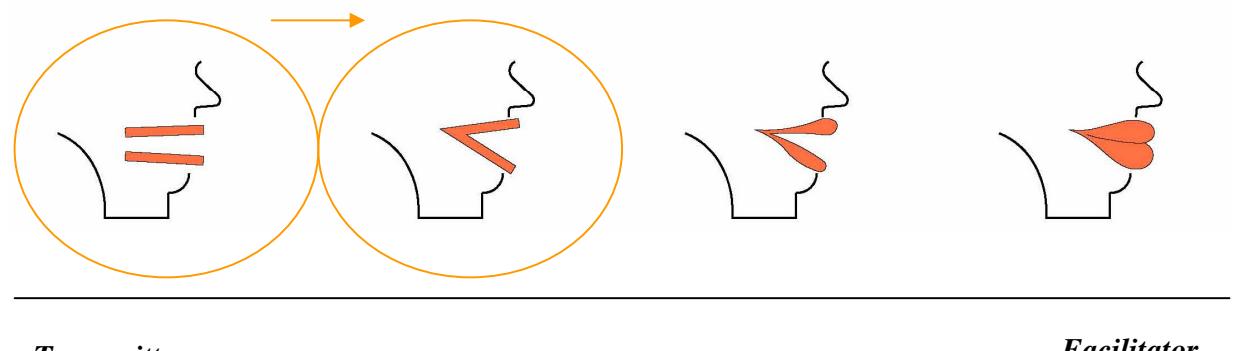
Figure 6.14 Visual representation of Lena's beliefs about the teaching and learning of mathematics

Lena's instructional behaviour made a slight shift on each of the continuums during the course of the year. Although mastering of content remained her focus, her learning task designs and one of her lessons indicated her intent to move towards improving the conceptual understanding of learners. She designed problems that required more hands-on involvement from the learners and aimed at getting them to identify patterns. However, the learners were seldom asked to communicate their thinking or reasoning as feedback and discussion during the class. Lena developed good relations with the learners, used a variety of individual and group work and her lessons became more learner-centred and task-based.
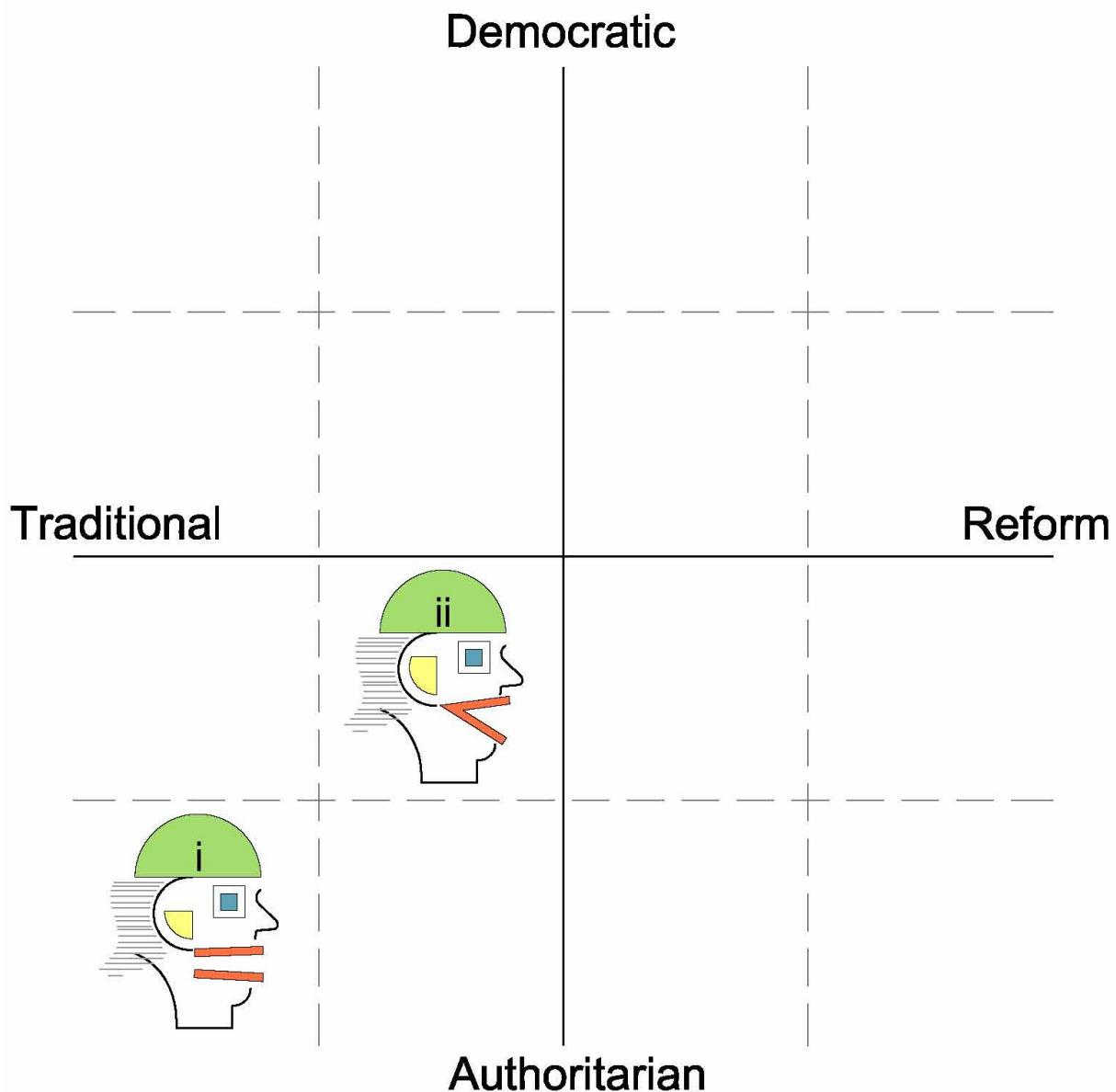
Figure 6.15 Mathematics and instructional behaviour profile changes of Lena from initial (i) to final (ii)

The changes that took place in Lena's mathematics profile are limited to her pedagogical content knowledge and her beliefs in the teaching and learning of mathematics. Both of these moved up one category. Her instructional behaviour profile also moved one sub-quadrant on each of the continuums.

6.2.3 Peta

As already indicated in chapter 5, Peta demonstrated a number of conceptual gaps in her subject matter knowledge throughout the course of the year. She made some fundamental errors in the baseline assessment and various errors were observed during her lessons.

Instrumental   *Relational*
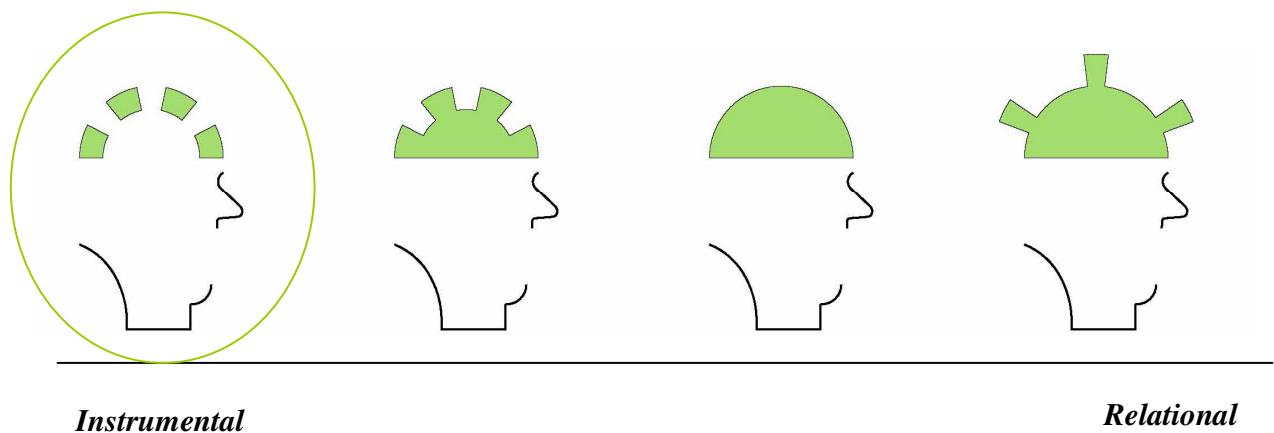
Figure 6.16 Visual representation of Peta's subject matter knowledge

Peta relied heavily on support from the lecturers in designing her learning tasks, but the quality of these learning tasks did improve significantly over the course of the year. She appeared to work more effectively with learners in lower grades and began posing questions in response to learners' questions as the year progressed and she gained more confidence. Peta did not investigate incorrect answers or thinking of learners although she did move towards designing lessons that were more learner-centred towards the end of the year. Her pedagogical content knowledge is therefore depicted as changing from the first to the second (more complete) category.

Less complete   **More complete**
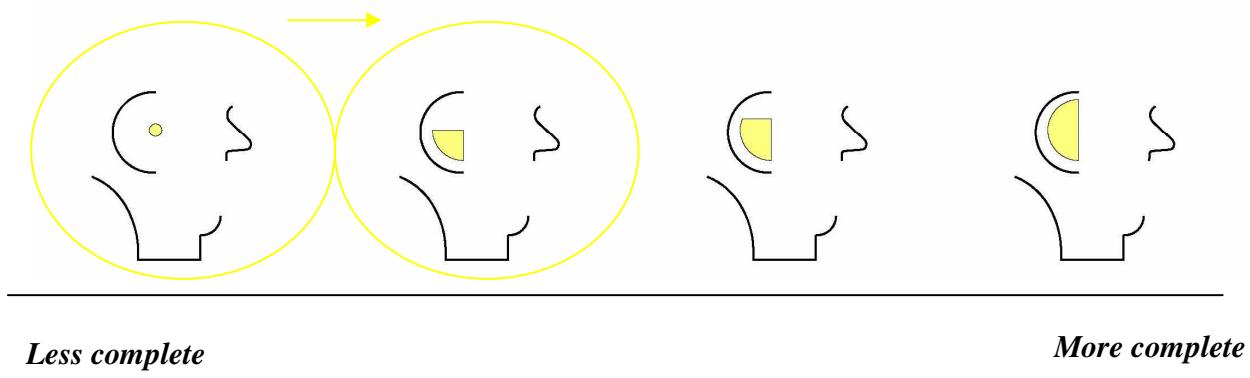
Figure 6.17 Visual representation of Peta's pedagogical content knowledge

From the beginning of the year Peta dealt with mathematics as a very rigid, structured and absolute (in terms of right or wrong) approach. Her focus remained content-orientated with an emphasis on using the correct methods and formulae and finding the correct answer. It was therefore not easy to find any evidence of a shift in this view of mathematics.

Absolutist   **Constructivist**
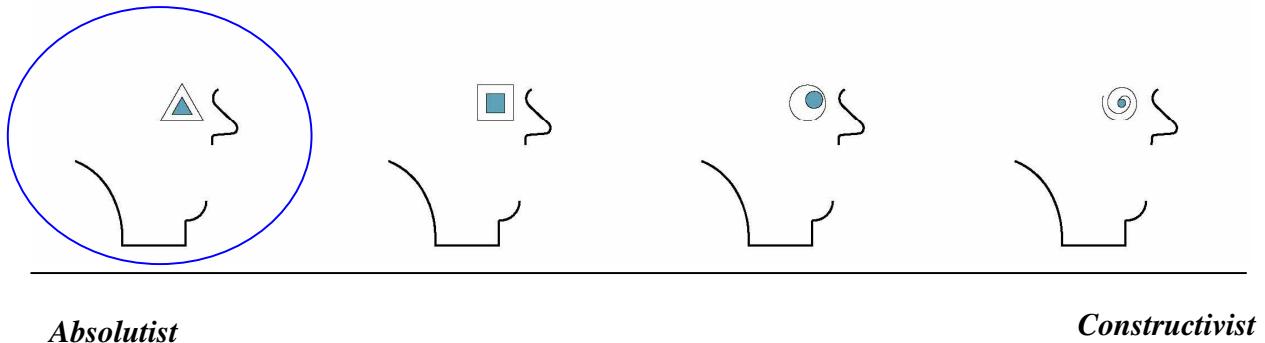
Figure 6.18 Visual representation of Peta's conceptions of mathematics

Peta initially seemed to teach without requiring any response or communication from the learners. This could perhaps have been due to the lack of confidence that she mentions in her own reflections. During the second school-based experience Peta began to provide more opportunities for learners to respond, although her questions mostly focused on computational solutions or recall rather than on mathematical thinking or processes.

Transmitter   **Facilitator**
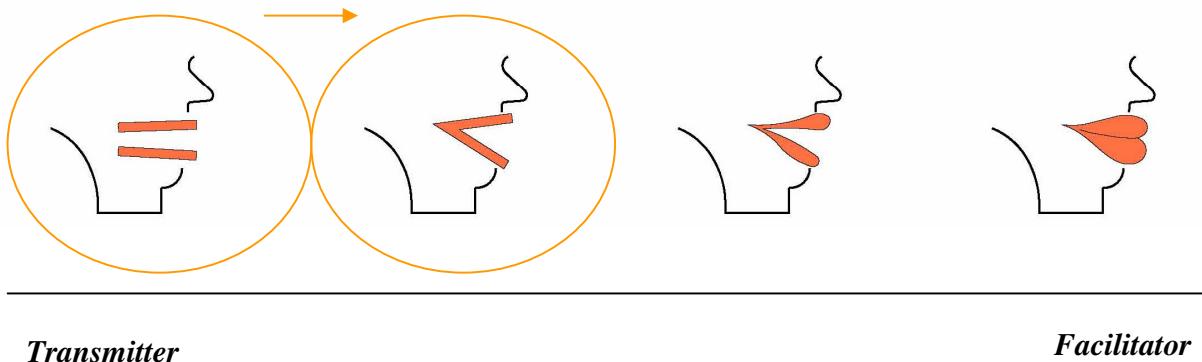
Figure 6.19 Visual representation of Peta's beliefs about the teaching and learning of mathematics

Peta's instructional behaviour made a slight shift up on the authoritarian/democratic continuum during the course of the year. This shift is indicated due to the more learner-centred and problem-solving approach she was able to implement later in the year that afforded the learners more active construction of knowledge, albeit at a low level. Although these learning tasks required more hands-on discovery from the learners, mastering of content remained her focus. Discussions encouraging feedback and investigating learners' thinking were not observed and questions posed did not elicit high-level reasoning, pattern identification or any of the other approaches to the teaching and learning of mathematics that would indicate a positive shift towards more reform type teaching.

Figure 6.20   Mathematics and instructional behaviour profile changes of Peta from initial (i) to final (ii)

The changes that took place in Peta's mathematics profile were within her pedagogical content knowledge and her beliefs in the roles of teaching and learning of mathematics. Both of these moved up one category. Her instructional behaviour profile also moved one sub-quadrant up on the authoritarian/democracy continuum.

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6.2.4 Kapinda

Like Lena, Kapinda showed no fundamental gaps in her subject matter knowledge throughout the year. She was able to draw on this effectively to design creative and engaging learning tasks. Kapinda's interactions with the mathematics content and processes in her learning tasks and observed lessons did not show the depth of relational understanding that both Marge and Toni demonstrated.

Instrumental   *Relational*
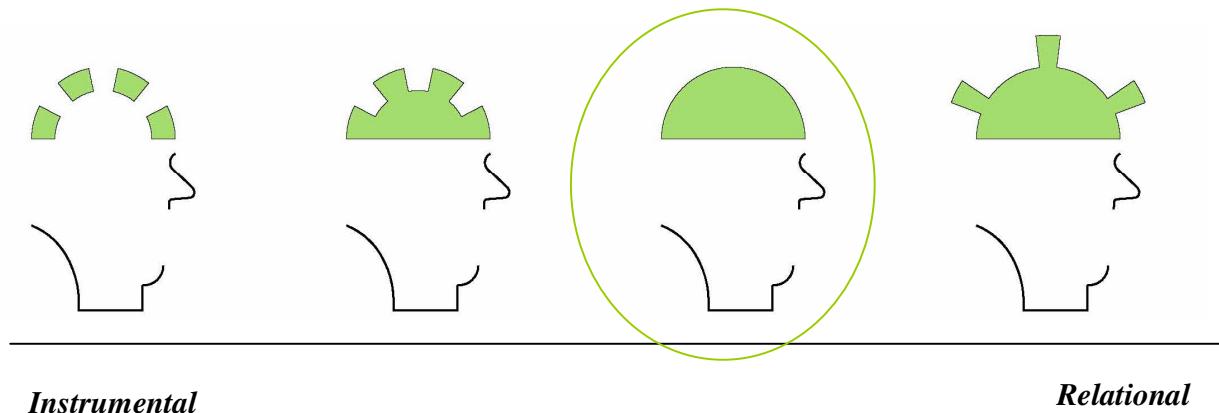
Figure 6.21 Visual representation of Kapinda's subject matter knowledge

Kapinda demonstrated an excellent understanding of the learners' context in terms of designing problems in authentic contexts that engaged the learners. Her learning tasks were creative and well planned. Kapinda's knowledge of the curriculum was good and she never seemed to experience any difficulties with classroom management. She progressively made more use of alternative assessments including peer assessment and the use of rubrics. Kapinda did not reach the point of investigating or valuing learners' errors though and the learners' thinking behind these and this is what restricted her pedagogical content knowledge from being placed in the fourth and most complete category.

Less complete   **More complete**
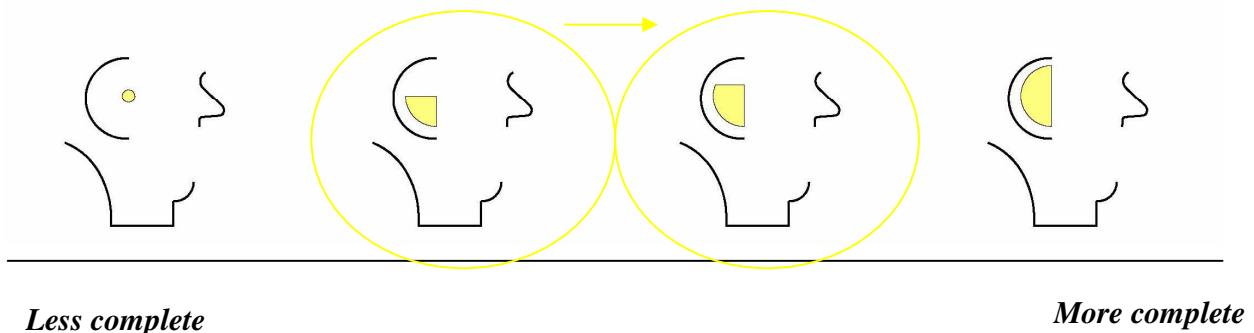
Figure 6.22 Visual representation of Kapinda's pedagogical content knowledge

Kapinda's view of mathematics was not very obvious from her reflections. However, her interaction with the content in the tasks she designed seemed to indicate a content orientation initially that was also calculational rather than conceptual. Her verbal response to my asking about the "mathematics silence" in her reflections also suggested that she willingly wanted to embrace and utilise the constructivist approach to the teaching and learning of mathematics but that she did not see how this could be possible in terms of how she "knew" mathematics as a subject both at school and university. Although her teaching became more process-orientated during the course of the year, knowing and correctly applying the rules and algorithms appeared to remain her focus.

Absolutist   **Constructivist**
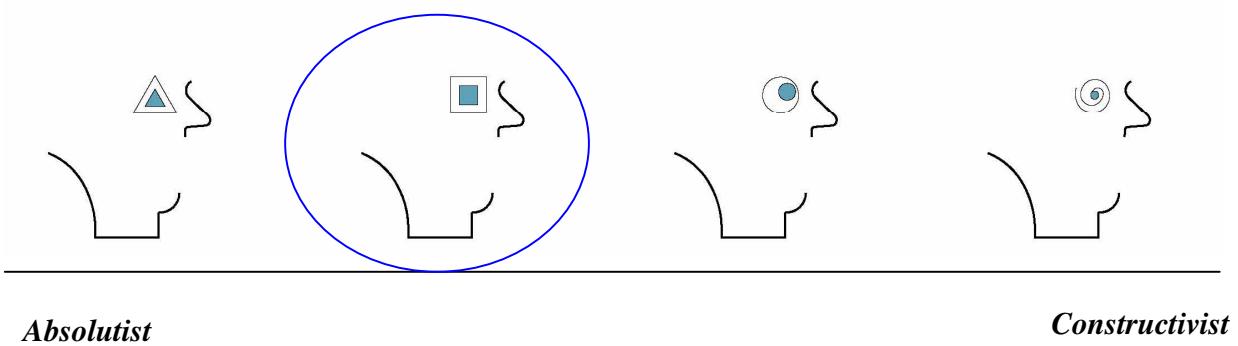
Figure 6.23 Visual representation of Kapinda's conceptions of mathematics

Kapinda acknowledged and involved the learners from the beginning of her teaching. The questions that she posed mainly remained at recall level, although some of the last worksheets

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she designed suggested that she wanted learners to conceptually understand the mathematics rather than merely follow the methods or apply the algorithms. Even towards the end of the year when learners were asked to explain their solutions to the rest of the class, the focus remained on the answer and not on investigating their thinking and understanding behind it.

Transmitter   **Facilitator**
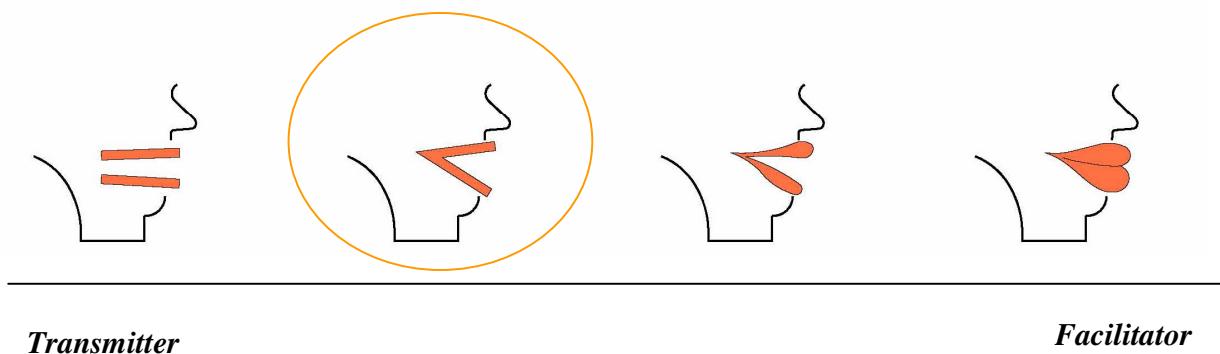
Figure 6.24 Visual representation of Kapinda's beliefs about teaching and learning mathematics

Kapinda's instructional behaviour, like that of Lena's, made a slight shift on each of the continuums during the course of the year. Although mastering of content remained her focus, her learning task designs and some of her final lessons indicated her intent to move towards improving the conceptual understanding of learners. She designed problems that required more hands-on involvement from the learners and aimed at getting them to identify patterns. However, even if the learners were asked to communicate their thinking or reasoning as feedback and discussion during the class, they were expected to present the solution rather than the reasoning. Kapinda consistently demonstrated very good relations with the learners, used a variety of individual and group work and her lessons became more learner-centred and task-based.
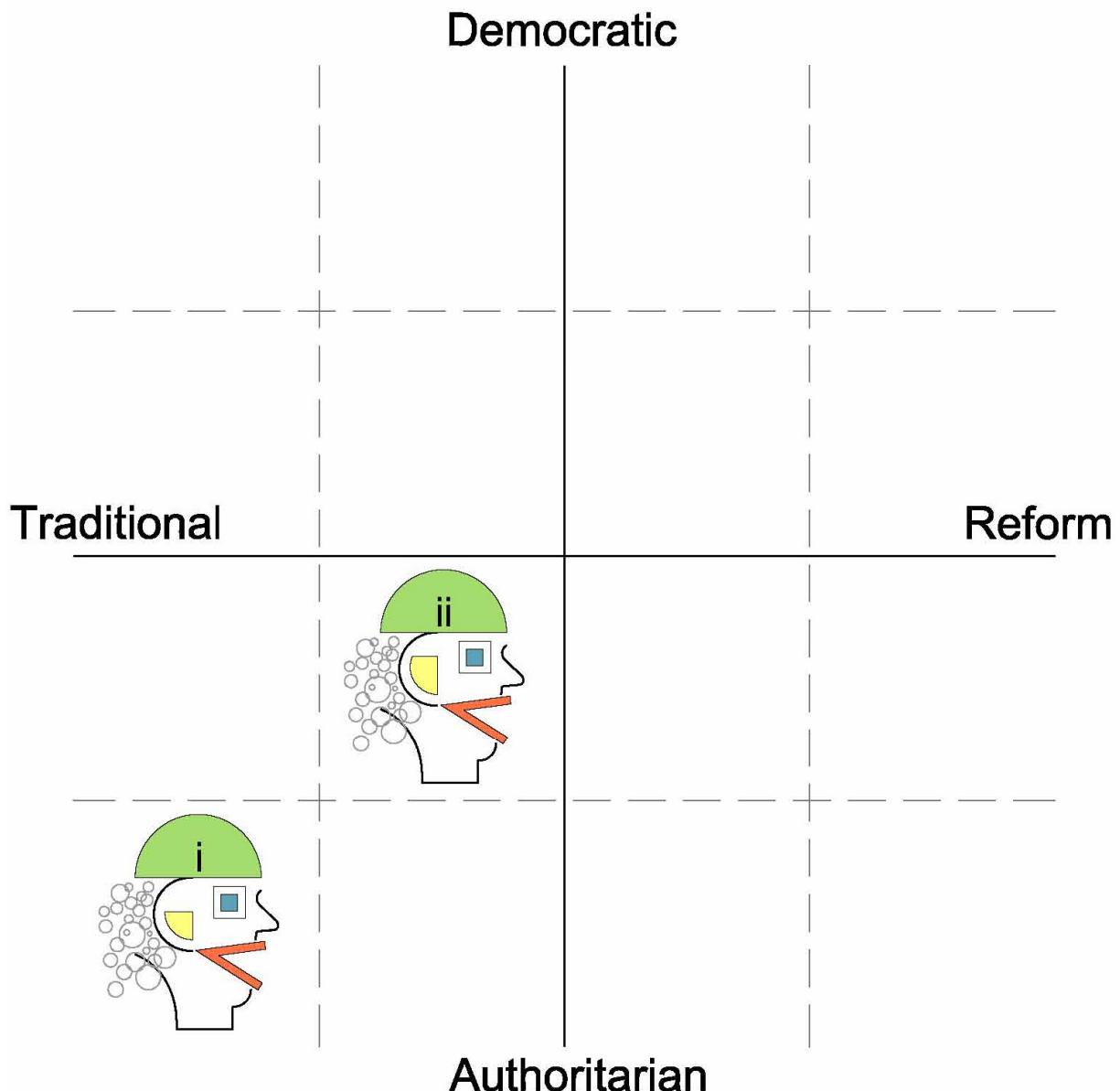
Figure 6.25 Mathematics and instructional behaviour profile changes of Kapinda from initial (i) to final (ii)

The only change that took place in Kapinda's mathematics profile is in her pedagogical content knowledge, which moved one category to the right. Her instructional behaviour profile also moved one sub-quadrant on each of the continuums.

6.2.5 Anabella

As already indicated in chapter 5, Anabella also demonstrated some conceptual gaps in her subject matter knowledge throughout the course of the year. She made two fundamental errors in the baseline assessment and various errors were observed in her learning tasks and during her lessons.

Instrumental   **Relational**
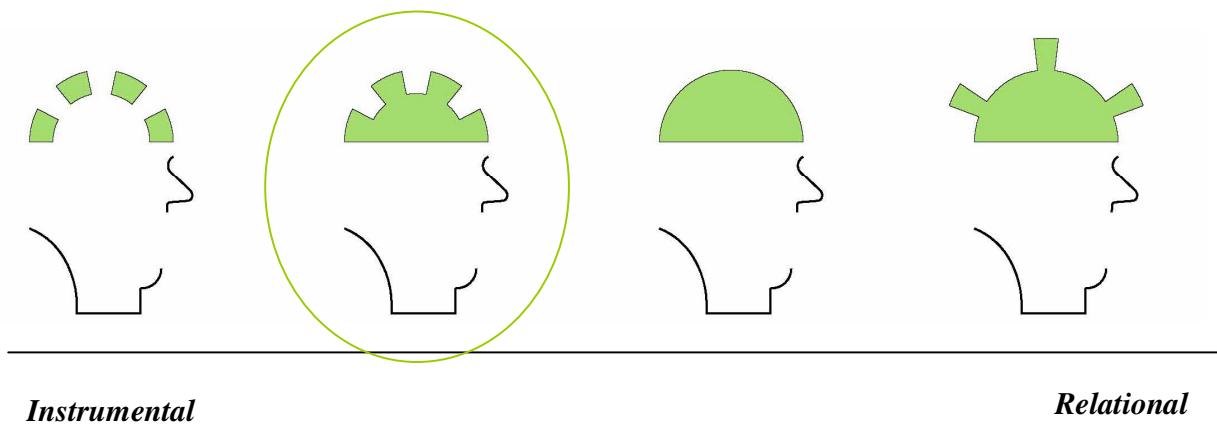
Figure 6.26 Visual representation of Anabella's subject matter knowledge

Initially Anabella struggled to design learning tasks to achieve the mathematical outcomes she wanted to achieve. She seemed to use neither alternative assessment nor the curriculum in determining the prior knowledge with which she expected learners would enter her lessons. Similarly to Peta, the quality of Anabella's learning task designs improved a lot during her second school-based experience. She appeared to work more effectively with learners in lower grades and began posing questions in response to learners' questions as the year progressed and she gained more confidence. She also began to implement some alternative forms of assessment. Anabella did not investigate incorrect answers or thinking of learners although she did move towards designing lessons that were more learner-centred towards the end of the year. She also made use of scaffolding as the year progressed (which is a competency that differentiated her from Sophie and Peta who both ended the year in the second pedagogical content knowledge category). Her pedagogical content knowledge is therefore depicted as changing from the first to the third (more complete) category.

Less complete   **More complete**
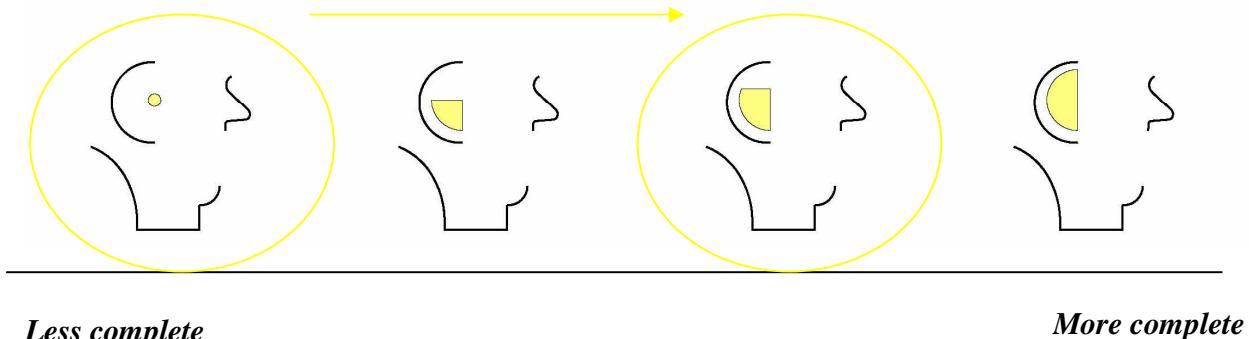
Figure 6.27 Visual representation of Anabella's pedagogical content knowledge

At the beginning of the year Anabella dealt with mathematics as a very rigid, structured and absolute approach. Her focus was initially content-orientated foregrounding computational solutions. During the second school-based experience Anabella was given a Grade 8 class as her responsibility and here her learning tasks showed more of a process-orientated and calculational shift. Her view of mathematics appeared a little less absolute and rigid and she was able to integrate problem solving within her final few lessons in a more authentic context.

Absolutist   **Constructivist**
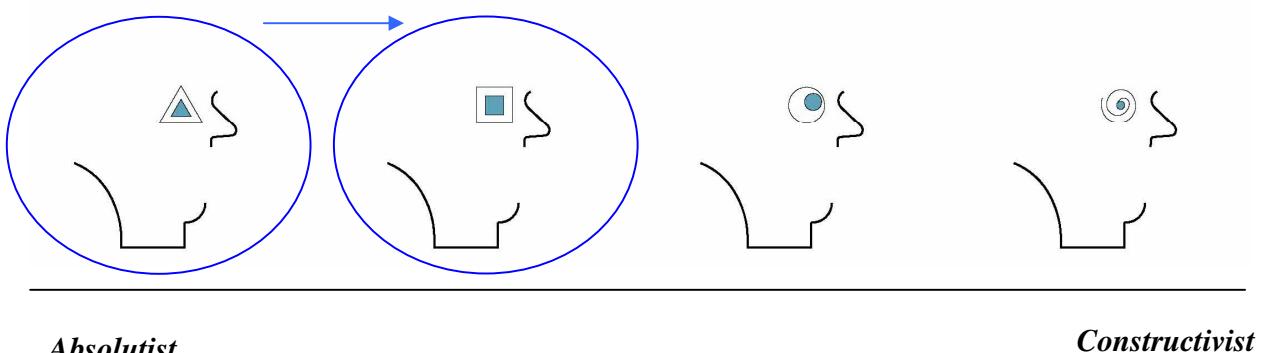
Figure 6.28 Visual representation of Anabella's conceptions of mathematics

Anabella initially seemed to demonstrate expository teaching without encouraging any response or communication from the learners. During the second school-based experience Anabella began to provide more opportunities for learners to respond, although her questions did not elicit high-level reasoning or an explanation from learners of their thinking processes.

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Transmitter   **Facilitator**
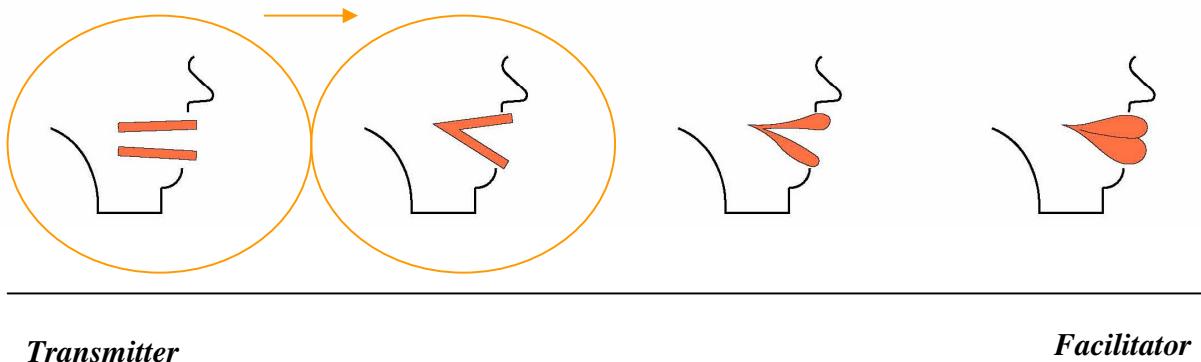
Figure 6.29 Visual representation of Anabella's beliefs about teaching and learning mathematics

Anabella's instructional behaviour made a slight shift up on the authoritarian/democratic continuum during the course of the year. This shift is indicated due to the more learner-centred and pro blem-solving approach she was able to implement later in the year that afforded the learners more active construction of knowledge, albeit at a low level. Although these learning tasks required more hands-on discovery from the learners, mastering of content remained her focus. Discussions encouraging feedback and investigating learners' thinking were not observed and questions posed did not elicit high-level reasoning, pattern identification or any of the other approaches to the teaching and learning of mathematics that would indicate a positive shift towards more reform type teaching.

Democratic

Traditional

Reform

Authoritarian

Figure 6.30 Mathematics and instructional behaviour profile changes of Anabella from initial (i) to final (ii)

Anabella's mathematics profile changed in three of the four components. Her pedagogical content knowledge moved two categories to the right while her conceptions and beliefs both moved one category. Anabella's instructional behaviour profile also moved one sub-quadrant up on the authoritarian/democracy continuum.

6.2.6 Sophie

Sophie demonstrated a number of conceptual gaps in her subject matter knowledge throughout the course of the year. She made fundamental errors in the baseline assessment and various errors were observed during her lessons.

Instrumental   **Relational**
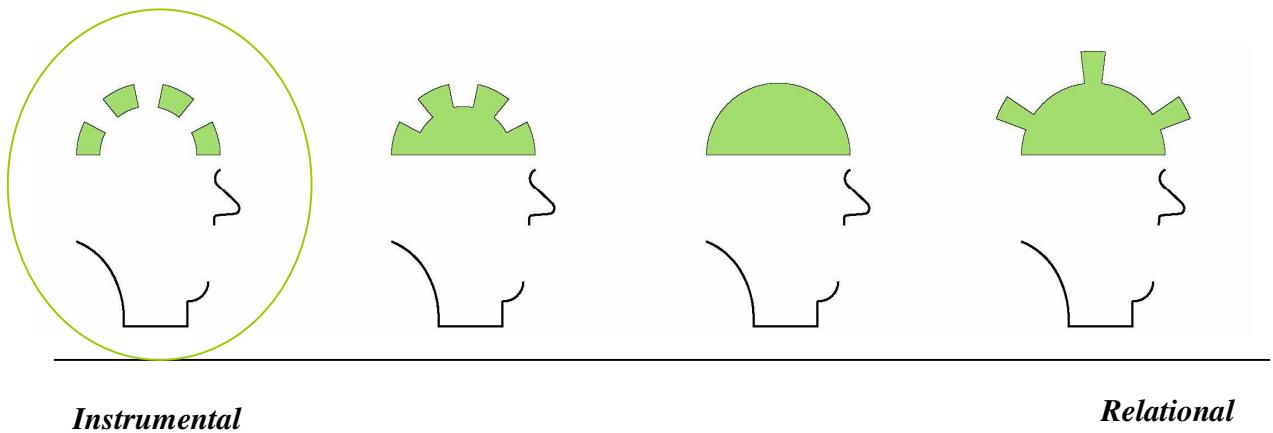
Figure 6.31 Visual representation of Sophie's subject matter knowledge

Sophie struggled to improve the poor quality of her learning task designs. Although the context and quality of problems improved and the intentions and course of her lessons later became clearer in her learning task designs, Sophie continued to present tasks and worksheets to learners with instructions that were unclear or ambiguous. She did not investigate incorrect answers or thinking of learners although she did move towards designing lessons that were more learner-centred and contextual towards the end of the year. These contexts, though, often detracted from the intended curriculum outcomes to be achieved. Sophie's pedagogical content knowledge is therefore depicted as changing from the first to the second (more complete) category.

Less complete   *More complete*
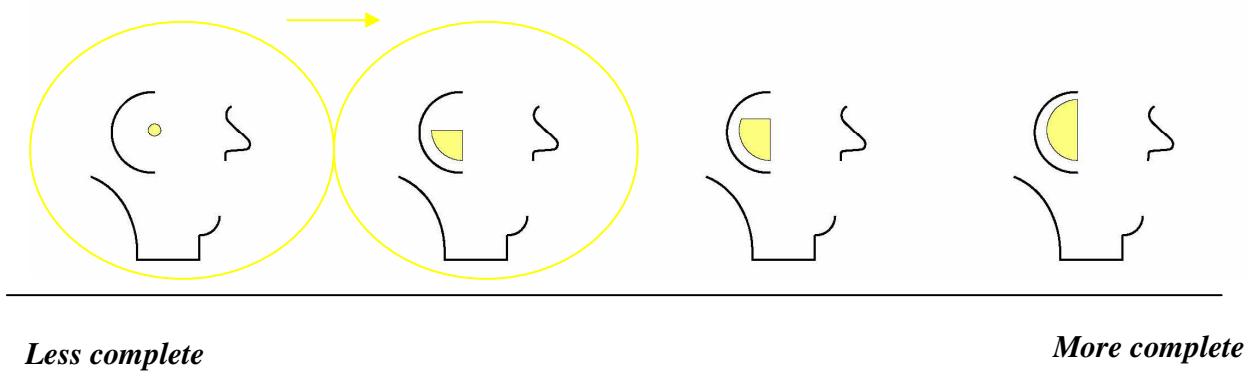
Figure 6.32 Visual representation of Sophie's pedagogical content knowledge

From the beginning of the year Sophie dealt with mathematics as a very rigid, structured and absolute (in terms of right or wrong) approach. Her focus remained content-orientated with an emphasis on using the correct methods and formulae and finding the correct answer. It was therefore not easy to find any evidence of a shift in this view of mathematics throughout her final portfolio or interaction with the mathematical content.

Absolutist   *Constructivist*
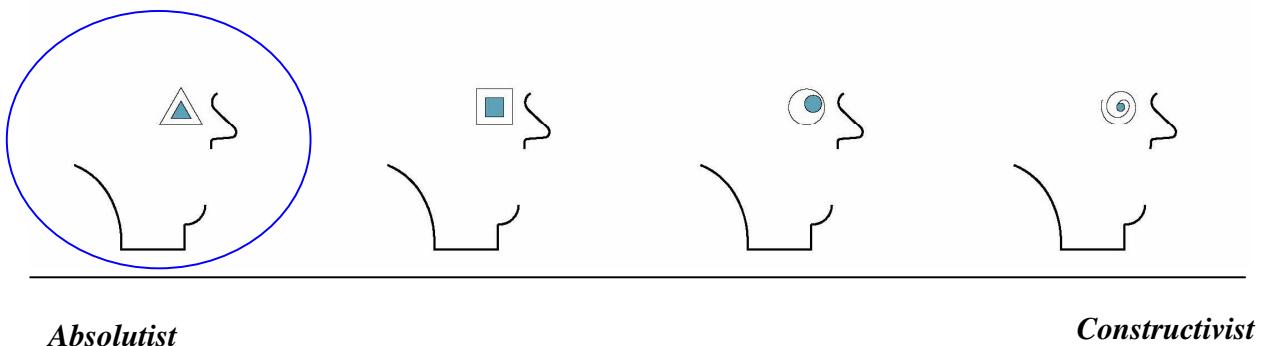
Figure 6.33 Visual representation of Sophie's conceptions of mathematics

At the beginning of the year Sophie seemed to teach without requiring any response or communication from the learners. This could perhaps have been due to her not being comfortable with teaching in English as it is her second language. During the second school-based experience Sophie slowly began to provide more opportunities for learners to respond, although her questions mostly focused on computational solutions. and facts (such as recalling formulae) rather than on mathematical thinking or processes.

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Transmitter   *Facilitator*
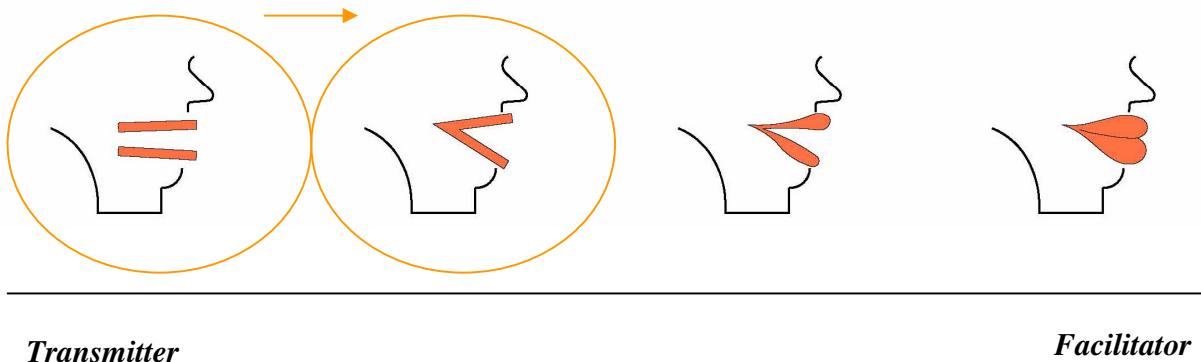
Figure 6.34 Visual representation of Sophie's beliefs about teaching and learning mathematics

Sophie's instructional behaviour made a slight shift up on the authoritarian/democratic continuum during the course of the year. This shift is indicated due to the more learner-centred and attempted problem-solving approach she was able to implement later in the year that afforded the learners more active participation in the lesson. Although these learning tasks required more hands-on engagement from the learners, not much mathematical thinking or reasoning was required from learners. Neither tasks nor discussions encouraging feedback and investigating learners' thinking were observed and questions posed did not elicit high-level reasoning, pattern identification or any of the other approaches to the teaching and learning of mathematics that would indicate a positive shift towards more reform type teaching.
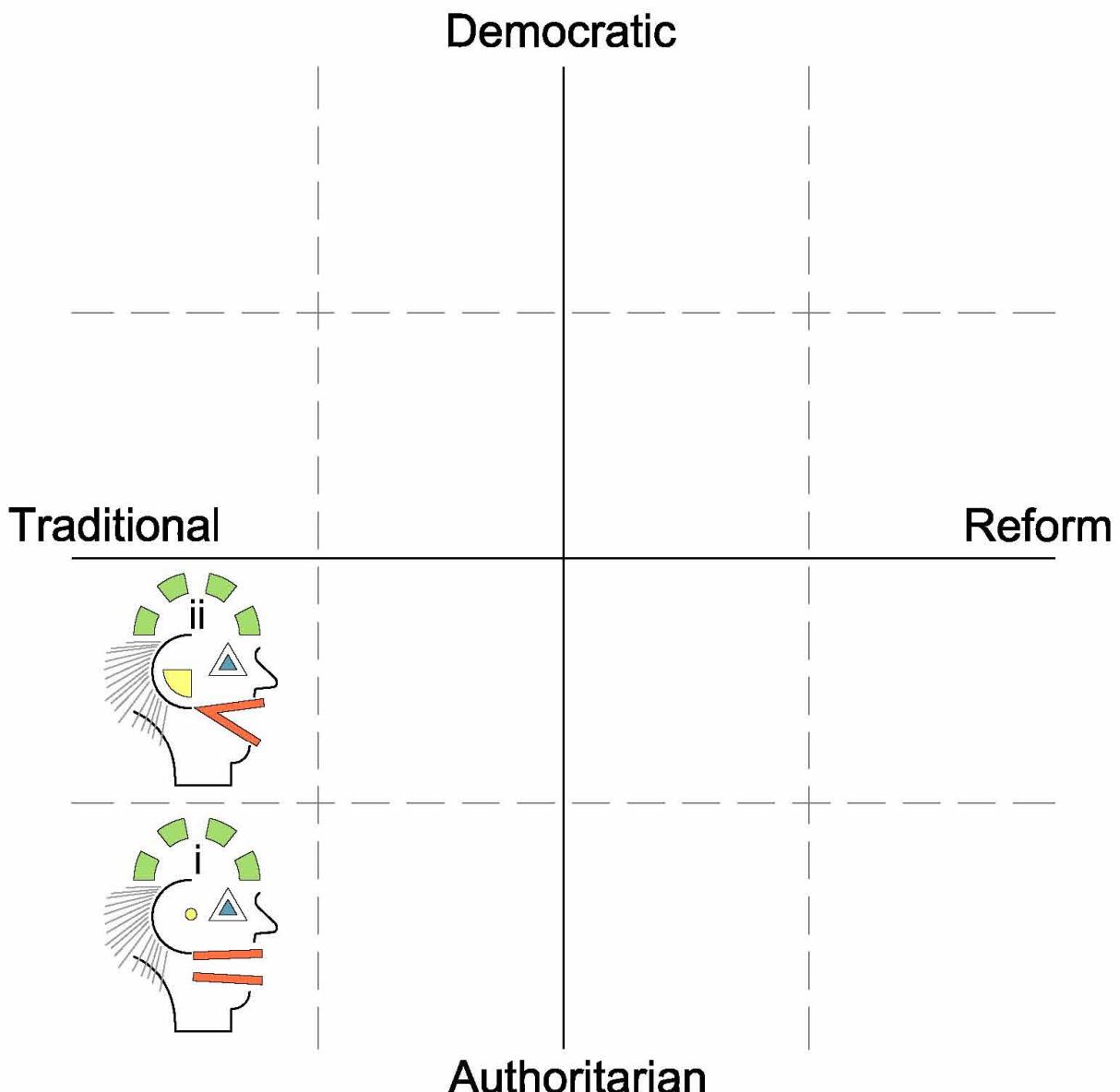
Figure 6.35   Mathematics and instructional behaviour profile changes of Sophie from initial (i) to final (ii)

Sophie's mathematics profile changed in two of the four components. Her pedagogical content knowledge and beliefs about the teaching and learning of mathematics both moved one category to the right. Sophie's instructional behaviour profile also moved one sub-quadrant up on the authoritarian/democratic continuum.

6.2.7 Toni

Like Marge, Toni also displayed strong subject matter knowledge throughout the year. He was able to effectively draw on this in designing learning tasks of a high mathematical standard and ask questions that elicited a high level of thinking from the learners.

Instrumental   **Relational**
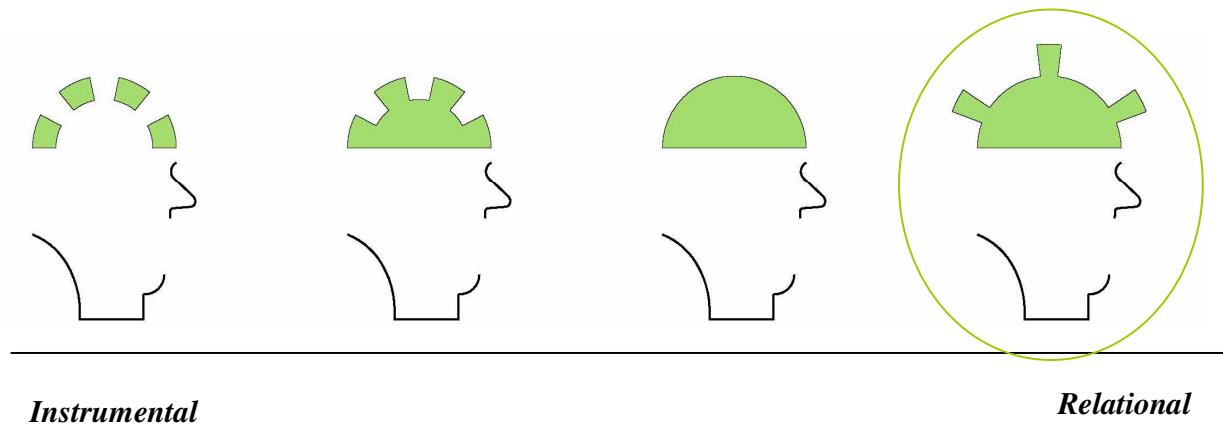
Figure 6.36 Visual representation of Toni's subject matter knowledge

From the beginning of the year when Toni started trying to design contextual problems, he ensured that the mathematical content was not lost amidst the context. His planning was of a high quality and he made effective use of scaffolding to enable learners to work more independently and used various forms of alternative assessment towards the end of the year. His knowledge of the curriculum and his classroom management were also both outstanding throughout the course of the year. However, Toni did not reach the point of investigating or valuing learners' errors and the learners' thinking behind these and this is the main reason he did not progress to the final category on the right, as this is in my opinion an important facet of pedagogical content knowledge.

Less complete   **More complete**
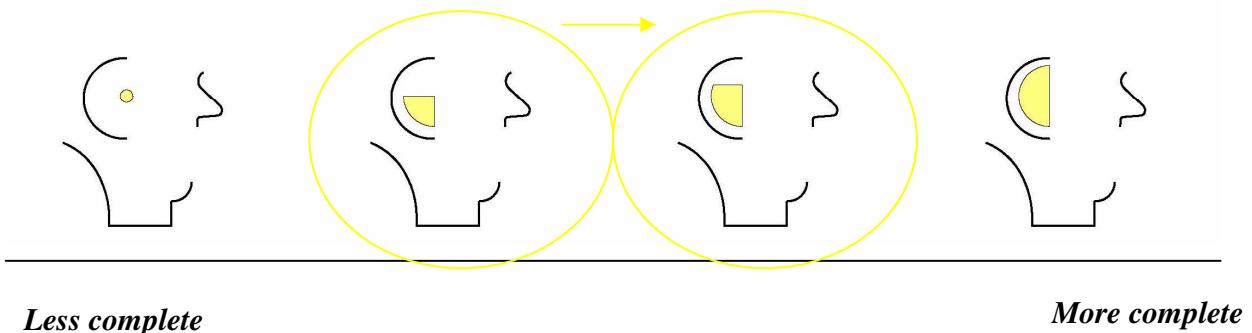
Figure 6.37 Visual representation of Toni's pedagogical content knowledge

Toni's initial view of mathematics seemed to be more instrumentalist with a focus on rules and algorithms. During the course of the year his teaching became more process-orientated though, moving from a focus on calculational to more conceptual understanding.

Absolutist   **Constructivist**
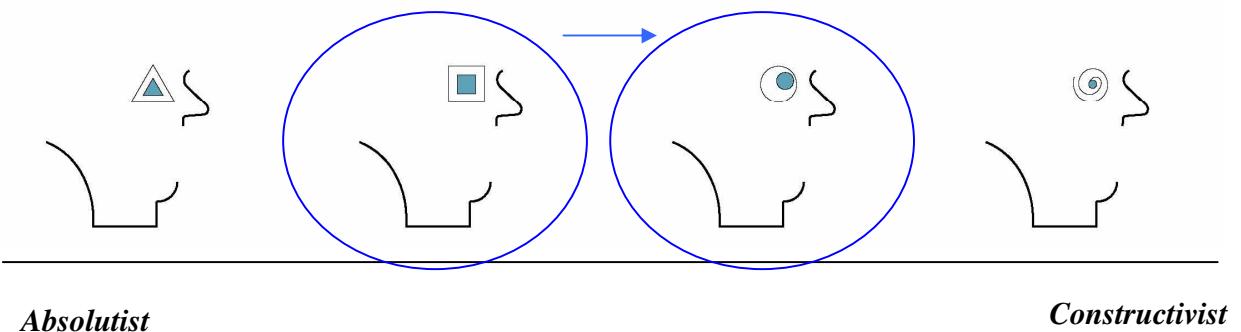
Figure 6.38 Visual representation of Toni's conceptions of mathematics

Toni treated the learners as 'transceivers' from the beginning of his first school-based education. He demonstrated a strong ability to think on his feet and involve a number of learners in his still-dominantly-expository but transactional teaching. Toni's final profile depicts him as an explainer (rather than facilitator) as, similarly to Marge, he never demonstrated the ability to facilitate mathematical discussions on a continuous basis that required the learners to do most of the talking and use high-level reasoning and thinking (which I refer to as decoding).

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Transmitter   **Facilitator**
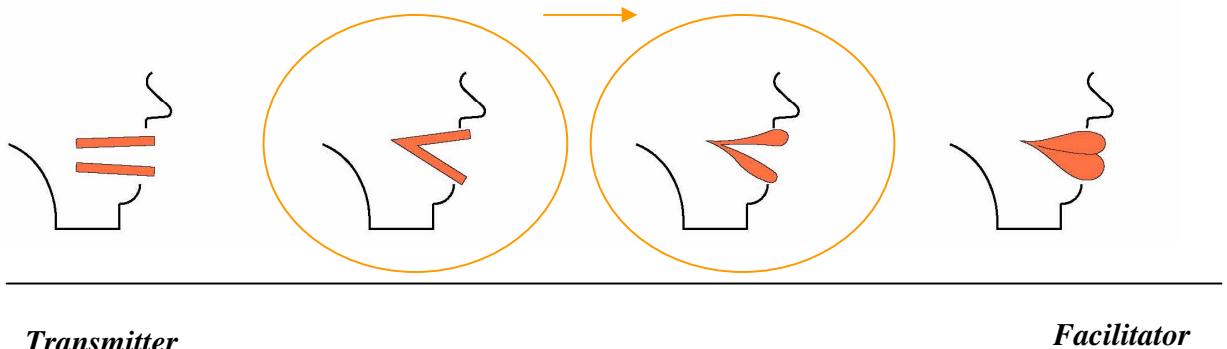
Figure 6.39 Visual representation of Toni's beliefs about teaching and learning mathematics

Toni was the only other participant (alongside Marge) whose instructional behaviour changed significantly during the course of the year. As he began to embrace a more constructivist and problem-solving approach to the teaching and learning of mathematics, the design of his learning tasks began to change. His learning task designs and lessons began making more use of hands-on discovery, identification of patterns and exploration. Toni began demanding more high-level reasoning from his learners but not to the extent where it was being required often enough or with enough heuristic listening on Toni's part. He still seemed more comfortable being in control of the lesson and the class, rather than this being a negotiation and sharing of thinking between learner and facilitator. This is the reason his instructional behaviour profile made changes on both continuums but not to the optimal reform and democracy quadrants.

**Democratic**

Traditional

Reform

Authoritarian
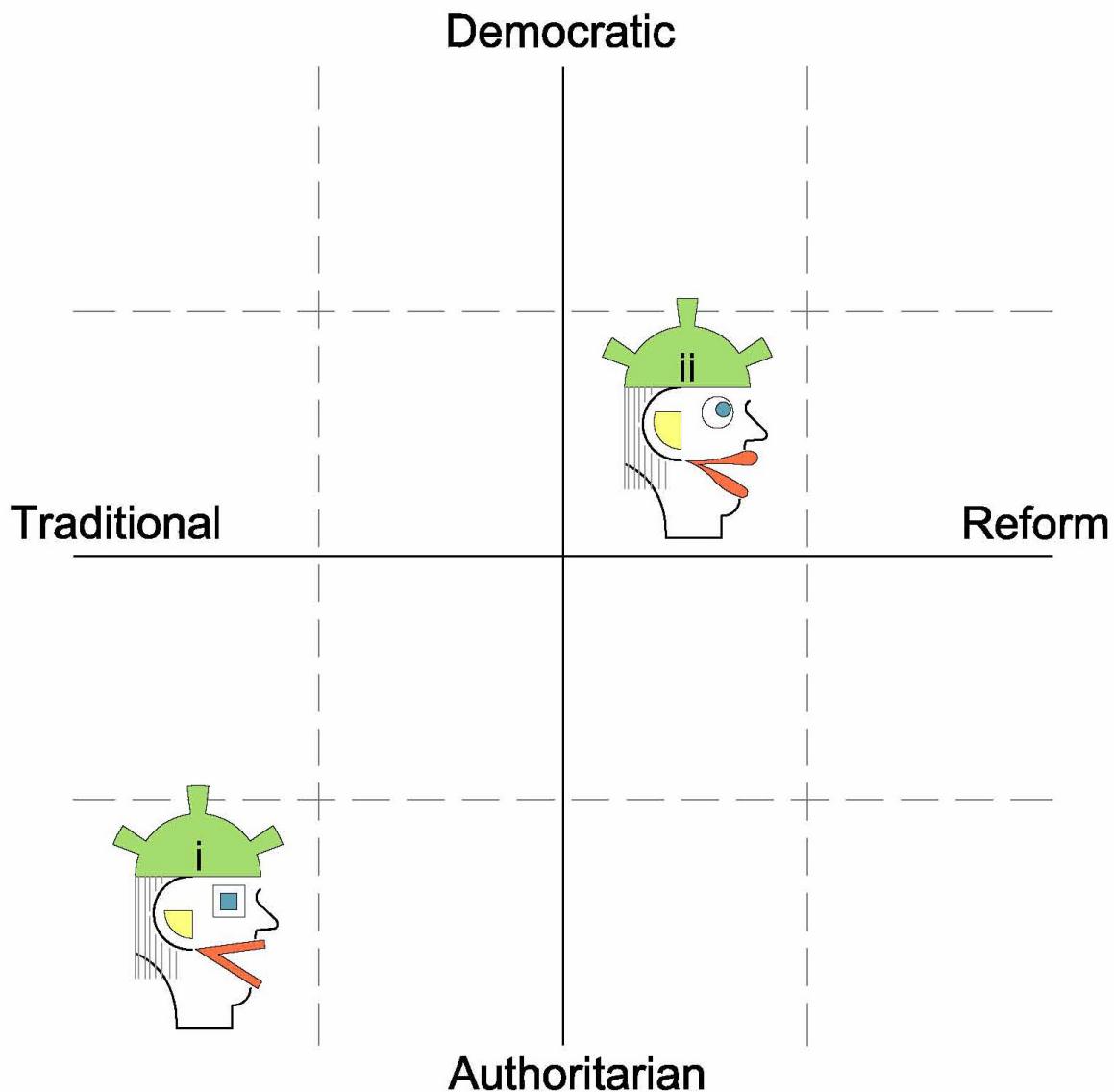
Figure 6.40   Mathematics and instructional behaviour profile changes of Toni from initial (i) to final (ii)

Toni's final mathematics profile indicates a shift of one category to the right in the pedagogical content knowledge, conceptions and beliefs components. The changes in his instructional behaviour were also evident in the changes he made towards a more reform-dominated practice and encouraging more democracy within his approach to the teaching and learning of mathematics.

6.3 Cross-case comparisons

Changes in individual participants' mathematics profiles and instructional behaviour were discussed in the section above. In this section I discuss the cross-case comparison. This was done by first grouping participants with identical starting mathematics profiles and comparing their final mathematics profiles and the changes in their instructional behaviour. This process was then repeated by comparing participants who had similar (only one component differed) initial mathematics profiles or similar final mathematics profiles. Differences in the various profiles are also discussed.

6.3.1 Identical initial mathematics profiles

Marge and Toni have identical starting profiles as do Peta and Sophie. I have grouped these pairs together calling them Groups 1 and 2. Their visual profiles are depicted in Figure 6.41.

Group 1 (Marge and Toni) both exhibited excellent relational subject matter knowledge. They both started off the year displaying some pedagogical content knowledge, having an instrumentalist conception of mathematics and indicating a belief that their role in the teaching and learning of mathematics pertained mainly to instructing. During the course of the year they both changed this belief to enact the role of explainer. Marge's pedagogical content knowledge moved to the most complete category and her conceptions of mathematics changed to a problem-solving view. Toni's pedagogical content knowledge moved one category to the right and his conceptions changed to the Platonist view. In my opinion, the main reason for these final mathematics profile differences is the vast amount of literature that Marge accessed and incorporated into her practice, her reflections and her practice-theory as the year progressed. While Toni also did some reading of the literature, he did not cover nearly the extent that Marge managed to read through and internalise. Both these participants also demonstrated a high level of insight and an ability to be accurately self-critical in their reflections. These reflections also indicated their ongoing analysis of their practices and learning task designs in order to continually improve these.
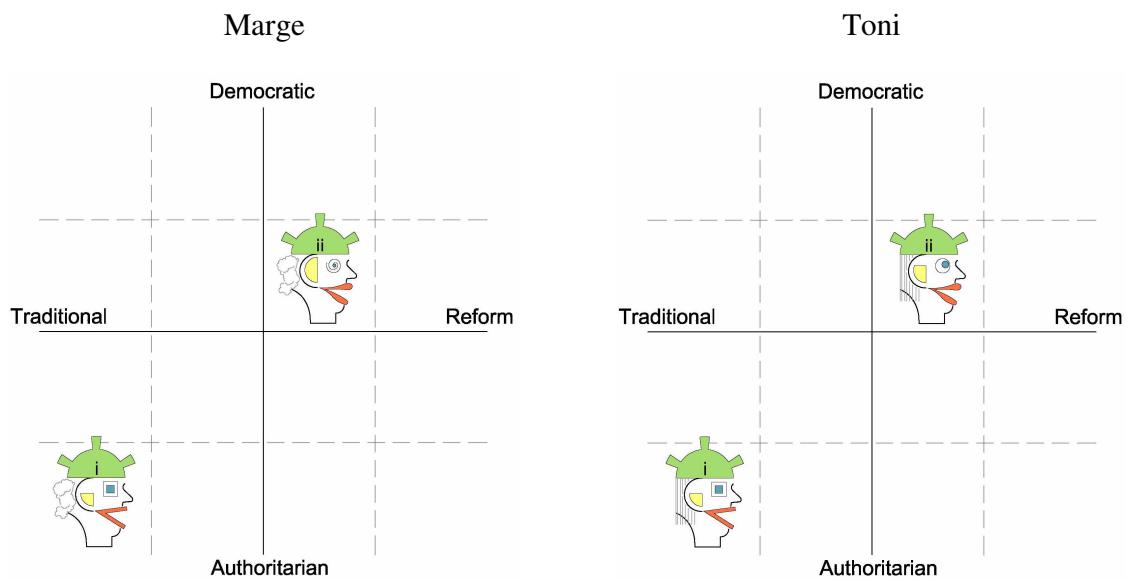
Figure 6.41 Visual profiles of Group 1 (Marge and Toni)

What is interesting is that both participants' instructional behaviour profiles followed the same trajectory of change. From this observation I am making the assumption that the additional change in the pedagogical content knowledge and conceptions categories for Marge did not necessarily enable more change in her instructional behaviour and neither did her vast engagement with the literature. It is also interesting to note that neither of these participants reached the role of facilitator in terms of their beliefs about the teaching and learning of mathematics. This is perhaps linked with both of them not moving into the final reform and democracy sub-quadrants. In order for a participant to be placed in the final reform sub-quadrant, they needed to continually be creating opportunities for learners to engage in and discuss their mathematical reasoning and understanding. These opportunities should demand high-level reasoning from learners that also allow them to deepen their conceptual and relational understanding and application of the domain of mathematics. This echoes the role of a facilitator whose learners are expected to "decode" problems and signal their process of thinking and understanding back to the facilitator. The facilitator enables and guides the discussions but does not necessarily dominate them. This, in turn, is linked to the final democracy sub-quadrant. Instructional behaviour in this quadrant would involve more heuristic listening on the part of the teacher. In this cross-case comparison, what is foregrounded for me is the importance of the belief component of the mathematics profile in

enabling optimum change in pre-service teachers' instructional behaviour. Another aspect that has emerged is the role that literature appears to play in enabling change in the mathematics profile of the pre-service teachers.

Group 2 (Peta and Sophie) have exactly the same initial and final profiles. They both demonstrated disquieting fundamental gaps in their subject matter knowledge, did not have very much pedagogical content knowledge to begin with, shared the absolutist conception of mathematics and initially enacted the role of transmitter regarding their beliefs about the teaching and learning of mathematics. During the course of the year, they both gained in pedagogical content knowledge (improved planning and quality of their learning task designs, some use of alternative assessment, responding to a question with a question and knowledge of the curriculum) and changed their enacted role from transmitter to instructor, where there was more evidence of them requiring participation and communication from their learners.
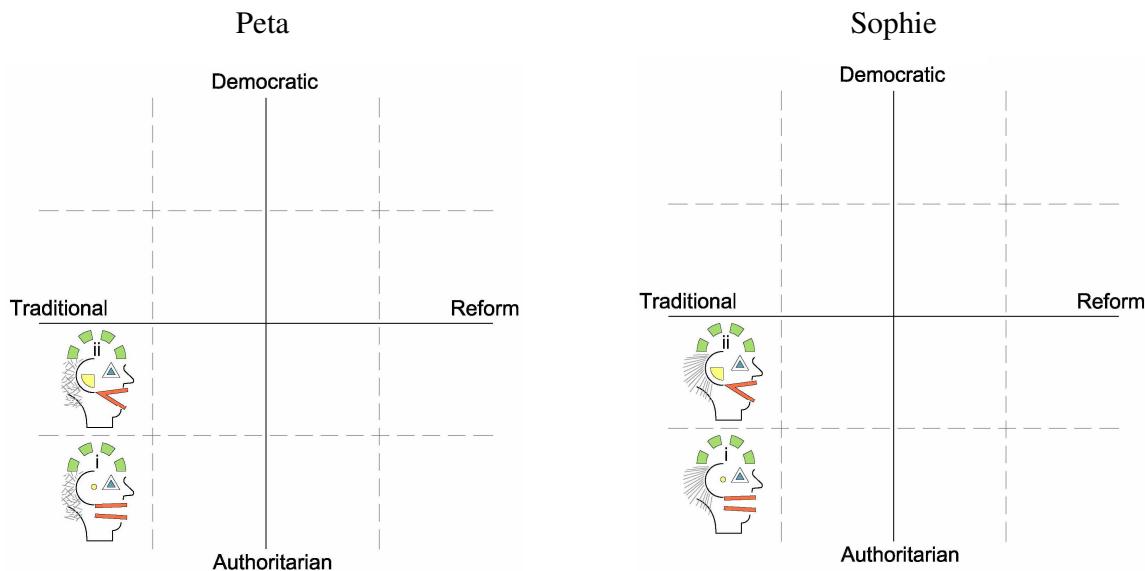
Figure 6.42 Visual profiles of Group 2 (Peta and Sophie)

In line with the comparison in Group 1, this pair also made the same changes in their instructional behaviour. They both started including problems in their learning task designs which engaged the learners (making the lessons more learner-centred and less authoritarian) but which did not promote the more reform type values and activities such as pattern identification, modelling, exploration and investigation with an emphasis on high-level

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mathematical reasoning. Peta's final learning task design did require pattern identification but this was not seen as enough evidence to move her instructional behaviour into the next sub-quadrant of the traditional/reform continuum. The continual low-level engagement with the conceptual issues and processes of mathematics and a consistent focus by both participants on mastering content were other aspects that restricted their movement on this continuum.

This cross-case comparison highlights an issue relating to the drive for more learner-centred lessons that our course often tries to propagate. Both participants reached a stage of including their learners more actively in their lessons. However, owing to the nature of the low level of mathematical processes being required (on average Mason's level 2), this increased activity from the learners only made the lessons less authoritarian and did not mean they were less traditional. In South Africa, with our new curriculum being embedded in the philosophy of Outcomes-based Education, learner-centredness is often seen as an indicator of a more "outcomes-based" lesson which is also often understood to be "less traditional" and more in line with the reform ideology. I have felt uncomfortable with this in my own specialisation module and this cross-case comparison has enabled me to understand the reason in terms of the superficial change that a more learner-centred lesson (in terms of activity rather than mathematical reasoning) can imitate. I think the issue of what is meant by a more learner-centred lesson is something that needs to be reviewed for the purposes of my own teaching. In chapter 7 I elaborate on this in the personal reflection.

6.3.2   Identical final mathematics profiles

Lena and Kapinda *(Group 3)* had similar initial mathematics profiles (differing only in their enacted beliefs) and identical final mathematics profiles. Neither of them displayed gaps in their subject matter knowledge during the course of the year, although their knowledge did not appear as relational as that of Marge and Toni. Both Lena and Kapinda held an instrumentalist conception of mathematics throughout the year as deduced from their interaction with the content (mostly content-orientated and computational or calculational) and their focus on mastering of the content. They both enacted an instructors belief about the teaching and learning of mathematics and both moved one category towards "more complete" in their

pedagogical content knowledge. In fact, pedagogical content knowledge appeared to be the only change in Kapinda's mathematics profile.
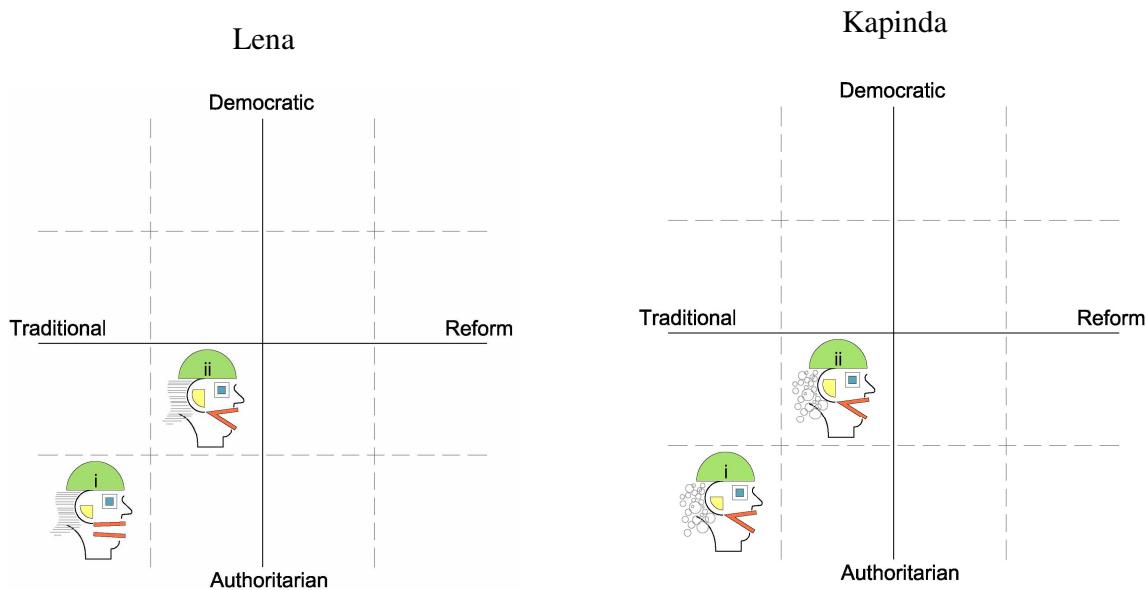
Figure 6.43 Visual profiles of Group 3 (Lena and Kapinda)

Lena and Kapinda both made the same sub-quadrant changes in their instructional behaviour, moving towards being less authoritarian and less traditional in their teaching. However, neither of them moved onto the reform or democratic side of these continuums. Looking at this cross-case comparison in relation to the groups mentioned above, it appears that the pedagogical content knowledge component does not play a role in effecting change in on the authoritarian/democratic continuum but may perhaps influence participants' instructional behaviour in becoming less traditional. Both participants in Group 2 had the second category of pedagogical content knowledge in their final profiles (I refer to this as 'some pedagogical content knowledge'). Both participants in Group 1 (Marge and Toni) and these in Group 3 (Lena and Kapinda) ended on the third (or in Marge's case fourth) category of the pedagogical content knowledge component. All these participants in Groups 1 and 3 made some positive change in their approach to teaching in becoming less traditional (in the case of Group 3) or even more reform orientated (in the case of Group 1).

Anabella
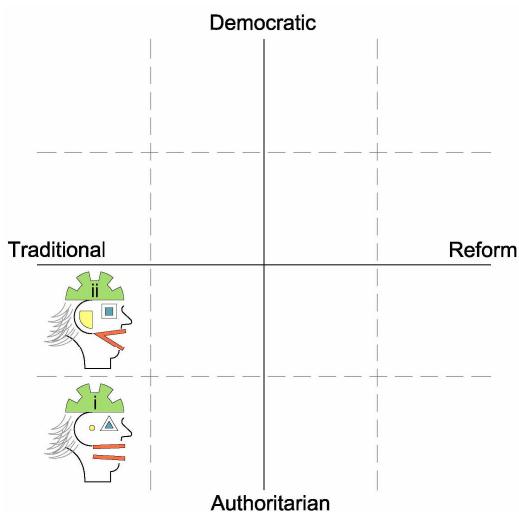
Figure 6.44 Visual profile of Anabella

One of the participants who did not share an identical initial or final mathematics profile with any of the other participants was Anabella. However, Anabella has a similar final mathematics profile to both Lena and Kapinda with the only difference being her subject matter knowledge. Her pedagogical content knowledge for her final mathematics profile was in the third category and yet her instructional behaviour did not become noticeably less traditional. This therefore does not substantiate my assumption above that more complete pedagogical content knowledge enables pre-service teachers to teach in a less traditional manner. It is interesting though that in the mathematics specialisation course I teach, I spend a lot of time working on improving the pedagogical content knowledge of our students. It appears that this component might not be as influential in changing the instructional behaviour of pre-service teachers as I expected. I also revisit this in the personal reflection in the concluding chapter.

6.3.3 Similar initial and final mathematics profiles

Toni, Marge and Kapinda *(Group 4)* share similar initial mathematics profiles with the only difference being the more relational subject matter knowledge demonstrated by Marge and Toni. Their final mathematics profiles differ in terms of conceptions of mathematics and their enacted beliefs. Despite starting off similar, Marge and Toni's mathematics profiles and

instructional behaviour profiles changed more substantially than Kapinda's. With the only initial difference in their mathematics profiles being in the subject matter knowledge, a surface reason for the differences in changes may be the more relational subject matter knowledge of Marge and Toni. I do think this is an important point as only the two participants with relational subject matter knowledge were able to make a change to the positive side of both instructional behaviour continuums. However, I think another reason lies in the quality and nature of the reflections as well as individually (outside of what is prescribed) consulting and incorporating literature from the domain of mathematics and mathematics education into one's practice. Kapinda did not show any evidence of this in her final portfolio, apart from the prescribed literature that is part of the PGCE course. Her reflections were not as analytical as those of Marge and Toni and perhaps did not play such an important role for her in her professional development. As mentioned in chapter 5, the content of Kapinda's reflections never pertained to the actual mathematical processes or content. This could be another aspect constraining her instructional behaviour change.
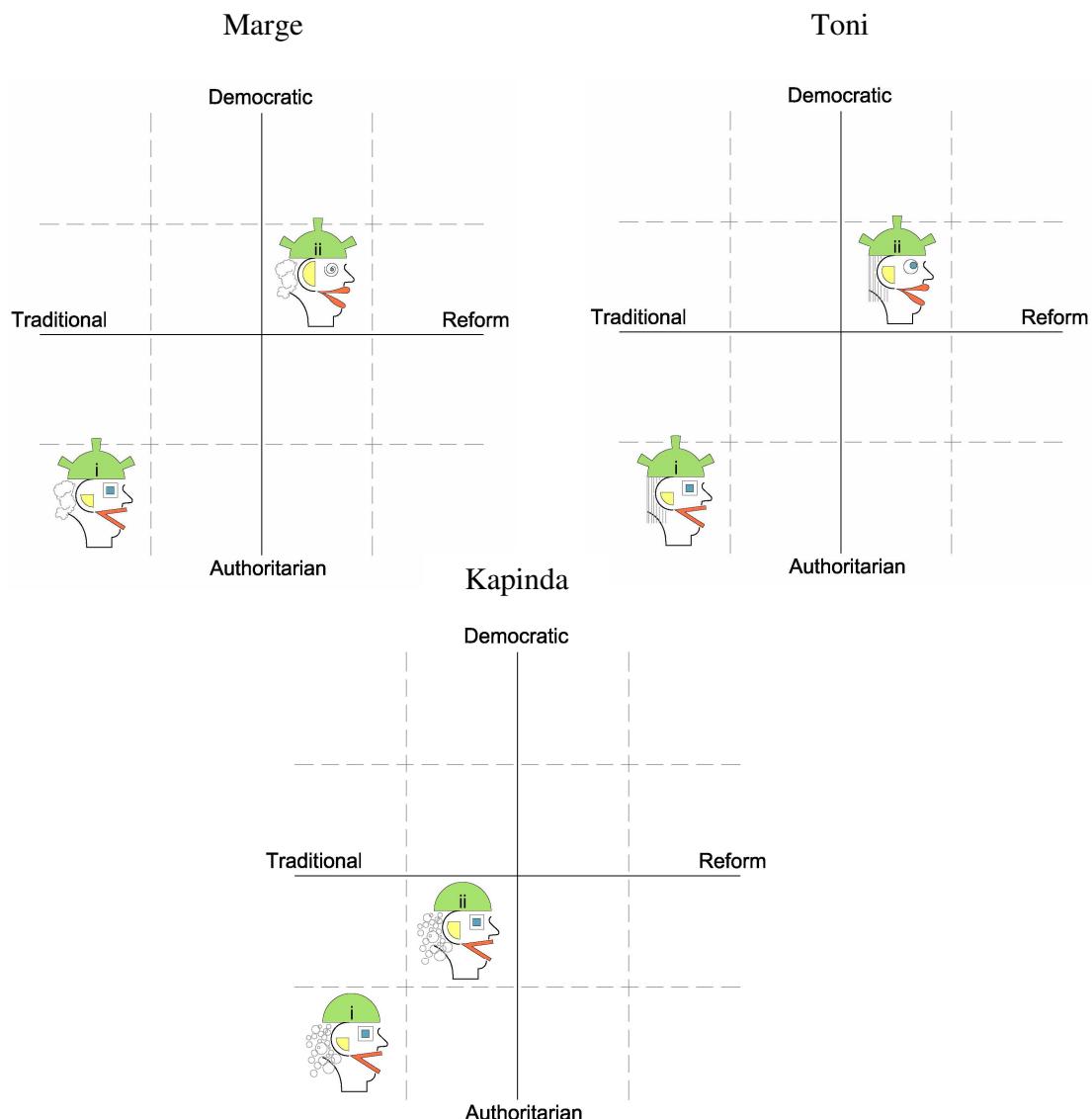
Marge

Toni

Kapinda

Figure 6.45 Visual representation of Group 4 (Marge, Toni and Kapinda)

Lena did make use of increasingly analytical reflections and was also self-critical. However, her instructional behaviour was not as substantial as that of Marge or Toni. This could therefore reinforce the importance of relational subject matter knowledge in changing instructional behaviour. Lena made some reference to literature that she had sought and read herself (although not as much as Toni). This may be what enabled the change in her mathematics profile of her enacted role from transmitter to instructor. Perhaps Kapinda's not reading in the mathematics and mathematics education field is what constrained the development of the conceptions and belief components of her mathematics profile.

Peta, Sophie and Anabella can also be grouped together *(Group 5)* as having similar initial mathematics profiles. They differed initially only in their level of subject matter knowledge, with Anabella demonstrating less fundamental conceptual gaps and more integration of the various topics in mathematics. Their final mathematics profiles looked different though, with Anabella displaying more complete pedagogical content knowledge than the other two, and changing her conception of mathematics to instrumentalist rather than absolutist (where the other two participants' views remained). All three of them moved from transmitter to instructor in their enacted beliefs.
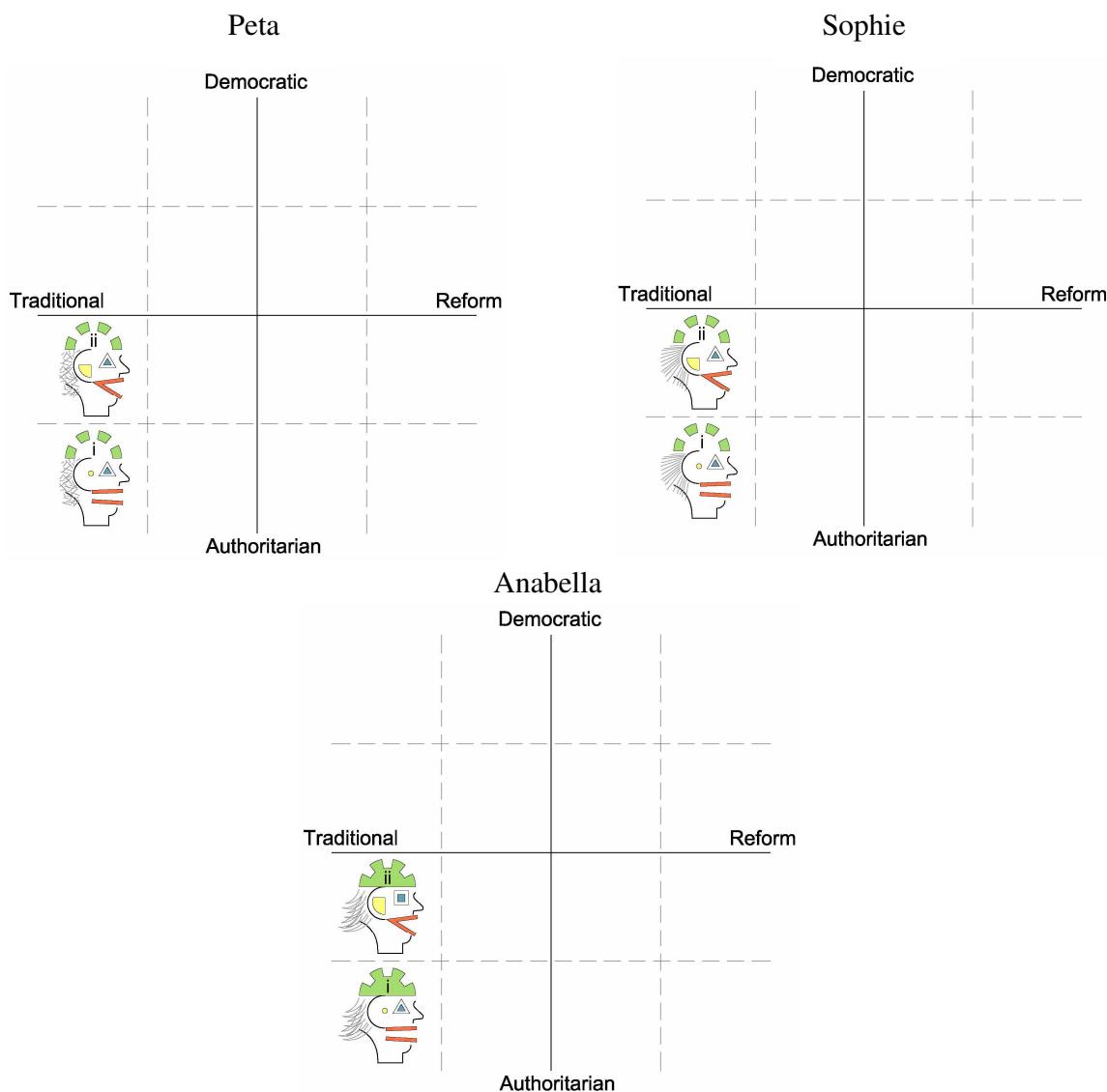
Figure 6.46 Visual profiles of Group 5 (Peta, Sophie and Anabella)

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All three participants also demonstrated similar change in their instructional behaviour, becoming less authoritarian towards learning but not less traditional in their teaching approach. This reiterates what I mentioned above, that Anabella's change in pedagogical content knowledge, conceptions and enacted beliefs (which means she ended with a final mathematics profile similar to Kapinda and Lena) did not enable her to teach in a more reformed manner. I am therefore led to conclude that the component in the mathematics profile that appears to be most enabling in pre-service teachers moving towards the positive side of the traditional/reform continuum is their subject matter knowledge. Neither Anabella, Sophie nor Peta provided evidence of reading literature in mathematics or mathematics education, beyond the prescribed readings for the course. This supports the discussion above where this aspect relating to literature might have a constraining influence on the changes in participants' mathematics profiles. I initially suspected that the lack of deep conceptual knowledge might be the cause of participants not changing their conceptions of mathematics beyond instrumentalist and their enacted beliefs beyond instructor, but Kapinda and Lena both showed subject matter knowledge without any conceptual gaps and they both had instrumentalist conceptions and instructor roles in their final mathematics profiles.

6.4 Discussion

For this summarising discussion I want to highlight some obvious differences in the groups discussed above. Group 1 (Marge and Toni) and Group 2 (Peta and Sophie) differed greatly in their mathematics profiles as well as the changes to their instructional behaviour. Three aspects stand out that may have influenced this. The first one relates to the subject matter knowledge. Group 1 demonstrated the most relational subject matter knowledge and made the most substantial changes to their instructional behaviour. Group 3 (Kapinda and Lena) had slightly less relational subject matter knowledge (with no conceptual gaps evident) and they made slightly less of a change in their instructional behaviour. Group 2 and also Group 5 (to include Anabella) presented the most gaps in their subject matter knowledge and they also made the least changes and I would venture to say progress in their instructional behaviour. From these differences the *component of subject matter knowledge does appear to play an*

important part in enabling or constraining the changes in pre-service mathematics teachers'
instructional behaviour.

The second aspect pertains to the level and quality of the reflections participants kept during the year which were included in their final professional development portfolios. Marge, Toni and Lena were the most analytical, insightful and self-critical in their reflections. Kapinda and Anabella would be the participants I would place next in line although their reflections were more affective and less analytical at times and more focused on the learning task design requirements rather than the mathematics processes and content. Peta and Sophie then follow with reflections that were more an account of what happened in the lesson and how this made them feel. This order above, in terms of quality of reflections, closely (although not exactly) resembles the order of quality of instructional behaviour changes. From this I am suggesting that not just reflecting on one's practice/experiences but that *the quality of these reflections may affect the extent of positive change pre-service teachers make in their instructional behaviour.*

The third aspect deals with students accessing, reading, understanding and incorporating literature from the mathematics and mathematics education domain into their beliefs and practices. Marge was definitely the participant who did the most reading in this regard, beyond the prescribed works. She searched for her own articles on problem-solving approach, on constructivism and on the theory of realistic mathematics education in particular. By her own admission, she initially did not do much of this owing to time constraints. However, when she took time towards the middle of the year to read, changes started manifesting. Marge was the participant who reached the most complete category of pedagogical content knowledge and the only participant to change to a problem-solving view of mathematics. Toni also did a fair amount of reading, followed by Lena who did a little. Kapinda, Anabella, Peta and Sophie did not indicate any evidence of finding or reading additional sources in this domain. This order above is similar to changes noted in the mathematics profiles. Lena, Kapinda, Anabella and Peta were not able to change their conceptions of mathematics beyond instrumentalist or their enacted beliefs about the teaching and learning of mathematics beyond instructor. Not even the higher level of subject matter knowledge displayed by Kapinda and Lena supported this. I therefore suggest that *this aspect of literature is also one that needs to be foregrounded in*

developing and improving pre-service teachers' mathematics profiles, with particular reference to their conceptions and beliefs.

Finally an aspect that did not appear to affect the differences in the amount of change taking place in participants' instructional behaviour was the pedagogical content knowledge component of the mathematics profile. Marge was the only participant to have her final pedagogical content knowledge component defined by the "most complete" category. After that Toni, Lena, Kapinda and Anabella all had pedagogical content knowledge components in the third (almost complete) category. However, their final instructional behaviours differed substantially. Anabella, Sophie and Peta, on the other hand, ended the year in the same instructional behaviour sub-quadrant and yet Anabella's pedagogical content knowledge had gone from being "less complete" initially to "almost complete" at the end of the year while the other two ended up with "somewhat complete" categories of this component. This led me to conclude that *an improvement in pre-service teachers' pedagogical content knowledge possibly does not have the extent of influence on changing their instructional behaviour I had expected.* Much of our undergraduate courses in training FET mathematics teachers at the institution where I am employed, as well as the PGCE mathematics specialisation module, places emphasis on this component of the mathematics profile without perhaps considering the importance of the conceptions of mathematics and enacted beliefs components.

6.5 Conclusion

This chapter has presented a third and final data reduction in the form of visual presentations of the participants' mathematics profiles and their instructional behaviour profiles. These are the two main constructs being explored in order to gain some insight into the influence of pre-service teachers' mathematics profiles on their instructional behaviour. In chapter 4 the first data reduction was a selection of reflections and entries from participants' final portfolios for their PGCE year which they use to show their professional development. In chapter 5 the second data reduction was a reflection of each participant written by myself as one of the PGCE lecturers and as the researcher. This commented on each participant in terms of their mathematics and instructional behaviour profiles according to my experiences and assessments of them and in response to their own reflections. The data reduction in this

chapter has drawn on those first two data reduction processes and summarised the mathematics profile and instructional behaviour profile of each participant. This was first done verbally (guided by data analysis tables for each of the mathematics profile components and instructional behaviour continuums) and then presented visually for the purposes of making the cross-case comparison simpler and more effective. Three of the four main aspects that emerged out of the cross-case comparison foregrounded the importance of the influence of subject matter knowledge, quality and insight of reflections and accessing and processing literature in the mathematics and mathematics education domain. The fourth aspect highlighted that the impact of the pedagogical content knowledge component of the mathematics profile on pre-service teachers' instructional behaviour was less than expected. These four main aspects are further discussed in the concluding reflections chapter 7 with reference to the conceptual framework.

CHAPTER SEVEN   CONCLUSION

7.1 Introduction

In this chapter I conclude that the focus in training pre-service mathematics teachers may benefit from shifting the focus from reforming their instructional behaviour to ascertaining and optimising their mathematics profiles. I investigate the relationship between the mathematics profiles of pre-service mathematics teachers and their instructional behaviour. Pre-service teachers with a stronger mathematics profile demonstrated greater positive changes in their instructional behaviour towards a more reformed and democratic style of teaching and learning. Put another way, a stronger mathematics profile may result in positive reform in pre-service mathematics teachers' instructional behaviour.

This final chapter serves to draw together the research question, the process of the research, the research findings, conclusions and recommendations that emerged from the study. A summary of the study is presented in section 7.2, followed by a discussion of the research findings in section 7.3. In sections 7.4, 7.5 and 7.6 scientific, methodological and personal reflections about the findings are provided. In presenting these reflections I attempt to demonstrate and so offer ontological credibility to the value of the reflective process by subjecting myself as the researcher and a mathematics teacher to a reflective exercise. The chapter closes with recommendations for policy and practice and further research and development work.

7.2 Summary of the research

The purpose of this research was to investigate how the mathematics profiles of pre-service teachers influence their instructional behaviour. This was done by compiling a mathematics profile and instructional profile for each participant and examining the relationship between these two constructs. Participants all completed their Post Graduate Certificate in Education at the same institution specialising in teaching mathematics in Further Education and Training Phase. Each year the PGCE students are required to compile a series of professional portfolios

over the year, which demonstrate their professional growth. At the end of the year, instead of writing a summative examination the students compile a final portfolio consisting of a selection of reflections, learning task designs, video-recorded lessons, experiences and any other information they want to include. Students were instructed to make use of a metaphor to assist them in guiding the reader of the portfolio through the storyline. Once the PGCE students had been assessed, they were requested to make their portfolios available to me for the purpose of the study. These portfolios then became my main source of data. I also supplemented this data set with data from my own assessments, observations and experiences of the students as well as assessment reports I had from the other lecturer who assisted me with the module while I was on study leave.

The Post Graduate Certificate in Education taught at a large university in South Africa formed the context for this study. This is a one-year diploma for which students enrol for as a means of qualifying as a teacher, once they have gained an initial undergraduate degree. The focus of this course is therefore not on subject matter knowledge as the assumption is that students would have covered this in their degrees. The course rather aims to prepare students more in terms of pedagogical content knowledge and learning theories in education. Students complete a number of professional modules, which pertain to more generic educational principles such as assessment, diversity within the classroom, facilitating learning and compiling their professional portfolios. They are then also required to take certain specialisation modules according to the phase and subject(s) in which they intend specialsing. Intermediate and Senior Phase students specialise in two subjects during the year, while the Further Education and Training students only specialise in one subject. When the students are not on their school-based practical periods at the school, they spend intensive time at the university completing theory and assignments relating to their professional and specialisation modules.

Each of the participants was introduced in chapter 3 of this report with a "sneak preview" of what their initial mathematics profiles looked like visually. Some background on each student was provided as presented by the students in their portfolios. The metaphors students used in taking the reader through their portfolios were also briefly outlined. This personal account of each participant was intended to provide readers of this study with a personal frame of reference for the participants as if they were almost being introduced to them personally. For

confidentiality purposes, photographs could not be used but the "shots" of the visual mathematics profiles were included to personalise each participant.

A qualitative case study design was used as the research methodology for this exploration. The case study was carried out retrospectively or post-hoc, in that the data set was only analysed once the students had completed their PGCE course. A slightly alternative data collection technique was used in this qualitative approach. Although the research was conducted in a social constructivist paradigm, interviews were not conducted with any of the participants. As mentioned, the final portfolios that participants handed in were the main source of data. This means that the participants themselves initially selected the "data" they chose to present. I then did the first data reduction in selecting reflections and other entries from participants' portfolios to compile the participant reflections in chapter 4. These were taken directly from the portfolios and written in the voice of each participant. The second data reduction was done in writing the researcher reflections in chapter 5. These reflections were written as a response to the participant reflections based on my experiences and assessments of the participants as their specialisation lecturer. In the third data reduction, the participant and researcher reflections were deductively analysed using the relevant categories discussed in the literature in chapter 2. This analysis was then presented visually displaying an initial and final mathematics profile for each participant and placing each of these in a sub-quadrant on the instructional behaviour Cartesian plane. This plane was made up of the traditional/reform teaching continuum (*x*-axis) and authoritarian/democratic learning continuum (*y*-axis).These visual representations facilitated the cross-case comparison.

7.3 Summary of research findings

Four main aspects emerged from the comparison. Firstly, the component of subject matter knowledge does appear to play an important part in enabling or constraining the changes in pre-service mathematics teachers' instructional behaviour. Secondly, I am suggesting that not just reflecting on one's practice/experiences but that the quality of these reflections may affect the extent of positive change pre-service teachers make in their instructional behaviour. Thirdly, I suspect that encouraging students to access and read more literature in the mathematics and mathematics education domain is something that could be considered

developing and improving pre-service teachers' mathematics profiles, with particular reference to their conceptions and beliefs. Finally, it appears that an improvement in pre-service teachers' pedagogical content knowledge does not necessarily have the extent of influence on changing their instructional behaviour that was expected.

These four aspects have important implications for training mathematics teachers in the Further Education and Training Phase. As I reflected on the current intended outcomes and content of the PGCE course that forms the context for this study, I realised that we spend most of the year focusing on improving the pedagogical content knowledge of our students (both general and more domain specific) and on training them to approach teaching and learning in a more reform and democratic-orientated way. Research (e.g Ernest, 1989; Boaler, 2002) indicates that this type of approach to teaching and learning is more likely to result in independent and critical-thinking learners. What I have realised from this study though, is that the mathematics profile appears to have more of an influence on the instructional behaviour of students than I originally anticipated. As long as we continue trying to focus on training and changing the instructional behaviour of our students without considering their mathematics profiles, we will not be able to achieve our intended outcomes. I am therefore suggesting that evaluating students' initial mathematics profiles and then working to improve and expand the necessary components may be more effective in reforming students' instructional behaviour. The emphasis on improving pedagogical content knowledge without considering students' conceptions of mathematics and their beliefs about the teaching and learning of mathematics does not appear to enable this intended reform. The issue of how best to assist students who exhibit conceptual gaps in their subject matter knowledge also needs to be considered owing to the enabling or constraining impact of this component suggested in this study. In the following discussion these final conclusions are now expanded on in relation to findings from other studies and the broader body of literature.

7.4 Discussion of research findings

The research question guiding the study was:

> *How does the **mathematics profile** of a pre-service teacher of mathematics influence their instructional behaviour?*

a) *How are the mathematics profiles of PGCE pre-service mathematics teachers reflected in their instructional behaviour?*

b) *What similarities or incongruities are there between the pre-service teachers' instructional behaviour and the mathematics profiles they portray?*

c) *Are differences among the pre-service teachers in their instructional behaviour related to differences in their mathematics profiles?*

Before discussing the research findings, two important limitations of the study need to be highlighted. Firstly, as this was an explorative case study, only 7 participants were included in the sample. This allowed me to present in-depth narratives on each participant but carries the inherent constraint of generalisability of the results. Secondly, in terms of the mathematics profiles, it was not possible to represent any change in participants' subject matter knowledge as this is not in any way a focus of our PGCE course. The subject matter knowledge representation for each participant was decided upon by examining the types of errors that participants made in their baseline assessments, their Learning Task Designs and their video-recorded or observed lessons. As the PGCE course does not directly address the issue of mathematics subject matter knowledge, and due to the nature of how I chose to represent this component (focusing on the types of errors as an indicator of their mathematical understanding), I viewed this component more or less as a constant, rather than changing component of the profile. The participants' knowledge of mathematics content probably did improve during the course as they were confronted with teaching various content. However, as I outlined and represented their subject matter knowledge (based on Ball and Skemp's work and drawing on the types of errors), the extent of their content was not the focus for this exploration but rather their understanding of the subject (instrumental or relational) demonstrated by the types of errors and the lessons they designed and presented. This interpretation of subject matter knowledge is seen as a limitation in terms of the complexity of the construct in comparison to the limited view I was able to apply in this study. With these limitations on the table, the research findings are now presented.

In addressing the first specific question, it appears that the mathematics profile of a pre-service teacher of mathematics at secondary school has a considerable influence on their instructional behaviour. The visual representations suggest that *the participants who made the most*

substantial changes in their mathematics profiles also made the most significant changes in their instructional behaviour. I do not argue for a mathematical direct proportion here in that more changes in the mathematics profile imply more changes in the instructional behaviour. Rather I am foregrounding the trend that the students with final mathematics profiles with components predominantly in the third or fourth category (see Figure 7.1) demonstrated the most movement in terms of their instructional behaviour. Students' whose final mathematics profiles were predominantly in Category 1 and/or 2 of each component similarly demonstrated the least movement in their instructional behaviour. This implies that focusing on all of these components of the mathematics profile in teacher training is an important aspect in reforming pre-service teacher's instructional behaviour.

Category   1   2   3   4
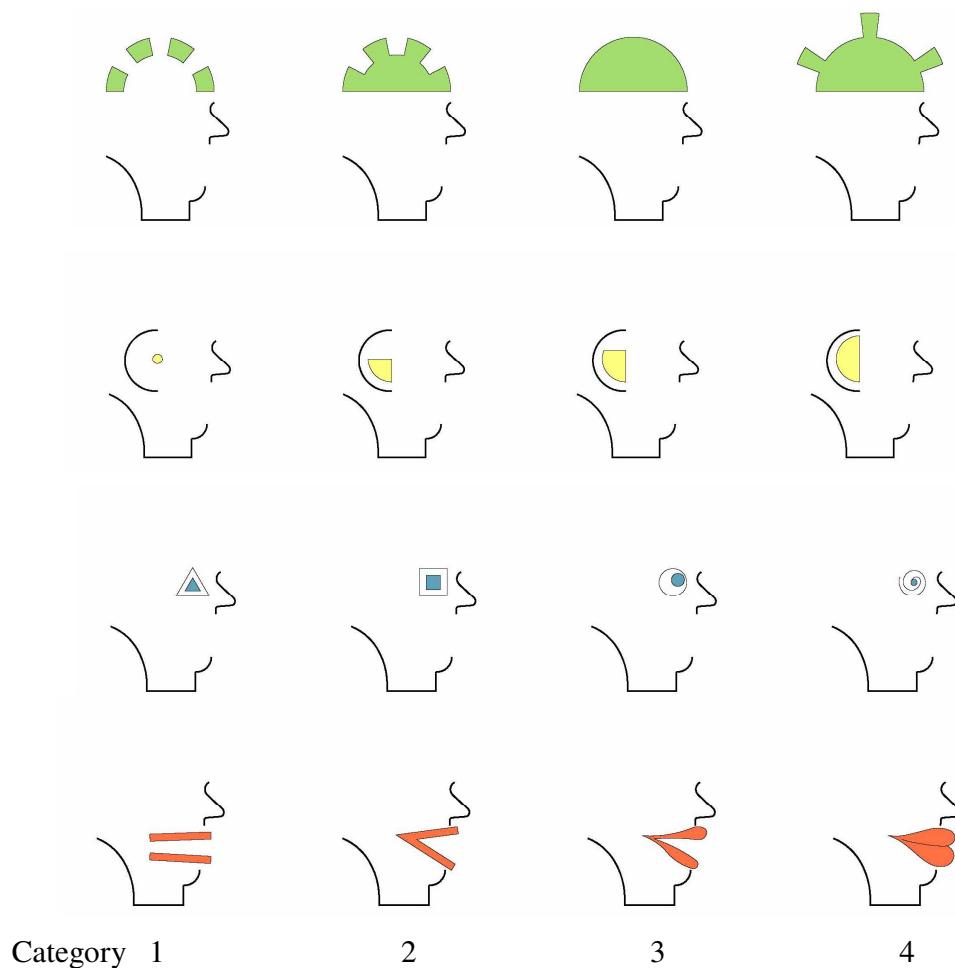
Figure 7.1 Illustration of the four categories of each component of the mathematics profile

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Pertaining to the second specific question, there are two examples of where I see *incongruities between the instructional behaviour and the mathematics profiles of participants*. These are Lena and Kapinda. Both of these participants had final mathematics profiles suggesting good subject matter knowledge and almost complete pedagogical content knowledge but with an instrumentalist conception of mathematics and displaying the role of instructor in their beliefs about the teaching and learning of mathematics. I expected that both of these students would have made more movement on both instructional behaviour continuums due to their strong subject matter and pedagogical content knowledge. However, their strengths in these components did not necessarily enable them to develop learning tasks for their learners that demanded modelling and exploration or ask questions that commanded high-level reasoning from their learners. They both remained evaluative listeners throughout the year with a focus on mastering of content. This is what prevented my placing their final instructional behaviour profiles on the positive side of either of the instructional behaviour continuums. I suggest that this limitation in their instructional behaviour was a result of their inability to make further changes to their conceptions of mathematics and their beliefs about the teaching and learning thereof. Simply having adequate subject matter and pedagogical content knowledge did not seem to be enough to "override" the apparent lack of change in the last two components of their mathematics profiles.

Finally with regard to the third specific question, the *difference among the students in their instructional behaviour does certainly appear to be related to the differences in their mathematical profiles*. My understanding of "related" is that while the differences in students' instructional behaviour do appear to have been impacted by their mathematical profiles, there are also a range of other factors that can also affect this relationship. These could include differences in personality, different personal circumstances each student encountered during the year, various factors related to the schools and the learners where students carried out their school-based experiences, students' experiences of mathematics at school and university, gender and emotional intelligence. However, none of these factors was the focus of this study. Therefore while I am acknowledging that they may play a role, it was not my intention to go beyond the scope of components or factors that pertain directly to our training at the university.

Within the scope of this study the role of the quality of reflections kept by students during the year seemed to emerge as an important aspect that could also account for differences in students' instructional behaviour. There appears to be a resemblance between the quality, insight and critical level of students' reflections and their differences in instructional behaviour. The ranking of students according to the above-mentioned levels of their reflections is similar to the ranking of students according to the extent of change in their instructional behaviour over the year. This could either indicate that quality of reflections plays an important role in changing the instructional behaviour of students or that students who are able to engage in quality reflections are also the most likely to alter their instructional behaviour. This is further discussed below in section 7.5.

7.5 Reflection on conceptual framework

For this section I reflect on the findings discussed in relation to the conceptual framework presented in chapter 2. The conceptual framework draws predominantly on the work of Ernest (1988, 1991) supplemented by other researchers such as Ball (1988a, 1988b, 1990), Hill et al. (2008), Thompson (1984), Thompson et al. (1994), Shulman (1986), Mason (1989) and Veal and MaKinster (2001) in the various components that make up the mathematics profile and Goldin (2002) and Davis (1997) in the instructional behaviour components.

In general the findings from this study concur with the conceptual framework. Hill et al. (2008) also illuminated claims that teachers' subject matter knowledge plays an important role in their teaching of mathematics. Thompson (1984) established the relationship between the conceptions which teachers hold of mathematics and how this affects their instructional behaviour. As Ernest (1988, 1991) and Ball (1991) also proposed, there is an interaction between pre-service teachers' knowledge of and about mathematics, their assumptions and explicit beliefs about teaching and learning and their conceptions of mathematics that shapes the way in which they teach mathematics to learners. In this study, however, the improvement of pedagogical content knowledge (Shulman, 1986) without a positive change in the other components of the mathematics profile did not appear to result in extensive reform within the instructional behaviour of the participants.

However, I want to foreground one of the four main results that emerged from the cross-case comparison mentioned in section 6.3 that is not explicit within the conceptual framework. This pertains to *the quality, insight and critical or analytical value of the participants' reflections presented in their portfolios*. There appeared to be a similarity (although not a point-to-point mathematical mapping) of the ranking of participants in descending terms of the quality of their reflections and the extent of change in their instructional behaviour. The two students who wrote the most analytical, insightful and critical reflections were also the students who made the most substantial changes in reforming their instructional behaviour, while the two students on the other end of the reflections ranking also made the least changes in their instructional behaviour.

The quality of reflections is not a component that I had included as part of the conceptual framework. However, reflections formed a large part of the data I analysed using the framework. In revising the conceptual framework I suggest that 'quality of reflections' should form the central part of improving each of the four components of the profile (see Figure 7.2). Teaching students to be more critical and analytical in their reflections, and focusing their reflections on the four components of the mathematics profile is a tool that can be used to help optimise the strength of pre-service teachers' mathematics profiles. According to the results from this study, stronger mathematics profiles subsequently result in more positive reform within the instructional behaviour of pre-service mathematics teachers. The grey arrow in the conceptual framework in Figure 7.2 indicates the intent of this study to explore this influence of the mathematics profiles on the instructional behaviour. The black arrow in the updated conceptual framework depicts the influence that has been suggested through the results of this study.

Mathematics profiles

Instructional behaviour

Subject matter knowledge

Beliefs regarding teaching and learning

Quality of reflections

Conceptions of mathematics

Pedagogical content knowledge

Teacher's mathematics education ideology

Learners' mathematical experiences

Learner-centred

Traditional   Reform

Teacher-centred
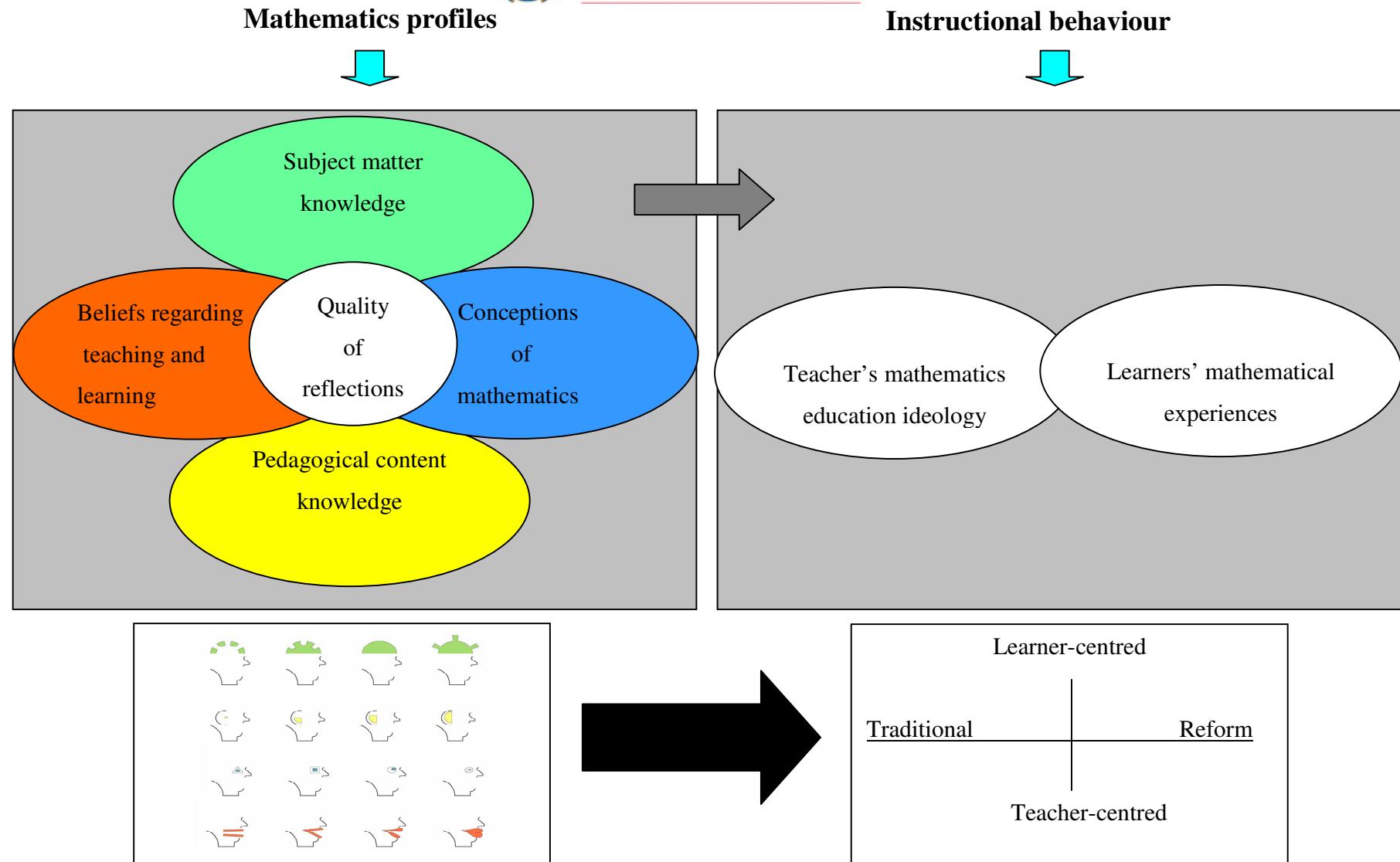
Figure 7.2 Adapted conceptual framework

The importance and quality of reflections was not an issue I addressed in the literature review as this emerged as an important factor only on completion of the analyses. I therefore now review the literature in relation to this. Returning to the literature led me to three important writings: work by Skemp (1971; 1989) on reflective intelligence, a study by Cady, Meier and Lubinski (2006) on the effect of locus of authority in sustaining reform practices in mathematics teachers and the link between mathematisation and reflection (Perry & Dockett, 2002). In the discussion that follows I elaborate on this literature. In so doing I offer credibility to my argument that the conceptual framework described in chapter 2 will be significantly enhanced through an integration and embedding of the reflective process in the training of pre-service mathematics teachers.

Skemp (1971) took the term known as "reflective intelligence" from Piaget. Skemp (1989) differentiates between a delta-one level in "which we are centring consciousness on a task to be done" (p. 106). However in a delta-two level, "our consciousness is directed towards the methods themselves, devising new ones, comparing them in terms of their relative merits, and also testing their validity. While the first level includes routine processes, and also intuition, by which we arrive at new ideas or methods without necessarily knowing how we got there, the second level is that of reflective intelligence. Using this definition I think it would be fair to say that students who presented better quality reflections demonstrated more use of the second level reflective intelligence than those participants who were focused on the routine processes of reporting on the events that happened in the class and how they handled them rather than the understanding thereof. This seemed also to be reflected in participants' profiles overall as it played out in: the instructional behaviour as more traditional teaching (mastering content as the focus with no exploration into the understanding of how and why), their mathematics profiles as less relational subject matter knowledge and, as an absolutist or instrumentalist view of mathematics in terms of their conceptions of mathematics. This foregrounds for me even more the importance of students learning not only to reflect during their PGCE year (as this could just remain on level 1 as indicated above) but rather to gain reflective intelligence.

In recent years, some authors have referred to reflective intelligence as meta-cognition or meta-cognitive processes (for example Perkins, 1995; Skemp, 1989). In the current PGCE

course the students are actually required to include meta-learning or meta-cognition in their learning task designs as the year progresses. However, many of the participants in this study viewed this as the learners thinking about or doing a calculation individually before moving into groups to continue working on the problem. This view means that learners were still remaining on level 1 of Skemp's definition above rather than reflective intelligence. I intend to adopt Skemp's terminology and definitions for a dual purpose within my own PGCE specialisation module in the future. I plan to use it as guidance for the students to reflect more effectively to enhance their mathematics profiles and to provide them with a tool to make use of in improving the independent thinking and reasoning skills of their learners. Doing this within the context of the subject domain of mathematics may possibly also serve as a means to improve students' relational subject matter knowledge and bring their conceptions of mathematics to the fore so that these can also be challenged and reflected on.

Cady, Meier and Lubinski (2006) conducted a longitudinal study on the development of mathematics teachers from pre-service to experienced teachers. The study focused on using the philosophy of cognitively-guided instruction (CGI) and mathematics practices recommended by the National Council of Teachers of Mathematics (NCTM) in the United States. They cite pre-service teachers' prior experiences as learners and students of mathematics, their beliefs and preconceptions about teaching and learning mathematics, their traditional views on teaching, their anxiety about doing mathematics and their lack of mathematical knowledge "rich in connections" (p. 296) as factors limiting the pre-service teachers learning alternate ways of teaching mathematics (Ball, 1990).

During the study researchers ascertained that the pre-service participants became focused on their learners' thinking, became reflective about their own practice and adopted practices in line with recommendations from current research. This shift, though, was limited to the school-based periods within their final year as pre-service teachers. This trend was not sustained within their transition into first-year teachers. However, after a period of six years, some of the participants showed a movement back towards the reform practices and approaches to which they had been exposed at university. Making the move back towards these approaches depended on whether or not the teachers had developed an internal locus of authority (relying on an internal decision-making process) or if they still depended on an

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external locus of authority where they were still seeking external affirmation to ensure they were doing the "right" thing. Teachers who demonstrated the former (which corresponds with a higher level of intellectual development) were the ones who were able to incorporate reform practices into their teaching of mathematics.

In their paper, Cady et al. (2006) used the concept of locus of authority to determine the intellectual development of their participants "from accepting knowledge from authorities to constructing one's own knowledge" (Baxter Magolda & King, 2004; Perry, 1970 as cited in Cady et al., 2006, p. 296). They base this on the fact that students' "ways of knowing" (their epistemic assumptions) influence the way in which they interpret information presented to them in their courses at university. At universities our ideal is to get students to reflect on and critically evaluate different perspectives rather than the reality of many students who still view knowledge as absolute and certain. These students in turn believe that the lecturers or teachers are the authorities who hold the knowledge they as students simply need to acquire and reproduce. As students intellectually mature, however, they are able to defend their own opinions using reason and logic. They develop an internal locus of authority that no longer attributes the source of all knowledge to an external authority such as the lecturer.

Cady et al.'s study (2006) again highlights the importance of getting students to reflect critically as a means of establishing an internal locus of authority. This internal locus of authority appears to facilitate a sustained effect of the teacher training courses on the instructional behaviour of the pre-service teachers once they enter the teaching profession. The idea of reflective practice in teacher education is not new (e.g. Adler et al., 2005; Henniger, 2004; Korthagen, 2001; Schielack & Chancellor, 1994) but the results of this study concurring with those of Cady et al. (2006) foreground the importance of the *quality* of this type of reflective activity and intelligence and the possible effect thereof in reforming and sustaining this reform in pre-service teachers' instructional behaviour.

According to Perry and Dockett (2002) mathematisation always goes together with reflection. As they put it,

> *This reflection must take place in all phases of mathematisation. The students must reflect on their*
> *personal processes of mathematisation, discuss their activities with other students, evaluate the*

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products of their mathematisation, and interpet the result. Horizontal and vertical mathematisation comes through students' actions and their reflections on their actions. In this the activity of mathematisation is essential for all students – from an educational perspective. (p. 80)"

Mathematisation is a term from within the theory of Realistic Mathematics Education (RME) which has its roots in Hans Freudenthal's interpretation of mathematics as a human activity (Freudenthal, 1973; Gravemeijer, 1994). To this end, Freudenthal accentuated the actual activity of doing mathematics: an activity, which he propagated should predominantly consist of organising or mathematising subject matter taken from reality. Learners should therefore learn mathematics by mathematising subject matter from real contexts and their own mathematical activity rather than from the traditional view of presenting mathematics to them as a ready-made system with general applicability (Gravemeijer, 1994). These real situations can include contextual problems or mathematically authentic contexts for learners where they experience the problem presented as relevant and real.

The verb *mathematising* or the noun thereof *mathematisation* implies activities in which one engages for the purposes of generality, certainty, exactness and brevity (Gravemeijer & Cobb, 2002). Through a process of progressive mathematisation, learners are given the opportunity to reinvent mathematical insights, knowledge and procedures. This is similar to the process Ernest (1991) presents as the interaction between objective and subjective knowledge. In doing so learners go through stages referred to in RME as horizontal and then vertical mathematisation (see Figure 2.1). *Horizontal mathematisation* is when learners use their informal strategies to describe and solve a contextual problem and *vertical mathematisation* occurs when the learners' informal strategies lead them to solve the problem using mathematical language or to find a suitable algorithm (Treffers, 1987). For example, in what we would typically refer to as a "word sum", the process of extracting the important information required and using an informal strategy such as trial and error to solve the problem, would be the horizontal mathematising. Translating the problem into mathematical language through using symbols and later progressing to selecting an algorithm such as an equation could be considered vertical mathematisation*,* as it involves working with the problem on different levels (Barnes, 2004).

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During the analysis of this study I realised that while I, year after year, introduce my PGCE students to the Theory of Realistic Mathematics Education, I have not tried to use it as an approach to simultaneously improve their reflective abilities and understanding of mathematics while also modelling for them teaching and learning strategies they can employ in their own facilitating of learning. Mathematisation can therefore be considered as a possible way forward in improving the mathematics profiles of pre-service teachers with the intended outcome of significant and sustained change in their reflective intelligence, locus of authority and instructional behaviour.

Having elicited and understood the importance of quality critical and analytical reflections in strengthening the mathematics profiles and subsequently the instructional behaviour of pre-service mathematics teachers, I now employ my scientific finding to the following two sections. In sections 7.5 and 7.6 I offer methodological and personal reflections respectively on how the results of this study pertain to my "profile" and "instructional behaviour" as a researcher and as the mathematics specialisation lecturer for the PGCE. I present these reflections in the same font I used to depict the personal reflections of the participants in Chapter Four. In so doing I subject myself to a similar reflective process as that of the participants. Further, my aim is to apply the conceptual framework as I have developed it. While I cannot show here that this process will necessarily reform my instructional behaviour as a mathematics teacher, I can expose my growth as a researcher. I suggest that such growth will have a positive impact on my instructional behaviour.

7.6 Methodological reflection

This research was conducted as an explorative investigation to compile initial and final mathematics profiles for each participant and then try to understand the influence thereof on their instructional behaviour. The research approach has been labelled a post-hoc case study. The seven case studies were carried out retrospectively in that the final profiles handed in by participants were the main source of data. These data were only accessed and analysed once the participants had completed the course, the assessment on their portfolios had been completed and permission had been obtained from them to make use of their portfolios as data.

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Participants therefore took part in the study indirectly through their final portfolios and by simply being part of the mathematics specialisation module.

This post-hoc aspect of the research design liberated me (as the researcher and lecturer) from having to deal with or consider the power relationship that can form between students and researchers when the researchers are also the lecturers of the students. Students all filled in ethical consent forms for their portfolios to be used only when their final portfolios had been submitted and assessed. Another interesting facet of this part of the design is that students did not actually prepare their portfolios (or any of the data) for a research study as such. They went through their PGCE course meeting the usual requirements of the course and compiling their final portfolios to be assessed by the course leader, specialisation lecturer and external examiners. They therefore presented and defended their professional development for a public forum but not with the intent of providing the researcher with what he or she wanted to hear. This is often an interplay one needs to consider during classroom observations and interviews in qualitative research. Rather, I would say that these participants put together their portfolios to meet the PGCE course requirements and to pass the course. However, this also presents its own limitations for my research in terms of the data I had available to work with.

Although I have constructed mathematics profiles for each of the participants, I could only work with data that I had from their PGCE year. Therefore where there were silences or gaps or questions that came up, I could not delve deeper into these issues owing to the self-imposed methodological decision I had taken not to interview students. At the beginning of the research, I considered using the data I had (post-hoc) but where I wanted to know more I decided I would conduct interviews with the students in their present circumstances. However, I later took a methodological decision to keep the entire analyses post-hoc in order to maintain consistency and avoid the dynamic that may arise with the few months of teaching experience (or other work experience) participants would have by the time the interview took place.

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An interview would also bring back the dynamic of participants perhaps wanting to give the "correct" rather than perhaps transparent responses to their former mathematics specialisation lecturer; something I was pleased to have excluded in this study.

The construction of the profiles was not as scientifically controlled as I would perhaps have wanted. For example, not all the participants taught at the same schools or the same grades or the same topics. Some were given mathematical literacy classes to teach while others took responsibility for mathematics classes. Some were immediately given Grade 12 classes while others spent most of the year working with Grade 8 and 9 learners. Some of them had supportive and experienced mentors while others had mentors who had only qualified as teachers recently. I also seldom ever observed them teaching the same content. Of course, the results would be much more reliable if I could have controlled more of these above-mentioned variables. But this was not possible, nor probable considering the design of the PGCE course. I therefore want to reiterate that the profiles are a general classification of each participant based on their reflections of themselves, my reflections of them and the deductive data analysis process I followed (guided by the literature from chapter 2) in constructing the visual profiles.

7.7 Personal reflection

I have observed, not only with other people but also with myself…, that sources of insight can be clogged by automatisms. One finally masters an activity so perfectly that the question of how and why [students don't understand them] is not asked anymore, cannot be asked anymore and is not even understood anymore as a meaningful and relevant question (Freudenthal, 1983, p.469).

This quote from one of my favourite mathematics authors, Hans Freudenthal, captures the essence of the results of this study which presents as two different sides of the same coin. On the one side, our PGCE course accepts students who have an undergraduate degree in mathematics (and therefore we assume have 'sources of insight' into mathematics) and we spend the year giving them 'sources of insight' into

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pedagogical content knowledge and instructional behaviour. On the other side of the coin, the pre-service teachers in turn go off into schools to become 'sources of insight' into mathematics for their learners who don't appear to really be treated as 'sources of insight' themselves! I believe all these above-mentioned 'sources of insight' have become clogged by automatisms to some extent. Seeing the influence of the participants' initial and final mathematics profiles on the changes in their instructional behaviour has encouraged me to start asking the question of 'how and why'.

Our students arrive in our course with some sort of minimum undergraduate qualification in mathematics and yet some do not even, for example, know why one chooses to multiply fractions when in fact the calculation desired is division, or why one adds the exponents when multiplying the same bases or, as I started this report, how one mathematically determines whether the gradient of a straight line is positive or negative if you have forgotten the rhyme, rule or story someone once taught you to help you remember this. From research (for example Ball, 1988a, 1988b, 1990, 1991; Ball & Cohen, 1999; Grossman et al., 1990; Ma, 1999; Rowland et al., 2001) we know that the quality and extent of pre-service mathematics teachers' subject matter knowledge exerts an influence on the quality of their teaching. However, our course is not 'automated' to deal with this specific component of the mathematics profile as we assume it has been dealt with in the undergraduate programme. We don't ask 'how and why' anymore as our task is focused on training them in how to facilitate learning and in improving their pedagogical content knowledge. What this study has certainly highlighted for me is that there is empirical evidence from these particular case studies that subject matter knowledge remains an important component of the mathematics profile that can enable or constrain positive changes in the instructional behaviour of students. We therefore need to begin asking 'how' we can address improving the subject matter knowledge of pre-service teachers due to the relevance thereof, rather than consider this an irrelevant question as this training should already be complete by the time the students reach our course.

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The particular approach we use in our PGCE course has also run the risk of becoming 'automated'. Students have to comply with learning task designs that include a verbal presentation of a problem, a written presentation for the learners, feedback, consolidation and various other criteria that are deemed important in facilitating learning. Students are also required to keep daily (where possible) reflections of their school-based experiences so that these can feed into constructing and improving their practice-theories. Students are given a core set of concepts that they must include in their practice-theory concept maps and arrange according to their experiences and beliefs, but they actually only have autonomy in arranging, linking and adding to the concepts, rather than actually selecting them for themselves. In addition to this, students are expected (in theory) to access, read, understand and incorporate additional literature from the particular subject domain as they encounter problems or challenges in their practice. The research (other studies and theory) is supposed to then assist them adapting and refining their practice so that this becomes a continual reflexive action between the theory and their practice. This study has foregrounded how all these processes can be followed (albeit superficially) thereby meeting the necessary criteria to pass the course, but with students actually leaving the course without having made substantial progress or changes to their instructional behaviour. The ideals of using reflections analytically and literature reflexively are important ideals (as the results appear to indicate) but I suspect that with many students, these potential 'sources of insight' too have become 'clogged by automatisms', with students (and perhaps even lecturers) not necessarily understanding 'how or why' these ideals are being encouraged.

Instructional behaviour that is dominantly defined by a reform teaching approach (see section 2.3.5) and one that encourages more democratic learning opportunities for learners has been shown to be a positive approach in developing independent and critical learners who in turn become 'sources of insight' (e.g. Boaler, 2002; Ma, 1999; Pimm, 1987; Stigler & Hiebert, 1999). However, none of the participants in this study

was able to optimally (for pre-service level) interact with the learners in a manner that indicates that they actually believe the learners are 'sources of insight' (a reform teaching ideology). As teachers, the students predominantly behaved as the central 'sources of insight' in their classrooms (thereby creating fewer democratic learning opportunities for their learners). I draw on the following quote from Stigler and Hiebert, 1999, p. 25) to further illustrate this. In their study of a series of TIMSS videos one of the professors summarised the main differences among the teaching styles of Japan, Germany and the United States of America as follows:

> In Japanese lessons, there is the mathematics on one hand, and the students on the other. The students engage with the mathematics, and the teacher mediates the relationship between the two. In Germany, there is mathematics as well, but the teacher owns the mathematics and parcels it out to students as he sees fit, giving facts and explanations at just the right time. In U.S. lessons, there are students and there is the teacher. I have trouble finding the mathematics; I just see interactions between students and teachers.

In my opinion the way the Japanese lessons have been described in this quote indicates to me that the learners are treated as 'sources of insight' whereas in the German and U.S. lessons, the teachers remain the 'sources of insight'. In this study I would say that most of the participants' instructional behaviour remained typical of lessons in these latter two countries. This highlights for me the importance of the beliefs about the teaching and learning of mathematics component of the mathematics profile. One cannot assume that this will automatically be addressed as one focuses on equipping students for a reform/democratic instructional behaviour, but rather address this directly within the course along with the component on students' conceptions of mathematics. Even with strong, relational subject matter knowledge this beliefs component appeared to constrain either Marge or Toni from optimising their instructional behaviour approaches on either of the reform and democratic continuums.

Finally, the results of this study have shown me that my own 'sources of insight' have become 'clogged by automatisms'. I initially developed and have taught the specialisation module of the PGCE course for six years and have perhaps mastered

the activity to such an extent that I stopped asking 'how and why' even though for the past few years I have suspected that I need to be focusing more on what I then referred to as the 'mathematical make-up' of students in order to improve the extent of positive changes in their instructional behaviour. The apparent lack of observable changes in teaching and learning styles in South African mathematics classrooms, even with our country adopting the philosophy of Outcomes-based education, made me curious about how the mathematical make-up of our students would either enable or constrain these students in making the necessary changes in their instructional behaviour. This study has allowed me to conceptualise the notion of mathematics profiles and gain a better understanding of how I can focus on the components thereof in my own module as a means to positively effecting changes in students' instructional behaviour.

7.8 Conclusions and recommendations

From the analyses of the cases in this study, my view of *how the mathematics profile of a pre-service teacher of mathematics influences their instructional behaviour* can be summarised as follows:

- *Conclusion 1*

  Changes in the mathematics profiles of students appear to also result in changes in their instructional behaviour. Strong relational subject matter knowledge appears to play an important role in either constraining or enabling changes in pre-service teachers' instructional behaviour.

- *Conclusion 2*

  A mathematics profile containing a combination of good subject matter and pedagogical content knowledge alone is not sufficient to ensure substantial change in students' instructional behaviour.

- *Conclusion 3*

  The components of conceptions and beliefs seem to have an impact on either further enabling or constraining the resulting instructional behaviour.

- *Conclusion 4*

Evaluating and working with the mathematics profiles of pre-service teachers of mathematics (in the Further Education and Training Phase specifically) can therefore be deemed to be a potentially viable approach to training pre-service teachers of secondary school mathematics.

In my understanding of the thrust of the developing literature within the domain of mathematics recently, in order to produce critical mathematical thinkers from our schools, the philosophy of Outcomes-based education is not the solution. It is also not the problem or a hindrance. It is perhaps just another 'source of insight that has become clogged by automatisms' (to use Freudenthal's words again from section 7.7) where we no longer ask the important question of how and why is this enabling us to develop life-long learners who are also critical and independent thinkers. In my opinion Outcomes-based education is a philosophy of education and you cannot force such a philosophy on teachers or pre-service teachers if they do not believe in it. It is also difficult to show teachers exactly what Outcomes-based education looks like in terms of instructional behaviour. It has many disguises such as group work, recognisable outcomes and using a hands-on and learner-centred approach but these are not really the core of the philosophy. The core of it centres around enabling all learners to achieve their maximum ability. Spady (1994, p.1) defines OBE as:

> *…clearly focusing and organizing everything in an educational system around what is essential for all students to be able to do successfully at the end of their learning experiences. This means starting with a clear picture of what is important for students to be able to do, then organizing the curriculum, instruction, and assessment to make sure this learning ultimately happens.*

Killen expands on this definition and goes on to say that three basic premises underpin OBE (Killen, 2002):

o   All students can learn and succeed, but not all in the same time or in the same way.
o   Successful learning promotes even more successful learning.
o   Schools (and teachers) control the conditions that determine whether or not students are successful at school learning.

By placing such a large focus on OBE, we are asking teachers to support this belief (and therefore also the philosophy) when in fact many of them perhaps don't believe this, not even the 'fresher' pre-service teachers entering the universities.

In mathematics education it would suffice if we could embark on co-operative developmental research between the different universities in South Africa in constructing: an instructional behaviour profile that we would like to see our students progressing through and optimising in their training at university and also as they enter the profession. Similarly through a series of projects we could investigate the mathematics profile pre-service (and perhaps later in-service) teachers require, that would allow them to optimise their instructional behaviour. This could help us to establish some policy guidelines in terms of training of pre-service teachers of mathematics at tertiary institutions across South Africa with the intention of improving the quality of the teaching and learning of mathematics and in so doing also the performance of our learners in mathematics. These guidelines could draw on the importance that has been highlighted by this study of:

- teaching students to be more analytical and critical through reflections in order to develop an external locus of authority;
- the role that conceptions of mathematics and beliefs regarding the teaching and learning mathematics play in either enabling or disenabling reform in pre-service teachers' instructional practice;
- encouraging students to address these beliefs and conceptions through accessing literature and reflecting on their practice in relation to the literature;
- the advantage of a strong mathematics subject matter knowledge in enabling pre-service teachers to reform their instructional behaviour;
- placing less emphasis on the component of pedagogical content knowledge and trying to reform the instructional behaviour of pre-service teachers without considering the other components of the mathematics profile package.

From the reflections on the conceptual framework in section 7.5, I propose that the theory of Realistic Mathematics Education could also be considered as a useful approach to improving the training of pre-service mathematics teachers at secondary level. The strong link between mathematisation and reflection (Perry and Dockett, 2002) suggests that this theory provides a

vehicle through which all four of the components that make up the mathematics profile can be addressed while encompassing the guidelines highlighted above. Implementing the theory of Realistic Mathematics Education in the training of pre-service teachers would also provide them with a tangible framework and model to employ in their own instructional behaviour.

Regarding further research and development work, this exploratory study has introduced the idea and some understanding of the influence of pre-service teachers' mathematics profiles on their instructional behaviour. The trend mentioned in 7.3 relating to subject matter knowledge and the quality of reflections is something that warrants further investigation. The two students who wrote the most analytical, insightful and critical reflections were also the students who made the most substantial changes in their instructional behaviour, while the two students on the other end of the reflections ranking also made the least changes in their instructional behaviour. This was also the case regarding the subject matter knowledge of the same participants. Does this mean that students with stronger relational subject matter knowledge are able to reflect better than those with conceptual gaps in their understanding? Or is it that students who reflect better are at an advantage in terms of changing their practice? Or perhaps it could be a combination of both. These are questions that could be probed in a further research that can also add value to policy guidelines on training pre-service mathematics teachers.

In order to further investigate the above questions, a quasi-experimental approach could be used as a stronger design to probe the cause and effect. A more efficient and streamlined approach to analysing the mathematics profiles could also be developed. From these conclusions I am suggesting that our pre-service and perhaps even in-service teacher training courses in mathematics can be improved if we first evaluate the mathematics profiles of teachers and use these as an indicator of the focus of training required to assist individual teachers in developing more optimally. Modules could be designed to specifically address certain aspects of the mathematics profile and teachers could then be guided towards those modules that are most likely to enhance and improve their instructional behaviour. It is anticipated that this could then have a positive impact on the poor performance of South African learners in mathematics.

In this thesis I argue that the mathematics profile of a pre-service mathematics teacher has an influence on successfully reforming their instructional behaviour. Determining the mathematics profile of teachers and working towards optimising these is therefore an important part of strategically reforming their practice. An improvement in the pedagogical content knowledge of mathematics teachers without positive changes in their conceptions and beliefs and the quality of their reflections and subject matter knowledge does not result in reformed instructional behaviour. The mathematics profile as a package needs to be developed in order for pre-service mathematics teachers to make the required changes in their instructional behaviour towards a more reform-orientated approach to teaching and learning of mathematics.

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APPENDICES

Appendix A   -   NQF levels

The NQF consist of three bands, namely General Education (level 1 – schooling up to grade 9 and ABET), Further Education and Training (levels 2 – 4: grade 10 – 12), and Higher Education (levels 5 – 8). After completion of level 1 of the NQF, a learner could achieve a GETC and after completion of level 4 of the NQF, an FETC.

NQF LEVEL	BAND	QUALIFICATION TYPE
8	HIGHER EDUCATION AND TRAINING	• Post-doctoral research degrees • Doctorates • Masters degrees
7		• Professional Qualifications • Honours degrees
6		• National first degrees • Higher diplomas
5		• National diplomas • National certificates
FURTHER EDUCATION AND TRAINING CERTIFICATE		
4	FURTHER EDUCATION AND TRAINING	• National certificates
3		
2		
GENERAL EDUCATION AND TRAINING CERTIFICATED		
1	GENERAL EDUCATION AND TRAINING	Grade 9 | ABET Level 4 • National certificates

Source: http://www.saqa.org.za/show.asp?include=focus/ld.htm

Appendix B   -   PGCE course documents

Appendix C   -   Education paradigms

Appendix D   -   Baseline mathematics assessment

Appendix E   -   Letter of consent to participants

Appendix F   -   Data analyses tables

Table F-1 Summary of data analysis for the subject matter category in mathematics profile

Section 2.3.1	Subject matter knowledge
Baseline assessment	Careless or no errors, a few errors or solutions omitted, many errors, fundamental errors
Errors in LTD's	Errors made in calculations in learning task designs
Errors in observed lessons	Errors participant made in lessons observed or recorded

Table F-2 Summary of data analysis for pedagogical content knowledge category in mathematics profile

Section 2.3.2	Pedagogical content knowledge
Mason's levels	See Table 2.1
Pedagogy	Participant's handling of learner errors/misconceptions Quality of planning
Assessment	Traditional or more alternative and authentic and various forms
Context	Participants understanding of context of learners as viewed in LTD's and observed lessons
Curriculum	Knowledge of the curriculum according to LTD's and observed lessons
Classroom management	Issues such as discipline, handling classroom discussion, use of media, classroom culture

Table F-3 Summary of data analysis for the conceptions of mathematics category in mathematics profile

Section 2.3.4	Conceptions of mathematics
Orientation *Thompson (1984)*	Content orientation or process orientation
Orientation *Thompson et al. (1994)*	Computational, calculational or conceptually orientated
Ernest (1991) categories	Absolutist, instrumentalist, Platonist or problem-solving

Table F-4 Summary of data analysis for the beliefs category in mathematics profile

Section 2.3.4	Beliefs regarding the teaching and learning of mathematics
Role of teacher *(Ernest, 1988)*	Transmitter, instructor, explainer, facilitator
Role of learner *(Ernest, 1988)*	How the participant arranged learning experiences for the learners on a passive reception to active construction continuum

Table F-5 Summary of data analysis to determine the position of traditional/reform continuum of instructional behaviour profile

Section 2.3.5	Traditional versus reform practices

Values	Traditional – values content, correctness of learners' responses and mathematical validity of methods
	Reform – values finding patterns, making connections, communicating mathematically and problem-solving
Teaching methods	Traditional – expository, transmission, lots of drill and practice, step by step mastery of algorithms
	Reform – hands-on guided discovery methods, exploration, modelling. High level reasoning processes are central
Grouping learners	Traditional dominantly homogenous
	Reform dominantly heterogeneous

Table F-6   Summary of data analysis to determine the position of authoritarian/democratic continuum of instructional behaviour profile

Section 2.3.5	Authority versus democracy
Algorithms/techniques	Official methods taught versus learners' methods encouraged. Intentionally differentiating between horizontal (informal learner methods) and vertical (more formal algorithms) mathematisation
Learner relations	Encourages individual competition or collaborative group work

Section 2.3.5	Authority versus democracy
Teaching style	Expository class teaching or also use of projects, group and invidualised work
Listening	Evaluative, interpretive or heuristic

Marge

Table F-7 Summary of subject matter knowledge analysis for Marge

Section 2.3.1	Subject matter knowledge
Baseline assessment	No errors, found additional solutions
Errors in LTD's	None encountered
Errors in lessons	None observed

Table F-8 Summary of pedagogical content knowledge analysis for Marge

Section 2.3.2	Pedagogical content knowledge
Mason's levels	Progressed from initially Level 1 to Level 5
Pedagogy	Towards the end began to take notice of and explore thinking behind learners' errors Well thought out and planned LTD's
Assessment	First SBE mainly traditional began to use journal entries and other alternative forms in second SBE

Section 2.3.2	Pedagogical content knowledge
Context	Showed some understanding of their context
Curriculum	Excellent
Classroom management	Good

Table F-9   Summary of conceptions of mathematics analysis for Marge

Section 2.3.3	Conceptions of mathematics
Orientation *Thompson (1984)*	Initially content, progressed towards process
Orientation *Thompson et al. (1994)*	Initially calculational, progressed towards conceptual
Categories *Ernest (1991)*	From instrumentalist to problem-solving

Table F-10 Summary of beliefs about teaching and learning mathematics analysis for Marge

Section 2.3.4	Beliefs regarding the teaching and learning of mathematics
Role of teacher *(Ernest, 1988)*	From instructor to explainer

Role of learner (Ernest, 1988)	Progressed from passive reception towards more active construction of learning in LTD's

Table F-11 Summary of traditional/reform instructional behaviour analysis for Marge

Section 2.3.5	Traditional versus reform practices
Values	Initially valued content and mastery thereof Later started foregrounding more high level reasoning
Teaching methods	From transmission and expository teaching to more problem-solving approach that used hands-on discovery, identification of patterns and modelling
Group work	Did make use of group work Usually pre-determined groups

Table F-12 Summary of authoritarian/democratic instructional behaviour for Marge

Section 2.3.5	Authority versus democracy
Algorithms/techniques	Initially these were shown and taught. Later encouraged horizontal mathematisation first before proceeding to vertical mathematisation
Learner relations	Mostly positive with some difficulties noted in reflections
Teaching style	Initially expository class teaching but started to move towards a good balance of individualised and group work through tasks and projects
Listening	Initially evaluative moving towards more interpretive during second SBE

Lena

Table F-13 Summary of subject matter knowledge analysis for Lena

Section 2.3.1	Subject matter knowledge
Baseline assessment	No errors, omitted some solutions
Errors in LTD's	None encountered
Errors in observed lessons	None observed

Table F-14 Summary of pedagogical content knowledge analysis for Lena

Section 2.3.2	Pedagogical content knowledge
Mason's levels	Progressed from initially Level 1 to Level 4
Pedagogy	Later responded to questions with low level questions
	Did not investigate learners' errors
	Well thought out and planned LTD's
Assessment	First SBE mainly traditional. Used brain teasers as a warm-up at the start of lesson but not much use of alternative assessment even later in the year.
Context	Showed some understanding of their context
Curriculum	Excellent
Classroom management	Good

Table F-15 Summary of conceptions of mathematics analysis for Lena

Section 2.3.3	Conceptions of mathematics
Orientation **Thompson (1984)**	Initially content, progressed slightly towards more process orientated approach
Orientation **Thompson et al. (1994)**	Initially computational but progressed towards calculational

Categories	Remained instrumentalist
Ernest (1991)	

Table F-16 Summary of beliefs about teaching and learning mathematics analysis for Lena

Section 2.3.4	*Beliefs regarding the teaching and learning of mathematics*
Role of teacher (Ernest, 1988)	From transmitter to instructor
Role of learner (Ernest, 1988)	Initially very passive reception by learners. Later became more learner-centred in problem-solving approach and so slightly towards active construction

Instructional behaviour

Table F-17 Summary of traditional/reform instructional behaviour for Lena

Section 2.3.5	*Traditional versus reform practices*
Values	Mastering content and correctness of solutions still apparent throughout the year with only a slight attempt at improving conceptual understanding
Teaching methods	From transmission and expository teaching to more problem-solving approach. Supported identification of patterns but high level reasoning discussion not attempted
Group work	

Table F-18 Summary of authoritarian/democratic instructional behaviour for Lena

Section 2.3.5	*Authority versus democracy*
Algorithms/techniques	Initially methods were shown and taught. Later made some attempt to elicit horizontal mathematisation first before proceeding to vertical mathematisation
Learner relations	Mostly positive

Teaching style	Initially expository class teaching but started to move towards a good balance of individualised and group work through tasks and projects
Listening	Remained evaluative throughout the year

Peta

Table F-19 Summary of subject matter knowledge analysis for Peta

Section 2.3.1	Subject matter knowledge
Baseline assessment	Fundamental errors
Errors in LTD's	None encountered
Errors in observed lessons	Some observed

Table F-20   Summary of pedagogical content knowledge analysis for Peta

Section 2.3.2	Pedagogical content knowledge
Mason's levels	Progressed from initially Level 1 to Level 3
Pedagogy	Later responded to questions with low level questions
	Did not investigate learners' errors
	Need a lot of support from lecturers in designing LTD's
Assessment	First SBE mainly traditional. Made some use of rubrics during second SBE
Context	Showed some understanding of their context. Worked more effectively with lower grades
Curriculum	Sufficient
Classroom management	Improved over the year but still demonstrated difficulties regarding classroom discipline

Table F-21 Summary of conceptions of mathematics analysis for Peta

Section 2.3.3	Conceptions of mathematics
Orientation	Remained content orientated throughout the year

Thompson (1984)	
Orientation	Remained computational
Thompson et al. (1994)	
Categories	Initially absolutist moving to instrumentalist later in the
Ernest (1991)	year

Table F-22 Summary of beliefs about teaching and learning mathematics analysis for Peta

Section 2.3.4	*Beliefs regarding the teaching and learning of mathematics*
Role of teacher (Ernest, 1988)	From transmitter to instructor
Role of learner (Ernest, 1988)	Initially very passive reception by learners. Later became more learner-centred in problem-solving approach and so slightly towards active construction

Instructional behaviour

Table F-23 Summary of traditional/reform instructional behaviour analysis for Peta

Section 2.3.5	*Traditional versus reform practices*
Values	Mastering content and correctness of solutions still apparent throughout the year
Teaching methods	From transmission and expository teaching to more surface problem-solving approach. Mathematical discussions not used and questions posed did not elicit high level reasoning
Group work	

Table F-24 Summary of authoritarian/democratic instructional behaviour for Peta

Section 2.3.5	*Authority versus democracy*
Algorithms/techniques	Initially methods were shown and taught. Later an attempt

	to elicit horizontal mathematisation first before proceeding to vertical mathematisation
Learner relations	Extremely varied over the year. Struggled with discipline
Teaching style	Initially transmission with a move toward more hands-on discovery during second SBE.
Listening	Remained evaluative throughout the year

Kapinda

Table F-25 Summary of subject matter knowledge analysis for Kapinda

Section 2.3.1	*Subject matter knowledge*
Baseline assessment	Few careless errors, omitted some solutions
Errors in LTD's	None encountered
Errors in observed lessons	None observed

Table F-26 Summary of pedagogical content knowledge analysis for Kapinda

Section 2.3.2	*Pedagogical content knowledge*
Mason's levels	Progressed from initially Level 1 to Level 3
Pedagogy	Later responded to questions with low level questions
	Did not investigate learners' errors
	Very creative LTD's but not demanding high level of mathematical reasoning from learners
Assessment	Embraced alternative assessment as the year progressed, using journal entries, self-assessment, rubrics, peer-assessment and presentations
Context	Showed an excellent understanding of learners' contexts
Curriculum	Good
Classroom management	Good

Table F-27 Summary of conceptions of mathematics analysis for Kapinda

Section 2.3.3	Conceptions of mathematics
Orientation *Thompson (1984)*	Initially content, progressed slightly towards more process orientated approach
Orientation *Thompson et al. (1994)*	Initially computational but progressed towards calculational
Categories *Ernest (1991)*	Remained instrumentalist

Table F-28 Summary of beliefs about teaching and learning mathematics analysis for Kapinda

Section 2.3.4	Beliefs regarding the teaching and learning of mathematics
Role of teacher *(Ernest, 1988)*	From instructor to explainer
Role of learner *(Ernest, 1988)*	Attempted to include learners right from the beginning in a surface problem-solving approach which required active construction from learners but not at a very high level

Instructional behaviour

Table F-29 Summary of traditional/reform instructional behaviour analysis for Kapinda

Section 2.3.5	Traditional versus reform practices
Values	Mastering content and correctness of solutions still apparent throughout the year with only a slight attempt at improving conceptual understanding
Teaching methods	From expository teaching to more problem-solving approach. Supported identification of patterns but high level reasoning discussion not attempted
Group work	

Table F-30 Summary of authoritarian/democratic instructional behaviour for Kapinda

Section 2.3.5	*Authority versus democracy*
Algorithms/techniques	Encouraged learners to use horizontal mathematisation first before proceeding to vertical mathematisation
Learner relations	Very positive
Teaching style	Initially expository class teaching but started to move towards a good balance of individualised and group work through tasks and projects
Listening	Remained evaluative throughout the year

Anabella

Table F-31 Summary of subject matter knowledge analysis for Anabella

Section 2.3.1	*Subject matter knowledge*
Baseline assessment	Fundamental errors
Errors in LTD's	Some encountered
Errors in observed lessons	Some observed

Table F-32 Summary of pedagogical content knowledge analysis for Anabella

Section 2.3.2	*Pedagogical content knowledge*
Mason's levels	Progressed from initially Level 1 to Level 2
Pedagogy	Later responded to questions with low level questions Did not investigate learners' errors Quality of LTD's improved with lower grades during second SBE
Assessment	First SBE mainly traditional. Made some use of rubrics during second SBE
Context	Showed some understanding of their context. Worked more effectively with lower grades
Curriculum	Sufficient
Classroom management	Overall good but did not always optimise interactions with

individuals or groups while learners worked on tasks

Table F-33 Summary of conceptions of mathematics analysis for Anabella

Section 2.3.3	*Conceptions of mathematics*
Orientation *Thompson (1984)*	Remained content orientated
Orientation *Thompson et al. (1994)*	Initially computational moving towards more calculational with the lower grades during second SBE
Categories *Ernest (1991)*	Remained instrumentalist throughout the year

Table F-34 Summary of beliefs about teaching and learning mathematics analysis for Anabella

Section 2.3.4	*Beliefs regarding the teaching and learning of mathematics*
Role of teacher *(Ernest, 1988)*	Initially demonstrated role of transmitter but later in the year became more of an instructor
Role of learner *(Ernest, 1988)*	Initially very passive reception by learners. Later became more learner-centred in surface problem-solving approach and so slightly towards active construction although high level reasoning not encouraged

Instructional behaviour

Table F-35   Summary of traditional/reform instructional behaviour analysis for Anabella

Section 2.3.5	*Traditional versus reform practices*
Values	Mastering content and correctness of solutions still apparent throughout the year
Teaching methods	From transmission and expository teaching to more surface problem-solving approach. Mathematical discussions not used and questions posed did not elicit

high level reasoning

Group work

Table F-36 *Summary of authoritarian/democratic instructional behaviour for Anabella*

Section 2.3.5	Authority versus democracy
Algorithms/techniques	Initially methods were shown and taught. Later an attempt to elicit horizontal mathematisation first before proceeding to vertical mathematisation
Learner relations	Mostly fine. Engaged better with learners in lower grades. Initially had some discipline difficulties
Teaching style	Initially transmission with a move toward more hands-on discovery during second SBE.
Listening	Remained evaluative throughout the year, demonstrating some evidence of interpretive listening when working with individuals

Sophie

Table F-37 *Summary of subject matter knowledge analysis for Sophie*

Section 2.3.1	Subject matter knowledge
Baseline assessment	Fundamental errors
Errors in LTD's	Some encountered
Errors in observed lessons	Many observed

Table F-38 *Summary of pedagogical content knowledge analysis for Sophie*

Section 2.3.2	Pedagogical content knowledge
Mason's levels	Progressed from initially Level 1 to Level 2
Pedagogy	On occasion responded to questions with low level questions Did not investigate learners' errors

	Initially planning was incomplete and of a low quality. Later in the year, the LTD's improved and the planning became more complete.
Assessment	Remained mainly traditional throughout the year
Context	Struggled to understand the context of learners although some attempt was made to make use of authentic contexts during second SBE
Curriculum	Appeared to show gaps
Classroom management	In most lessons observed, and by her own admission, she struggled a lot initially with discipline having some improvement towards the end of the year making use of a reward chart. Time management and management in terms of learners' relations and classroom culture problematic throughout year

Table F-39 Summary of conceptions of mathematics analysis for Sophie

Section 2.3.3	Conceptions of mathematics
Orientation *Thompson (1984)*	Remained content orientated throughout the year
Orientation *Thompson et al. (1994)*	Remained computational
Categories *Ernest (1991)*	Initially absolutist and later instrumentalist

Table F-40 Summary of beliefs about teaching and learning mathematics analysis for Sophie

Section 2.3.4	Beliefs regarding the teaching and learning of mathematics
Role of teacher *(Ernest, 1988)*	Initially transmitter moving to instructor towards the end of the year
Role of learner	Initially very passive reception by learners. Later became

(Ernest, 1988)	more learner-centred in surface problem-solving approach but context appeared to dominate rather than mathematical reasoning or thinking

Instructional behaviour

Table F-41 Summary of traditional/reform instructional behaviour analysis for Sophie

Section 2.3.5	Traditional versus reform practices
Values	Mastering content and correctness of solutions still apparent throughout the year
Teaching methods	From transmission and expository teaching to more surface problem-solving approach. Mathematical discussions not used and questions posed did not elicit high level reasoning
Group work	

Table F-42 Summary of authoritarian/democratic instructional behaviour for Sophie

Section 2.3.5	Authority versus democracy
Algorithms/techniques	Initially methods were shown and taught. During the year some attempt was made to encourage learners to be more independent in their thinking
Learner relations	Extremely varied over the year. Struggled with discipline
Teaching style	Initially transmission with a move toward more hands-on discovery during second SBE, but mathematical outcomes disappearing into dominant, not optimal contexts
Listening	Remained evaluative throughout the year

Toni

Table F-43 Summary of subject matter knowledge analysis for Toni

Section 2.3.1	Subject matter knowledge

Baseline assessment	No errors
Errors in LTD's	None encountered
Errors in observed lessons	One observed

Table F-44 Summary of pedagogical content knowledge analysis for Toni

Section 2.3.2	Pedagogical content knowledge
Mason's levels	Progressed from initially Level 1 to Level 5
Pedagogy	Towards the end began to take notice of and explore thinking behind learners' errors
	Well thought out and planned LTD's
Assessment	First SBE mainly traditional began to use journal entries, self assessment and rubrics during second SBE
Context	Showed some understanding of their context but struggled to design tasks with authentic context for learners
Curriculum	Excellent
Classroom management	Good, especially discipline and interaction with learners

Table F-45 Summary of conceptions of mathematics analysis for Toni

Section 2.3.3	Conceptions of mathematics
Orientation Thompson (1984)	Initially content orientated, progressed towards process orientated later in the year
Orientation Thompson et al. (1994)	Initially calculational, progressed towards conceptual
Categories Ernest (1991)	Initially instrumentalist moving to Platonist during year

Table F-46 Summary of beliefs about teaching and learning mathematics analysis for Toni

Section 2.3.4	Beliefs regarding the teaching and learning of mathematics

Role of teacher *(Ernest, 1988)*	Progressed from instructor to explainer
Role of learner *(Ernest, 1988)*	Progressed from passive reception towards more active construction of learning in LTD's

Instructional behaviour

Table F-47 Summary of traditional/reform instructional behaviour analysis for Toni

Section 2.3.5	*Traditional versus reform practices*
Values	Initially valued content and mastery thereof Later started foregrounding more high level reasoning
Teaching methods	From transmission and expository teaching to more problem-solving approach that used hands-on discovery, identification of patterns and exploration
Group work	Did make use of group work Usually pre-determined groups

Table F-48 Summary of authoritarian/democratic instructional behaviour for Toni

Section 2.3.5	*Authority versus democracy*
Algorithms/techniques	Initially these were shown and taught. Later encouraged horizontal mathematisation first before proceeding to vertical mathematisation
Learner relations	Mostly positive, especially interaction while learners completing tasks
Teaching style	Initially expository class teaching but started to move towards a good balance of individualised and group work through tasks and projects
Listening	Initially evaluative moving towards being interpretive during second SBE

Appendix G   -   Examples from portfolio

Example of initial aim of education

VIEWS OF EDUCATION & FACILITATING LEARNING **BEFORE** THE PGCE JOURNEY STARTED

I expected PGCE to be a *walk in the Park* and a relaxed course compared to BSc. Mathematics. I did not expect a *walk in a Canyon*.

PURPOSE FOR ENROLLING IN PGCE PROGRAMME

- I enrolled for BSecEd(Sci) in 2004. The PGCE is part of the BSecEd(Sci) therefore I had to complete the PGCE to graduate. Although I thought PGCE is a good course to open doors for future career opportunities, I did not plan to become a teacher after completing the PGCE.
- My career goal was to go into Ministry after completing the PGCE.

AIM OF EDUCATION:

In January 2008 believed that "Education lays a foundation of general knowledge, basic manners, academic literacy and qualities. Learners absorb information. Education is the transfer of knowledge and wisdom.

Education is important to enrich people, and the community. It promotes development of civilization. Therefore the aim of education is to lay building blocks to build a stable strong "house." "

INITIAL VIEWS OF EDUCATION:

1. the teacher gives information to the learners
2. transcendental learning tasks is a good idea in theory but will not work in practice.
3. teaching is an unchallenging, stagnating job, with continuously the same routine.
4. learners only learn to forget
5. group work is the same as cooperative learning, and is ineffective since learners copy work from each other and do not focus when working together.

Example of a Learning task design

Learning Task Design

Type of paradigm	1. Transmission	
	2. Transaction	
	3. Transformation	X
	4. Transcendental	
Learning subject/area:	Mathematics: Volumes and Surface Areas	
Grade:	Gr. 10	
Date:	02/04/2008	
Time allocate to Learning Task (LT):	1 period- 30 minutes	

	Critical Outcomes		Developmental Outcomes	
Critical and Developmental Outcomes	1. Problem Solving	X	1. Learn more effectively	X
	2. Teamwork	X	2. Responsible citizenship	
	3. Self management	X	3. Culturally & aesthetically sensitive	
	4. Research & critical analysis		4. Explore education & career opportunities	
	5. Effective communication	X	5. Entrepreneurship	
	6. Science & technology			
	7. The world as a set of related systems	x		

Content: Learning Outcomes (LO'S) & Assessment Standards (AS's)		
LO1: Number & Number relationships	10.1.1 Identify rational numbers	
	10.1.2 Simplify using exponent law, round rational/irrational numbers	
	10.1.3 Investigate number patterns	
	10.1.4 Use simple and compound growth formula	
	10.1.5 Understand fluctuating foreign exchange rates	
	10.1.6 Solve non-routine, unseen problems	.
LO2: Functions & Algebra	10.2.1 Work with various types of functions	
	10.2.2 Generate graphs to generalize effect of parameters	
	10.2.3 Identify characteristics of functions and sketch graphs	
	10.2.4 Manipulate algebraic expressions	
	10.2.5 Solving equations and inequalities	
	10.2.6 Use models for real life problems	
	10.2.7 Investigate average rate of change in function	

LO3: Space, Shape & Measurement	10.3.1 Effect on volume/surface of cylinders/prism by multiplying dimension	X
	10.3.2 Investigation of triangles, quadrilaterals and other polygons	
	10.3.3 Represent geometric figures in Cartesian plane	
	10.3.4 Transformations	
	10.3.5 Similarity of triangles and use of trigonometric functions	
	10.3.6 Solve two dimensional problems with trigonometric functions	
	10.3.7 Contribution of geometry and trigonometry by different cultures	
LO4: Data Handling & Probability	10.4.1 Collect, organise and interpret univariate numerical data	
	10.4.2 Use probability models and Venn diagrams	
	10.4.3 Identify sources of bias and errors. Make conclusions/predictions	
	10.4.5 Use theory in authentic form of assessment	

Learning Task outcomes:	1. Learners should determine which volume of two cylinders is the biggest. 2. Learners should understand the effect of change in height vs. change in radius in a cylinder 3. learners should be able to calculate volume and surface area of a cylinder 4. learners should be able to use above knowledge to solve real life problems
Learning task assessment standards:	1. observation during experiments 2. marking of homework assignment
Integration with other subjects:	

Real life problem that Learners need to solve:

Learners should investigate changes in volume due to radius change versus height change of jam and fruit tins in a fabric, and advise the manager about the cost difference between them.

Product Outcome:

Learners should be able to calculate the volumes and surface areas of cylinders, and understand the relation between the above mentioned.

Authentic Learning context:	
Organisation of Learning Space:	Tables are moved head-to-head, learners sit in their cooperative learning groups.
Roles, functions and organisation of participants:	Learners participate in discussions, and also during the experiment. Learners cooperatively work together. FOL presents the learning task, and then reduces involvement during experiment. Thereafter FOL explains concepts, and formula.
Material and Equipment:	Two A4 sheets of paper 350g Whole-wheat puffs

	Ruler
	Textbooks
Learning Process:	Learners first work in cooperative learning groups, and learn through experience.
	Thereafter transmission, transaction and transformation take place when facilitator of learning explains definitions and formula.
	Learners engage in meta-learning at home when completing a homework assignment.
Learning Product:	- two cylinders which have been filled with puffs
	- Worksheet
	- Homework assignment
Resources:	- Shuters Mathematics Grade 10 Textbook

Learning content:

Introduction:

Today we are discussing the concepts of surface area and volume, and their relationship to each other. During today's lesson we will investigate the Cylinder.

Knowing to calculate surface areas and volumes is important in many occupations and in everyday life. Engineers, builders, plumbers, painters and many other people often work with areas and volumes.

Class activity:

Learners work in cooperative learning groups of 4 learners per group. Learners may perform and discuss the experiment together as a group.

The worksheet needs to be handed in at the end of the period.

Experiment (part 1):

Each group get two A4 sheets of paper. Take the first sheet of paper, roll it up to form a baseless cylinder. Now take the second paper, rotate it, and form another baseless cylinder.

Use the wheat puffs and think about the volume of each cylinder and answer the following question.

Question 1:
- Are the two volumes equal?
- Does the short cylinder have greater volume?
- Does the tall cylinder have greater volume?

Discussion:

Revise definitions of:
- Surface Area
- Volume

Revise formula of:
- Circle
- Rectangle
- Surface area of open/closed cylinder
- Volume of cylinder

Discuss why volumes of two cylinders from experiment differ.

Experiment (part 2):
Question 2:

Use your rulers and measure the surface area and volume of the two cylinders.

Homework:

A homework assignment is handed out, to be completed the next period.

HOMEWORK ASSIGNMENT

1. A factory makes jam tins. The radius of the lid of a tin is 50mm and it is 140mm deep.

    a. calculate the volume of the tin.

    b. A bigger tin is made for fruit. It is twice as deep as the jam tin and its lid has the same radius as the jam tin. Calculate its volume and compare it with your answer in (a).

2. If we double the radius and the height of a tin, will the volume also double? Explain your answer.

3. Suppose you have been appointed to advise the management of the jam tin factory about the cost of making their tins. The cost depends on the amount of metal used. Calculate the surface area of each of the two tins, and report how this will affect the cost.

    a. What happens to the surface area when you double the height but not the radius?
    b. What happens to the surface area when you double the radius but not the height?
    c. What happens to the surface area when you double both the height and radius?

Reflection: My own LT operationized in Cluster

Honestly, it did not go as well as I expected. Usually I am not afraid of speaking in front of an audience. I think what made this different was the fact that I knew I was being critically assessed, and every sentence or movement was watched.

My topic was Volumes and Surface areas of cylinders, Gr.10 Maths. The class enjoyed the practical work, where the cooperative learning groups had to figure out which cylinder has the biggest volume.

I think my topic and ideas were very good, I just did not present the task as well as I could.

Possible reasons why it did not go as well as I hoped:

- I decided to change my topic two days before the presentation. I figured that this topic would be more practical than my first idea for a topic. That might be true, but I don't think it was a good idea to change topics on such late stage, because I didn't have enough time to prepare *well enough*.

- Some of the learners in the CLG cluster didn't have maths as a subject after Gr.9. Therefore I think it was challenging for me to operationize a a learning task where the learners are actively involved and participate in figuring out the problem. Especially if I wanted to move into the transcendental paradigm where I do not give learners the formula, etc. I think it was more challenging for me to present a good learning task, than for example a Gr.5 Life Orientation facilitator, since the audience are more familiar with Gr.5 work.

- The cluster student who presented just before me, needed a lot of space in the classroom and moved the tables to the back of the class. I forgot to move the tables forward before starting my lesson. Therefore the gap between me and the learners was too big and that affected interaction.

How can I improve?

1. next time choose a topic well in advance and stick with it. Then become a specialist in that field before I walk into the classroom so that I will feel more competent.
2. move tables closer to the front to improve interaction.

Learning Product

Experiment 1:

The wheat puffs completely filled the tall cylinder, but not the wider cylinder, although their surface areas are the same.
Cylinders with the same surface area don't have the same volume.

The area of the base of a cylinder = Πr^2
The volume of a cylinder = $\Pi r^2 h$

The volume will increase/decrease more rapidly with a radius change than with a height change.

Experiment 2:

Use formula of the volume of a cylinder
$$\begin{aligned}
&= \Pi r^2 h \\
&= 3.14(7.5)(29.7) \\
&= 699.4 cm^3
\end{aligned}$$

Example of a reflection

LEARNING TASK 2: VOLUMES

(presented in Cluster Groups).

REFLECTION:
This was my **worst learning task** which has been executed.

INITIATING LEARNING:

LEARNING TASK DESIGN (LTD)
- Real life challenge was neither urgent nor was it a realistic challenge since none of the learners work in a fabric where jam jars are made.
- did not plan media well (posters was written too small)
- I did not understand the terms *assessment standards* and *learning content*
- no assessment rubrics or memorandum included
- the following was not included in the learning task design:
  1. learning task sequence number
  2. number of learning tasks presented in each paradigm
  3. integration with other learning areas
  4. supportive resources
  5. learning task categories
  6. learning product (homework assignment)

LEARNING TASK PRESENTATION (LTP)
- history of volumes is irrelevant to learners
- presentation was unclear and disorganised, there was no chronological flow during the learning task presentation.

LEARNING: AUTHENTIC LEARNING (AL)
Learning was not authentic since no real meta-learning took place. Learners immediately worked in cooperative learning groups. It was ineffective since learners could not individually contribute to the group.

MAINTAINING LEARNING:

LEARNING TASK EXECUTION (LTE)
Interaction between facilitator and learners was poor; tables were moved too far to the back. Facilitator also did not give enough chance for the learners to answer questions and to interact. All the learners did not participate since meta-learning did not take place, therefore not all learners attempted to contribute. Only the stronger mathematical learners did the work.

LEARNING TASK FEEDBACK (LTF)
Learning task feedback was not at all effective. I did give acknowledgement to learners by my presence and interest on how they solved the problem of discovering which cylinder has biggest volume. I did not give any resilience because I did not really encourage anyone who seemed to be disappointed for not finding a solution. I did ask clarifying questions to determine where the learners are, but did not use the information I gained to encourage

meta-learning actions. When I saw that learners were on the wrong track (for example not knowing what the radius means), I did not guide the learner in realising he was on the wrong track. I did not require resourcefulness since I did not suggest to any learner to find resources or advise auto-education. I provided edutainment only after the learning task was completed. This did not

LEARNING TASK CONSOLIDATION (LTC)
No consolidation took place at the end of the learning period; therefore I did not evaluate the *rate of progress* or *quality of learning*, and although I gave homework, I did not really provide an effective *continued challenge*.

Appendix H   -   Example of assessment report

PGCE report

Name of student: Toni

Date: 9 May 2008

Time: 12:20 – 13:30

Grade: 10 Mathematics

Topic: Word problems

General comments

- You appear confident, at ease and friendly, all of which are assets in the teaching profession.
- Your patience and passion will also stand you in good stead!
- Your interaction with the various groups is to be commended.
- Congratulations on knowing so many of the learners' names already. I think this is one of the most important ways of gaining respect and maintaining discipline.
- Watch out for overuse of "teacher pauses" – where you ask a question and leave a slight pause, but answer the question yourself anyway. Consider the classroom culture this encourages – learners simply wait for you to answer the question.

Pedagogical issues

- This was a nice idea for groupwork – good distribution.
- I know that you are limited by this textbook, but if you can, try not to get too "textbook bound". Try to find some real-life problems for learners to solve that will interest them and things they are currently involved with.
- In my opinion word problems allow learners to a) practice the principles of problem solving (see Polya for readings) and b) to practice identifying the unknown variable and representing the other information that is known in terms of the unknown variable. For achieving the second outcome, I would avoid encouraging learners to work with two unknowns (x and y) for example. I would rather encourage them to practice writing information in terms of only one variable. Also, using two different variables does not always allow one to solve a problem.
- I did not think that your lesson had turned to "chaos" – try to differentiate between bad noise and constructive noise. I doubt you will be able to avoid the latter in group work. Consider also the implications of having different cultures in your classroom and how this may contribute to what you evaluate to be "too much noise" or "chaos".
- When you decided to revert back to a more traditional teacher-centred approach, I thought you could have first asked which learners would liked to have written their solution on the board and explained their thinking to the rest of the class.

- When you were showing them the age solution, I thought it would have helped if you had used the concept of both sides of an equation needing to be equal and used actual values to demonstrate the "11x" greater principle and avoid the misconception you also fell into.
- In reflecting on your practice theory, consider the value of an explanation from you versus self-discovery on their part. Although self-discovery is not always possible, or practical, it can be practiced in the mathematics classroom far more than it is. It does not mean that the learners are left alone to discover everything, but that you guide them to an understanding through various questions and prompts – called scaffolding. Scaffolding would be a good term for you to read up on in the literature (theory) on mathematics education, and to try out in your own practice in order to feed into your practice-theory.
- I have attached an article for you to read through to acquaint yourself more with the theory of Realistic Mathematics Education (RME) and in particular with the concepts of horizontal and vertical mathematisation. I think that in this lesson, more use of horizontal mathematisation is helpful in helping learners understand. For example, learners could have been encouraged to use diagrams/pictures or tables to represent the information provided in the word problem and their understanding thereof. This will help them to ascertain what they know and what they are trying to find. For example: (Janet and Ellen problem)

	Now	3 years ago
Janet	X	$x - 3$
Ellen	$30 - x$	$30 - x - 3$

Equation: $x - 3 = 11(30 - x - 3)$

- The textbook shows learners the different "patterns" of word problems that one may encounter but I am concerned that this may lead to instrumental rather than relational understanding. I suggest you look up (either on google, or in a book in the library – also see attached chapter) some readings by Richard Skemp on relational and instrumental understanding to further your practice-theory in this regard. It will help you reflect on the type of instruction these learners are accustomed to and whether or not you agree with this or intend to structure your practice-theory differently to endorse a more constructivist approach to teaching.

Suggestions:

- Sending worksheets down the rows saves time rather than you having to hand them out individually.
- Write the information about the pages (p. 27 I think) from the textbook on the board. That way you would not have to keep repeating it.
- Being able to translate from English/Afrikaans into mathematical expressions is a skill that is vital to being able to solve word problems using equations. Consider preceding a lesson

like this either by a baseline assessment where you establish how proficient they are at translations or by first having them complete a worksheet on translations.

- Help take the pressure off yourself by having a Plan B already in your planning, in case learners are not able to commence or carry out the exercise as you intended. You could also consider planning some scaffolding exercises and/or questions to have available if they need a "kick-start".
- What about presenting a real-life problem to learners to get them challenged and excited. They could meta-learn by solving that one on their own, or through you scaffolding them through it, and then go on with others. Remember that you want to grab their attention right at the beginning of the lesson to set the learning culture.

Some reflections to consider (and please email me a written response within a week again):

- What was your outcome(s) for the lesson? Do you think this was achieved, and if so how can you provide us with evidence thereof?
- Propose a mark for this lesson.

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Faculty of Education

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PGCE

LECTURER
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THE PGCE PROGRAMME
Becoming an authentic facilitator of learning

INTRODUCTION

Globally more and more visionaries, futurists, corporate leaders and change agents are becoming increasingly concerned about the rapid decrease in the quality and relevance of our educational outcomes (Goodlad, 1983:66; Grulke, 2000:56; Senge, Cambron-Mccabe, Lucas, Smith, Dutton, and Kleiner, 2000:27-48; nuwe artikel). "More than half of America's young people leave school without the knowledge or foundation required to find and hold a good job" (Dreyden and Vos, 1999:29) and it could not be very different in other developed countries, not even trying to imagine the state in developing countries. Even many of those school leavers, world wide, who find jobs are so ill equipped that the corporate world need to retrain them to do the job they need to do at extremely high additional cost (Senge, Cambron-Mccabe, Lucas, Smith, Dutton, and Kleiner, 2000:8) and, in addition, employers complain about the lack of even the basic life skills of beginner employees (Claxton, 1999:274-275). And although the situation is rapidly deteriorating we insist on knowing what to do to rectify it by simply doing more of what we have done before. "[I]t's so much more comfortable to live in this nice illusion that we know much more than we actually do. The only problem with this is that it is an illusion" (Peck, 1993:75). Living in this illusion has caused civilization to hurtle through one of the most significant turning points in history. (Covey, 2004:2). We are entering an era of a rapidly increasing, uncertain emerging future for which society is totally unprepared (Drucker, 2000:8). It has brought about an "anxiety-ridden age of insecurity" (Hargreaves, 2003:28) that carries with it the danger of the demise of civilization, warns Tarnas (1991:191). Slattery (1995: 248) explicates in the following way: "Contemporary society, like education, has reached the apex of modernity, an absurd psychodrama of self-destruction" and most of society completely unaware of it. This time calls for an unprecedented change in the human condition (Covey, 2004:12) and to empower the incalculable assets of human intelligence and creativity (Land and Jarman, 1992:68) to survive this relentless challenge. "The seismic scope of this change forces us to completely rethink everything we've ever understood about learning, education, schooling, business, economics and government" (Dreyden and Vos, 1999:21). Most fortunately is that the human condition can change. In fact, we now only begin to understand the incredible potential human beings posses to do so. But unless education, therefore, expeditiously acquires an innovative new paradigm that would cultivate practical, creative wisdom to enhance this most profound revolution in the human condition, it cannot fulfil its aim.

WHAT IS THE AIM OF EDUCATION?

To determine the aim of education, it is important to know what the purpose of life is, because the aim of education obviously needs to fulfil the purpose of life!

❑   **WHAT IS THE PURPOSE OF LIFE?**

Unfortunately, our current world view is still governed by 17th Century Newtonian science consciousness which has caused progressive disenchantment, increasing non-participation, rigid distinction, and uncompromising fragmentation (Berman 1988: 16; Bohm, 1990:1-2), 'providing an increasingly unworkable and dangerous blueprint for human thought and activity' (Tarnas 1991: 409). This alienation has broken down fundamental relationships, and since it is relationships that provide meaning we have lost meaning in an ultimate and religious sense. When meaning is lost, value systems starts to crumble and with it life, the individuals and community that lives by them and we lose our sense of being (Berman, 1988:15), and subsequently the purpose of life. We have to agree with Levin (1998: 419) that it is only the restoration of vision that will expose the truth (Gr Aletheia = opening or unconcealment ≠ correctness or correspondence) of our potential as human beings contained in authentic wholeness (Berman, 1988:23) that will revive our purpose of life. In this context, the purpose of life is to become fully and passionately engaged in the great adventure of discovering who we really are, what we are actually capable of, and what our ultimate purpose is. To accomplish this, we need to continually seek and create opportunities to stretch ourselves way beyond what we may think our capacity is: continuously tuning our bodies, expanding our senses, cultivating our minds,

exploring our consciousness, deepening our relationships, and serving others – in short, the purpose of life is **to fully utilise human potential** (Leonard and Murphy, 1995:14). This is not only a useful purpose, it is absolutely necessary because "[a]ccording to some of the most distinguished and thoughtful students of the mind, one of the most devastating and damaging things that can happen to anyone is to fail to fulfil his potential. A kind of gnawing emptiness, longing, frustration, displaced anger takes over when this occurs. Whether the anger is turned inward on the self or outward towards others, dreadful destruction results, (Hall, 1976:4).

❑ **IS THIS PURPOSE OF LIFE EDUCATIONAL?**

Since the essence of being human consists of our capacity to care (Levin 1998: 22), our purpose of life always require an ethical practice of utilising our full potential through which a corresponding moral character with underpinning values is constructed (UNESCO 1998: 244-245; Noddings, 1992; Noddings, 1993; Noddings, 1995; Noddings, 2002; Palmer 1998; Palmer 1999; Miller 1999; Tatum 2002; Niebuhr 1996; Fullen 2001). Since caring is the essence of love and love "is the will to extend one's self for the purpose of nurturing one's own and another's spiritual well growth" (Peck, 1990:85), Having a life purpose and pursuing it is always accompanied by great responsibility towards everything and everyone including oneself. The purpose of life should therefore always be guided by a norm for it to be educational. The norm is to fully utilise human potential **towards a safe, sustainable and prosperous universe for all**.

❑ **WHEN WILL THIS AIM BE ACHIEVED IN EDUCATION?**

Because everything changes so quickly, we do not know what the future will be like. We also know so very little about the vastness of our potential: "Opening to the area of self-knowledge requires going into a world of invisibles beyond the conscious mind – where our imagination, intuition and dream world gives us access to our inner wisdom. Here is where 90% of our potential lies. This is where we connect with our wave of possibilities" (Land and Jarman, 1992:156). "Our destiny is to learn and keep on learning for as long as we live" (Leonard and Murphy, (1995:xv). That is why learning in education is a process of **lifelong learning**.

❑ **WHAT IS THE KIND OF LEARNING THAT EDUCATION REQUIRES?**

You could imagine that the kind of learning to fully utilise human potential towards a safe, sustainable and prosperous universe, has to be something very special. It is! Since education is learning to live life and since the future is increasingly unknown, our world "is beset with problems that cannot be solved with either the traditional world-view or by existing interpretations of the newly discovered laws of nature" (Land and Jarman, 1992:95) and Einstein emphasises that you cannot solve a problem with the same consciousness that created it. "And even for graduates, knowledge gained in a degree courses is often outdated even before graduation" (Dreyden and Vos, 1999:31) We therefore simply do not have the knowledge to "explain where we have been nor inform us what next to do" (Slattery, 1955:244). The kind of learning that is therefore required in education is what to do when you don't know what to do (Claxton, 1999:11) and getting increasingly competent at knowing when, where, why, how and what to do when you don't know what to do. We do this because it gives meaning to our lives and our search for meaning is our primary motivation for living (Frankl, 1984:121). This learning is the construction of meaning but since "[t]his meaning is unique and specific in that it must and can be fulfilled by him alone" (Frankl, 1984:121), it is the construction of meaning by the learner him/herself. And only when meaning is constructed by the learner him/herself, "does it have significance which will satisfy his own *will* to meaning which means that the learner is able to use the constructed meaning to do something creatively new. The kind of learning that education requires, therefore is **the construction of meaning by the learner him/herself, who is then able to use it to do something creatively new.** This is the most natural innate power of the human being. In fact, we are engaged in this kind of activity from the very beginning of our lives.

❑ **HOW WILL THIS KIND OF LEARNING BE ACHIEVED?**

When we look at the kind of learning that education requires, we discover something interesting. Only the learner can do it. No one can do it for or on behalf of the learner. Piaget (1977:15) says that "[e]ach time one prematurely teaches a child something he could have discovered himself, the child is kept from inventing it and consequently understanding it completely". Understanding does not come through explanation, but through experience. Such an experience can only be *facilitated* by others (Claxton, 1999:17; Holstock, 1987:73). And for this kind of learning experience to be achieved in the most effective way, it also *has* to be facilitated by an extremely well-educated and highly professional facilitator of learning (FOL).

❑ **WHAT IS THE AIM OF EDUCATION THEN?**

The aim of education is to educate learners to fully utilise their human potential towards a safe, sustainable and prosperous universe for all, through facilitating lifelong learning. . And this aim is not only a nice choice. In the words of Sam Isaacs, the SAQA Executive Officer, it is a requirement: "The international trends of lifelong learning and highest quality in education and training require South Africa to develop, nurture and advance widened participation in a quality learning system that allows all learners, throughout their lives, to develop their full potential" – and this is what facilitating learning is all about.

WHAT IS FACILITATING LEARNING?

Current education is characterised by an outside-in paradigm: Something must be transferred by a teacher from outside the learner to inside the learner. But a facilitator of learning is described by Pike (1989:67) as "[I]deally you are the best kind of teacher – a facilitator of insight, change and growth, who teaches that answers come from within." Facilitating learning constitutes an inside-out paradigm and therefore the direct opposite of current education paradigm which is founded on the conviction that potential is already present inside the learner and it has to be fully utilised to live a life of extraordinary quality outside. Heidegger is very explicit in this regard when he says: "The real teacher, in fact, lets nothing else be learned than – learning. His conduct, therefore, often produces the impression that we properly learn nothing from him" (Armstrong, 1991:48). Since the learner's learning is the only thing that qualifies education as education, and since only learners are involved in their own learning and that no one can do it for or on behalf of them, there are only two things a facilitator of learning can do:

a. To get the learners to start learning – to initiate learning
b. To ensure that the learners keep on learning until the highest possible quality of learning has been achieved – to maintain learning

A. INITIATING LEARNING

Since the learning required to transcend the restrictions imposed on us by an increasingly uncertain emerging future is very specific, we need recognise its corresponding theoretical context. Von Glaserfeld's (1984:37) states that "[k]nowledge is not a transferable commodity and communication not a conveyance". According to constructivist epistemology, knowledge is not passively received either through the senses or by way of communication, but it is actively constructed by the individual through interactions with the environment (Heyligen, 1997). It is remarkable how constructivism has impregnated the current discourse in education and how it seems to be significantly contributing to our understanding of epistemology (Botella, 2004)**.**

Radical constructivism as thé conceptualisation for education (Von Glaserfeld, 1995:7) adds that the function of cognition is to organise the experiential world, not to discover an objective ontological reality. Piaget (1945:113) explains as follows: "The mind begins neither with knowledge of the self nor knowledge of things as such, but with knowledge of their interaction…" The models of reality constructed in this way serve as the basis from which to subsequently interact with the environment. A

selected model's reliability to provide the desired interaction acts as a coherence selection criterion that prevents constructivism to deteriorate into absolute relativism. However, since "it would be a miracle if the conceptual structures in different heads were the same" (Von Glaserveld, 2001:163), the criterion of consensus between different cognitive structures of individuals has to be activated because knowledge is constructed in a social context (Wortham, 2001). The knowledge construction process is therefore radically socio-constructivist.

In addition, Gergen's (1991) social constructionist perspective generated a growing interest in the relationship between constructivism and postmodern thought. Some authors explicitly explored this relationship and confirms the link (Tarnas, 1991; McNamee and Gergen, 1992; Kvale, 1992; Neimeyer, 1993; Polkinghorne, 1992; Novak, 1993). In addition, the most recent developments in experimental psychology, cognitive science, artificial science and neuroscience exposed an understanding of knowledge which "turns much of our conventional corporate and educational wisdom on its head" (Claxton 2000:10). The biological, physiological and neurological evidence regarding the natural functioning of the brain (Smilkstein, 2003) correlates with radical socio-constructivist epistemology.

How is this learning best initiated? Since learning is the meaningful construction of something by the learner him/herself which the learner did not have before it also active, creative learning. The necessity of this kind of learning has been realised from the earliest of time by Plato, Socrates, Montaigne, Milton, Franklin, Rousseau, Jefferson, Newman, Spencer, Dewey, Whitehead and many others (Foshay and Foshay, 1981:3). Such learning is initiated by the activation of critical, reflective thinking (Dewey, 1933). One does not learn to think critically and reflectively through instruction or teaching but being placed in situations where one cannot else but think critically and reflectively (Claxton, 1999:121-133). Such thinking presupposes thinking about thinking which, in turn, implies a problem to solve. (Hullfish, and Smith, 1961:212): "Where there is no problem, where no snarl appears in the normal flow of experience, there is no occasion to engage in thought …[I]t is important that teachers understand the intimate relationship between problem-solving and thought". In fact, educationists, both old (Smith, 1966:175) and contemporary (Hargreaves, 2003:xviii; Boekaerts and Minnaert, 2003:78; Vermunt, 2003:111-114, 116, 118-121, 123; Steinkueler, Derry, Hmelo-Silver and DelMarcel, 2002) eludes to the necessity of   creative problem solving to be the core of the curriculum itself.

But what is the kind of problem required to fulfil the educational aim. As early as 1929, Whitehead (1929:16) has stated: "Let the main ideas which are introduced into a child's education be few and important, and let them be thrown into every combination possible. The child should make them his own, and should understand their application *here and now* in the circumstances of his *actual life*" [own emphasis]. Dreyden and Vos (1999:26) say: "Use the real world as your classroom, and to learn it, do it". We now know that the notion to first teach the basics (theory) and then have learners apply it (practice), is fundamentally flawed on three accounts. First: Neuroscientifically, rational knowledge (what/theory) and practical know-how (how/practice) is located in completely different areas of the brain. It is through the direct immersion in experience – the natural learning ability of the brain – that practical know-how is developed in order to construct meaningful rational knowledge. If the neural networking is forced – because it is not natural – in the opposite direction, the practical know-how is always impeded and accumulatively restricted by the efficiency of the original transfer of the rational knowledge (Claxton, 1999:117-118, 331-333; Smilkstein, 2003:101-102; Van Merriënboer and Paas, 2003:8-12). Second: Psychologically, the learning environment is of crucial importance to enable the learner to utilise what he/she has constructed to subsequently do something creatively new. If the learning environment does not constitute a real life problem to be solved right now because it is impacting the quality of living life right now, it would be "so remote from real context and real concerns … that no transfer takes place" (Claxton, 1999:209). That is why Claxton (1999:210) advises that only if it is impossible in a particular circumstance to engage in real life, the learning environment should at least simulate it as closely as possible! Third: Practically, real life is holistic and the problems it presents are holistic problems which require the engagement of all human faculties to solve it to encounter our interconnected wholeness (Clark, 1997; Waldrop, 1992; Flake 2002; Capra, 2004).

Learning should therefore be initiated by a real life problem that the learners need to solve themselves.

What should the nature of such a problem be? Much of the nature of the required real life problem has already been implicitly revealed. If the problem is aimed at fully utilising human potential to solve it, then the problem must be challenging enough to do so. In fact, the level of the challenge has to exceed the current ability of the learner to such an extent that doubt about being successful might even occur. However, the intrinsic reward of improving the quality of life when the problem is solved would be the primary motivator. But to solve this problem need to require the complete immersion of the entire human being in order to acquire a new order of consciousness. Authentic learning "is often hard and protracted, confusing and frustrating … Much learning involves exhilarating spurts, frustrating plateaus and upsetting regressions … Even when learning is going smoothly, there is always a possibility of surprise, confusion, frustration, disappointment or apprehension – as well, of course, fascination, absorption, exhilaration, awe or relief" (Claxton, 1999:15-16). Because learning is "intrinsically an emotional business", always creates a peak experience of joy and self-fulfilment at achieving success (Csickszentmihalyi, 1991). And even if the problem itself is not solved, because the attempt was a holistic endeavour, the process inevitably enhanced other aspects of the quality of the learner's life, constituting success and subsequent joy and self-fulfilment in that regard.

Although life presents us with a series of problems, all life is not a problem, and besides problems, life always provides opportunities to improve its quality. We could therefore conclude that **learning is initiated by a real life challenge, either in the form of an existing problem to be solved or an opportunity to improve the quality of life**.

Initiating learning is also the only aspect of FL that can be designed because it is determined by all the initiating actions of the FOL. Maintaining learning cannot be designed because it is determined by the response actions of the learners on the initiating actions of the FOL. What would be the required first action of a facilitator of learning?

1.   LEARNING TASK DESIGN (LTD)

To enable the FOL to initiate learning, he/she needs to very thoroughly and carefully consider the format of such an event since it needs to constitute real life, of which the world of work and what it demands in real life is crucial, since between 60-80% of our lives are occupied in that domain. "Learning tasks nicely fit the ideas that are prevalent in the world of work. Learning tasks are concrete, authentic and meaningful real-life experiences that are provided to learners" (Van Merriënboer and Paas, 2003:9). A Learning Task (LT) constitute authentic real life in its uncompromising holistic complexity. A LT, therefore, is pivotal in education and provides a powerful learning environment aimed at complex holistic learning as would real life demand it (Van Merriënboer and Paas, 2003:9). De Corte (2003: 21-33) describes powerful learning environments as environments that best enhances transfer of learning. Van Merriënboer and Paas (2003: 3-28) reports that real-life has become the dominant consideration in designing powerful learning environments. In fact, they say that "learning needs to be situated in problem solving in real life, authentic contexts" (Van Merriënboer and Paas, 2003: 5), where the environment contains ill structured information in which no answers are embedded, but it requires total engagement of the learner through meaningful experiences which enables "the learner to learn the ways of knowing of an expert" (Van Merriënboer and Paas, 2003: 5). Claxton (1999: 307-311) echoes the same notion and adds the crucial importance that learning to learn (metalearning through metacognition) includes the self-discovery of the tools (algorithms) to solve problems and the self-discovery of the relevance of the application of such tools according to the natural functioning of the brain (Claxton, 1999:198-211). De Corte (2003:25) suggests that the acquisition of such competencies requires that learners be confronted as much as possible with demanding real life challenges in authentic contexts that has personal meaning for them which they need to resolve personally as well as through interaction and collaboration with others.

A LT, therefore, is a demanding real-life challenge that the learners have to resolve by themselves. This challenge needs to compel them to stretch themselves beyond their abilities and capabilities. It

has to be a challenge that demands that learners engage in living the reality of real life right now and take responsibility for doing so, and thus fully utilise their potential to become joyous, self-fulfilled human beings.

But the LT must first be designed before it can operate to initiate and subsequently maintain learning. The operating concept "design" is used because of its root being that something is creatively constructed from "nothing" – as opposed to the concept "planning" which indicates that everything needed is already available and simply needs to be ordered appropriately. LTD is therefore a very demanding and highly professional responsibility that needs to be done with deep consideration and great care.

LEARNING TASK DESIGN (LTD)

1.   MINIMUM REQUIREMENTS

There are minimum requirements for reporting LTD according to the Department of Education. Institutions have and could develop their own LTD form and format. However, the minimum requirements to be included in such a LTD form and format are the following:

  a. Learning area/subject/discipline
  b. Learning level or phase.
  c. Learning outcomes (LO's) from the specific learning area/subject/discipline/phase.
  d. The associated assessment standard (AS) for each LO.
  e. Time allocated.
  f. Class organisation.
  g. Resources.
  h. Assessment methods tools and techniques that will be used.

What follows are guidelines for LTD and what is expected to be contained in a LTD.

2.   GUIDELINES FOR LTD

The headings that follow are the headings to be used in documenting the LTD

  ❑ **PERSONAL DETAILS**
Indication of full personal details: Name, student number, phase in which qualification is sought to facilitate learning

  ❑ **LEARNING PROGRAMME AREA/SUBJECT/DISCIPLINE**
Specify the area of specialisation in terms of a learning programme or learning area/subject/discipline

  ❑ **SPECIFIC LEVEL OF LEARNING**
Specify the level of learning (ie. which Grade, certificate, diploma, degree)

  ❑ **LEARNING OUTCOMES (LO'S) AND CORRESPONDING ASSESSMENT STANDARDS (AS'S)**
A careful *selection* of the specific LO's to be achieved with its corresponding AS's within the area of specialisation at the particular level of learning.
  ➢ Consult the NCS
  ➢ Identify those LO's and corresponding AS's that should be incorporated in all LT's
  ➢ Identify those LO's and corresponding AS's you particularly want to have learners achieve in this LT
  ➢ Copy all these LO's and corresponding AS's – their numbers AND their FULL descriptions – from the NCS and insert it under this heading

❑   **THE CHALLENGE**

TO DESIGN THE CHALLENGE, THE PROCESS INDICATED BY a) TO e) THAT FOLLOWS IS RECOMMENDED

a) ***To obtain a basic challenge:***
  ➢ Identify from the particular LO's and corresponding AS's you want learners to achieve in this LT and the knowledge areas, and the core knowledge and concepts in the NCSG any issue in real life.
  ➢ Generate as many aspects as possible about this issue.
  ➢ Identify all those aspects about this topic that are real life challenges: problem areas in real life or areas in real life that provide the opportunity to improve the quality of life.
  ➢ Choose from those identified challenges, five of the most important, urgent, prominent, pressing, exciting or rewarding.
  ➢ Select from the chosen 5 challenges, the one with the most prominent role or function in the life of the learners right now (or that needs to be addressed right now to prevent future complications)
  ➢ Determine the challenge the learners would most likely be able to actually experience in real time
  ➢ Determine whether the challenge will be legal, safe and practical for learners to experience.
    o If it is not safe and practical for learners to experience, then determine the next best challenge or the one closest to experiencing it in real time.
    o If it is safe and practical for learners to experience, then formulate this basic challenge in one sentence in the form of a question.

b) ***To obtain the specific challenge:*** The basic challenge should now be made specific by exploring and studying all available relevant material on it. Give correct, accurate, and full bibliographical details of all the resources within the particular learning area of specialisation that you have consulted:
  ➢ *authoritative resources* (official documents, scientific textbooks used in universities, technikons, and colleges, scientific journals and electronic media and multimedia software on the problem) which supplies the scientific soundness, correctness and accuracy perspective;
  ➢ *popular resources* (journals and periodicals and electronic multimedia software on the topic which are not so scientifically inclined) which supplies the context in a wider perspective;
  ➢ *general resources* (magazines, daily newspapers, radio, TV, and multimedia software as well as the internet) which displays the reality of daily living;
  ➢ *institutional resources* (prescribed textbooks for the learners and other electronic multimedia software).

By doing this, the facilitator of leaning is able to determine the scope, possibilities, limitations and implications of the problem or improvement as reflected in everyday life for which we are preparing our learners. This elaborated problem should now be categorised in the following components:

  o *WHAT* – content: core knowledge and concepts (facts, concepts, principles, laws, rules, etc), which represents the *meaning that has to be constructed* by the learners. It must be in structural form (like a concept map, diagrammes and sketches) and it must be complete.
  o *HOW* - competencies: abilities, skills and techniques, which represent what learners will do, which would also function as a demonstration that the assessment standards have been met.
  o *WHERE* - relationships: conditions under which the learners will execute the leaning task which represents the *authenticity* of the learning.

c. ***To obtain the final challenge:*** The specific challenge has to be transformed into a fully-fledged final challenge. This is done by answering the following question: How will I challenge, evoke and elicit learners to establish the necessary relationships with what is to be learned, so that they are compelled to implement the appropriate competencies, in order to construct the required meaning themselves: discovering and understanding the material in such a way that they are able to use it do something creatively new. The *popular* and especially the *general* resources will assist you in trying to find an answer to the question. To construct such a problem within the context of a learning task, is the most demanding aspect of LTD. To know exactly what the problem in LT context is, is therefore of crucial importance. The contributions of (Barrows & Tamblyn 1980:18), Claxton (1999), Slabbert (2000) and Van Loggerenberg (2000), can be summarized as follows:

- It is an unsettled, puzzling, unsolved, challenging, exciting issue that needs to be resolved.
- It is an unanticipated event that disrupted the normal cause of matters.
- It is a situation that is unacceptable and needs to be corrected.
- It is something for which there is currently no ready-made solution – it is therefore original and new.
- It is not offered as an example of the relevance of prior learning or as an application of knowledge already learnt.
- It is encountered for the first time in the learning situation.
- It serves as a focus or stimulus for the use of creative problem-solving skills.
- It serves as a focus or stimulus for the search for and study of information or knowledge needed to understand the cause of the problem and what it entails.
- It serves as a focus or stimulus for the search for and study of information or knowledge needed to find out how the problem might be resolved.
- The required skills for resolving the challenge have not yet been acquired.
- The effect of a problem is that what one needs to do next is always uncertain.
- It claims the complete personal involvement of the learners because the learners themselves really experience the challenge in real time – right now!
- It is both important and necessary to be resolved urgently through immediate action.
- It is something that will impact the enhancement of living their lives right now when they have solved the problem.
- It is something that needs to be resolved right now because the discomfort or excitement in experiencing it is too much to bear.

d) *Consider the following criteria for a challenge*

- It has to be a challenge in life context
- It has to remove the boundary between the educational institution and reality
- It has to be new, original and creative in nature
- It has to be credible
- It has to be a challenge for the learner
- It has to claim complete personal involvement of the learner
- It has to challenge learners to stretch themselves beyond what they believe their capacity is
- It has to compel learners to learn spontaneously
- It has to launch learners into a peak experience of joy and self-fulfilment

e) *Identify the category of the LT*

Since current curricula may not support only real life LT's, it is important to recognise what alternatives are available. There are four categories of learning tasks and the categories are also arranged in hierarchical order, which means that all effort has to be exerted into designing a learning task in the first category. Only when that becomes really impossible, should the next category be considered and so on. Only when the challenge within another category is much higher or the nature of the challenge demands it, is a deviation from the hierarchy allowed. These categories of learning tasks have been identified, based on the foundational work of two of the "mothers" who integrated drama as learning in education, Heathcote (1991) and O'Neill (1995) as well as other experts (Wagner, 1999; Andersen, 2004; Taylor and Warner, 2005):

❖ *Real life learning tasks* where learners operate in *real life* as it is and where the outcome of the learning task makes a direct positive contribution to society and the environment. Real life learning tasks are usually very *entrepreneurial* in nature. If your practice focuses on educating learners for a particular job or profession, then experiencing (really doing) this job or profession in real life is what this category of learning tasks portrays.

❖ *The world of work learning tasks* are learning tasks situated in the world of *work*. Any one or more jobs related to the learning task at hand are selected for the context, or, if your practice focuses on educating learners for a particular job or profession, then that job or profession will be the only context. These jobs are simulated and the learners and facilitator of learning are usually in role-play: They are portraying characters involved in or associated with the particular jobs.

❖   *Fictional or hypothetical learning tasks* are learning tasks which transcends the here and now into the imaginary and fantasy worlds. They are learning tasks situated in another place and/or in another time. Futuristic learning tasks are especially important in this category, in, not only anticipating the future, but more urgently, creating the future. These situations will also be simulated and role-play will be evident.

❖   *Pure play learning tasks* are learning tasks which are structured in the form of games which might have very fixed rules or very loose ones. The rules might be given as conditions or limitations by the facilitator or the learners themselves may create them.

d)   *Consider the following possible formats of LT's*

There are many life contexts or formats within which your learning tasks can be set. The following are some formats or ideas. The list is nowhere near complete but only suggests some ideas.

Anecdote - story	Meeting
Analogy – "the same as"	Mime
Carnival	Narration - storytelling
Case study	Obituary - outline of someone's life
Ceremony	Portrait making - learners making a still image or
Conference	photo story which represents something (eg
Commercials - TV, Radio	before/after) which can come alive to tell a story
Competition - various	Presentation
Court case	Production
Dance	Project
Design	Promotion
Detection	Re-enactment
Discovery	Research
Drama	Role-play - focus on roles to be acted out in a
Exhibition	particular situation and switching of roles
Festival	Scenario
Fieldwork	Seminars
Film making	Simulations - controlled representations of the
Forum	real world but the facilitator does not take a role
Game - existing or devised: high energy	War
activity with rules to achieve a	Writing
specific outcome	
Interview	
Interrogations	
Invention	

e)   *Consider the following items to spark off action*

Of importance is to get the LT into action. There are many items in life context, which may do so. The following are items that might spark off such action. Again the list is not complete but suggests some ideas.

Costumes	News
Documents - antique, past, present	Newspapers
Files - with information	Objects - single or collection
Journals	Photographs
Letters	Pictures
Log books	Poems
Messages	Script
Models	Sounds
Movement	Slides
Music	Video or film

e) *Consider the following frameworks in which to design your LT*

Your learning task should also be framed into one or the other life context. There are many frames into which your learning task can be set. The following are some suggestions.

FRAME	EXPLANATION
Time	Past, present, future
Perspective	* Living in the present, looking at the past or the future * Living in the past, looking at the present or the future * Living in the future, looking at the past or the present
Age	From unborn to past the grave
Social status	From "peasant" to "king"
Role	Responsibility, expert, novice, person, object, event, frame of mind, position
Reality	Real, hypothetical, fictional, imaginary
Communication	Verbal language (slang, dialect, code) non-verbal language, no language
Locality	Here, elsewhere, anywhere

AS A RESULT OF THE PROCESS ABOVE YOU ARE NOW ABLE TO FURTHER DOCUMENT YOUR LTD

      o   **CATEGORY**
Specify the category of this specific LT and why this category was (one of the four under categories of LT's)

      o   **AUTHENTIC LEARNING CONTEXT**
Creating an authentic learning context is of extreme importance (Heathcote, 1991; O'Neill, 1995; Wagner, 1999; Taylor and Warner, 2005). However, it must be emphasised that it is establishing the authentic context in the minds of learners (inner psychological and emotional environment) that is of crucial importance and this can be done without any physical manipulation of the outer environment – but this obviously needs careful consideration skilful expertise. A complete description with accompanying sketches where necessary of the authentic learning context in which the learning task will be executed should contain the following:
- How the learning environment will be organised to create the most authentic learning context or atmosphere.
- Specifying the role or function of the FOL, learner, and any other participant. What are the roles of the learners if any particular role will be played?
- Specify what kind of identification (clothing, nametag, props, etc.) will the role-players be identified with, if any?
- Supply an inventory of all the resources (as authentic as possible) the learners will be using (real objects, models, audio-visual, printed materials, electronic materials, computer software, etc) and what it will be used for.
- Supply an inventory of all the materials and apparatus (decorations and props, identity tokens for things and to indicate roles, costumes, etc) to be used and for what they will be used to create the most authentic learning context or atmosphere.

o   **PRESENTATION**

A demanding real life challenge (problem existing in real life or a opportunity and desire to improve the quality of life) needs to be formulated in its final form exactly in the format and way in which it will be presented to the learners. It has to adhere to the following criteria:

a)   It has to provide the entire framework of the problem to enable learners to work completely independently from the FOL.
b)   It has to state the challenge clearly and unambiguously.
c)   It has to require learners to plan before they start working: first individually, then cooperatively (See metalearning and cooperative learning later).
d)   It has to require learners to resolve the challenge: first individually, and then cooperatively.
e)   It has to require learners (implicitly) to produce end product outcomes.

o   **DOCUMENTATION**

The learners need to receive the challenge in an abbreviated form, but containing the essence and adhering to all the criteria as required in the presentation. This may be done through a work document. A work document may vary according to the nature of the challenge, from a document containing the challenge only, to a very comprehensive learning package containing the challenge, questionnaires, learning materials, etc.

o   **END PRODUCT OUTCOMES**

Supply the end product outcomes (at least one possibility) as would be expected from a learner who has executed the LT excellently.

✓   The answer to the problem or the resolved challenge as a product in at least one of the following forms:

➢   a physical object that has been produced
➢   a decision that has been made
➢   a process that has been generated
➢   a service that has been provided

This will represent the product of learning in terms of doing something creatively new
AND
✓   How the problem has been solved – the process or procedure. This will represent the process of learning through the competencies the learners obtained and employed.
AND
✓   A construction of all the core knowledge and concepts acquired (in the form of a concept map) and how everything is related regarding the solution to this problem. This will represent the content, which implies that the learners are actually writing their own (but much more relevant) "textbooks".

FOLLOWING ARE SOME OF THE LAST ASPECTS THAT SHOUL BE PART OF THE LTD BUT IT CANNOT AS SUCH BE RECORDED

a.   Collecting, making, buying everything needed.
b.   Preparing the learning area with everything in it.
c.   Testing everything.

A designed LT has no use unless it is put into practice. This means that your designed learning task has to be put into operation. This process is called **Learning Task Operation (LTO)** which contains the entire further process of facilitating learning from this point forward. The second required action of initiating learning is learning task presentation by the FOL

2.   LEARNING TASK PRESENTATION (LTP)

Even the best designed LT may fail badly when it is presented which may cause the whole LTO to collapse. Your LTP is therefore of major importance for the success of the LTO. It is your LTP that requires artistry and creative skill that again focuses on the uniqueness and professionalism of facilitating learning. That is why education is often referred to as an art. The LTP may also include some activity where the learners have to identify the challenge themselves instead of the FOL presenting them with a challenge. Facilitating learning through LTP is the first test of the facilitator of learning of true professionalism in educational interaction with learners. LTP needs therefore to adhere to very demanding requirements (Heathcote, 1991; O'Neill, 1995; Wagner, 1999; Andersen, 2004; Taylor and Warner, 2005):

a.   *Creating a totally conducive atmosphere*

The verbal presentation and everything that accompanies it has to work together to create the most conducive atmosphere in establishing the learning context. As has been indicated before, effectively executed, the verbal presentation alone may be sufficient to fulfil this aim because "it is all in the mind" and if the verbal presentation can touch the mind in such a way that it creates the appropriate emotional inclination, the creation of the atmosphere was sufficiently conducive.

b.   *Establishing roles and functions of the participants*

Whilst creating the totally conducive atmosphere is "setting the scene" the immediate need for the participants are their roles and functions in the situation because it immediately focuses attention to the presentation to establish expectations and anticipate possible actions.

c.   *Presenting the real life challenge*

Although the real life challenge should be presented authentically – as real life would present it – because this happens in education it has to be presented complying to the following criteria:

(i)   Clarity
The challenge to be resolved has to be absolutely clear to the learners so that they will not be distracted into doing something that would not resolve the challenge at hand because that was the aim of this particular learning period.

(ii)   Importance
The learners need to experience the importance of resolving this real life challenge. Even more importantly, they need to experience why it is important that they, and no one else, need to resolve the challenge.

(iii)   Urgency
The learners have to be convinced that they need to resolve the challenge right now and not any later.

(iii)   Action
The end of the presentation has to compel the learners straight into learning action.

B.   MAINTAINING LEARNING

Obviously, when the learners turn into learning action, initiating learning has ended and the responsibility of the FOL is now to ensure that the learning of the learners is maintained. The aim of maintaining learning is to improve the quality of learning until the highest possible quality of learning has been achieved which means that the learners were compelled to fully utilise their potential.

1. Learning task execution (LTE)

After LTP the LT need to be executed. LTE is done by the learners only, but it is facilitated intentionally and intensively by the FOL to continually improve learning quality which Torrance (1991:225-233) refers to as keeping it going and continually deepening expectations. This is the whole purpose of LTO: The learners need to resolve the challenge through which they fully utilise their potential and become lifelong learners. They do this *first* individually and *then* cooperatively.

a. Metalearning (ML)

The learners must first resolve the challenge individually and independently, so that each learner can take control over and responsibility for his/her own learning. This is the only way in which the learner will become an active, effective, independent, lifelong learner. The LT needs to require the learner to plan, execute, monitor and assess his/her own learning. This is based on metacognition introduced by Flavell (1976:88): "'Metacognition' refers to one's knowledge concerning one's own cognitive processes and products or anything related to them…". Spring (1985:291) explains that "[m]etacognition is the ability of learners to know how they know and regulate the learning process constantly" and Ford (1981:360) say that metacognition is "a prerequisite for learning how to learn effectively" and Flavell (2004) concurs. Many contemporary experts also integrates metacognition and its skills with effective learning in powerful learning environments (De Corte, 2003:23; Lethinen, 2003: 36; Vermunt, 2003:121; Vosniadou and Kollias, 2003: 190; Keer and Verhaeghe, 2003: 227; Kuhn and 2004; Smith, 2005). Biggs and Telfer (1987:185) brought metacognition directly into the educational field which he called metalearning (ML), and in the following year it was fully established as an educational theoretical framework (Slabbert, 1988). ML is a continuous reflection of the learner on his/her own learning process through asking metalearning questions and answering them to improve the quality of learning. Following are the required metalearning strategies with their accompanying questions:

(i) Planning own learning
What is this all about? What do I know about this? What does this relate to? Do I know enough about this? Have I read it carefully and fully? What are the most important parts? How do the parts relate to each other? How does this relate to what I already know? Does this make sense? What will I have to find out for it to make sense? What am I required to do? What will I have to do in order to complete the task? How do I see the task?

(ii) Executing own learning
That which has been planned as a result of answering the planning questions has to be executed as planned. However, as the execution of the learning process progress, The learners should continuously ask questions to improve the quality of the learning process.

(iii) Monitoring own learning
How does this new knowledge compare to what I previously knew or predicted? Do I have to change my understanding of what I previously knew? Do I understand what I am doing? What will happen if ... ? How does this relate to ... ? How could this be? Why does this happen ? When does this not apply? Is this the best way of doing it? How am I doing? Does this seem correct? What should I do next? Am I checking all possibilities? Where will this lead me? How do I feel about this? Have I completed this fully and carefully? What else needs to be done?

(iv) Assessing own learning
How could I have done this even better? Do I fully understand this? What do I have to do to fully understand? Do I understand enough to justify stopping? How does mine compare with others? How do I feel about this? How can I use this in future? What did I learn from this? When will I need to do something similar? How do I feel now?

This process compels the learners to implement thinking skills and creative problem solving. But most importantly, metalearning serves as the instrument through which to acquire the fundamental intrapersonal life skills that is lacking so severely in first time employees. These life skills cannot be taught or learned – they are a consequence of living life fully because they form the character ethic of the human being (Covey, 1992: 5-11). From the many resources about life skills, those that fundamentally constitute intrapersonal life skills are the following (Slabbert, 2000:224-227):

LIFE SKILL	DESCRIPTION
Self-confidence	Feeling able to do it.
Motivation	Wanting to do it.
Initiative	Moving into action without any prompting.
Effort	Willing to work hard.
Perseverance	Keep on going no matter how difficult it is.
Common sense	Making the best choices out of many possibilities.
Responsibility	Doing what is right and carry the consequences.
Independence	Doing it yourself.
Joy	To be happy.
Love	To care ultimately for you and everything around you.

b. Cooperative learning (CL)

According to the maturity continuum manifested in the natural law of evolutionary development (Covey, 1992:46-52), we begin life as infants totally dependent upon others. Over time we become more independent, inner directed and self-reliant. Very soon, however, the reality of life by its very interdependent nature dawns on us as the highest human value because "[n]one of us is as smart as all of us" (Johanson and Johnson, 1990:107). "Growth, change, and ultimately evolution occur as individuals, organisations, and society increases the depth of their relationships by continually broadening and strengthening their interdependent connections" and our brains are especially hardwired for this purpose (Blakemore and Frith, 2005). The foundation of life and living it, is relationship (Wheatley, 2003) and learning through this fundamental life principle is not only necessary, it is inevitable (Alderman and Milne, 2005). Cooperative learning (CL) takes place when learners in small groups cooperate to learn with the exclusive purpose to increase the quality of each other's learning in order to fully utilise their individual potential (Kagan, 1992:6; Johnson and Johnson, 1990:110). CL is not group work because the most distinctive aspect about CL is the fact that it requires the following demanding criteria (Cohen, 2004) to be characterised as cooperative learning and to qualify as an instrument to improve the quality of learning (Jacobs, Power and Loh, 2002, McManus, 2005):

(i)   Optimal group size
The most effective group size for cooperative learning is 4 because it offers the smallest number of members with the highest number of communication lines as possible.

(ii)   Heterogeneous groups
Groups should be heterogeneous in every respect: ability, sex, culture, etc.

(iii)   Positive interdependence
The LT has to be designed in such a way that individual members have to be dependent upon another for the group to achieve success.

(iv)   Individual accountability
Although each member of the group may be working on a separate aspect of the LT, each member has to be fully aware of what all the other members are doing and how they are doing it because he/she may be assessed on any aspect of the LT and his/her contribution should be representative of all members to be graded as a group effort.

(v)   Promotive interaction
It should be clear that the previous criteria compels interaction between members, but it is promotive interaction because the interaction aims at critically assess the quality of all member's learning.

(vi)   Assessment of cooperation
Frequent and regular assessment of the quality of members' cooperation has to be done in order to eliminate harmful and enhance conducive cooperative behaviours.

Only through cooperative learning will the learner acquire the interpersonal life skills. What is of crucial importance is that metalearning has to precede cooperative learning, in that the LT or predetermined aspects of it, has been completed by the individual. Only then will the individual have had the opportunity to acquire the intrapersonal life skills and simultaneously constructed a meaningful contribution that he she can present to the group. Only then will cooperative learning fulfil its aim. In the same way as the intrapersonal life skills, the interpersonal life skills cannot be taught or learned – they are also a consequence of living life fully because they form the character ethic of the human being (Covey, 1992: 5-11). From the many resources about life skills, those that fundamentally constitute interpersonal life skills are the following (Slabbert, 2000:239-243):

LIFE SKILL	DESCRIPTION
Humanisation	How do I see you?
Communication	How do I interact with you?
Dealing with feelings	How do I react to you?
Justice and forgiveness	How do I want you to react to me?
Love	How do I care ultimately for you?
Leadership	How effectively can I lead you to fully utilise your potential?

LEARNER EMPOWERMENT

Metalearning and cooperative learning result in learner empowerment. For this to happen, it demands from learners the following new roles and responsibilities:

a. Taking responsibility for their own learning to maximise his/her potential and acquire the competencies necessary for living in a continuously changing new world order, and consequently becoming empowered to do so. It means to become ultimately versatile.

b. Controlling his/her own learning to become versatile. This means that the learner needs to possess the vastest array of learning strategies possible. Then and only then will the learner be able to *control* his/her preferences (learning style) and motives (learning approach) because he/she can make *choices* to suit the requirements of the learning task. If the learning task, for instance, requires the learner to recognise the chemical elements depicted on the chemical containers in order to conduct a chemical experiment, the way in which to accomplish the task would be to memorise names and respective symbols of the chemical elements on the periodic table - a typical surface learning strategy which suits the requirements of the learning task perfectly. There is no need for trying to find the rational or meaning behind the philosophy of the names and respective symbols of the chemical elements - a typical deep learning strategy. If however the learner only had the latter strategy in his/her repertoire, the learning task may be accomplished eventually, but in a totally ineffective way. Because the learner had a repertoire of learning strategies available and because the learner can discern between them to choose and select the most effective, the learner is in full control over his own learning and consequently empowered to determine the quality of his/her own learning. If however, the learner discovers *any* deficiency in his/her armour to effectively complete a learning task, it is the *learner's* responsibility to rectify the situation and *acquire* what is necessary, whether it is information or knowledge or a competency. Again this manifests the learner's control over his/her own learning and his/her empowerment to be a lifelong learner.

c. If additional information is needed to acquire some knowledge to solve the problem (learning task) at hand, it is the learner's responsibility not only *to **acquire** that knowledge or information* through the abundant resources available (not least of all the information technology), but also *to **find** those relevant resources* needed. It must be emphasised that the facilitator is not and should never be a source of information as facilitator. However, he/she might serve as a source of information or knowledge only if and when he/she is not acting as facilitator, but having the learners learn and experience the variety of resources available: The facilitator might decide to take the role of some individual who might have the information or knowledge available if such a person is not otherwise accessible. In this way the learner does not become dependent upon the facilitator but learns the many possibilities of different resources and at the same time the learner learns to master many other valuable competencies needed in life, for instance, the competency of interviewing. This makes it possible for learners to effectively access and acquire the most recent knowledge (contents and structure) immediately when it becomes available. A personal experience should be recorded here because it illustrates our ignorance of learners' abilities. In the one situation, the learners of a grade 9 class had a "practical" on roots and stems of plants and the different kinds of each. This is work that has been *taught* since grade 4 and repeated virtually every year with a little more detail. In spite of this repetition of *knowledge or information transfer* as well as the fact that it has been taught just the previous week, the learners doing the practical had difficulty answering direct knowledge reproduction questions and they could not with any certainty identify the different roots on the plants they were supplied with. In another situation, which was witnessed within days of the first, a learner exhibited the material she gathered and compiled for a project. The topic was exactly the same: roots and stems of plants and the different kinds of each. She had done *everything* on her own. She had studied the resources available, collected the material, wrote up a report and assembled her exhibition. She could not only answer knowledge *production* questions, but could easily on request identify different roots/stems. She also demonstrated her thinking ability when confronted with difficult questions - she demonstrated the knowledge of what was expected from the grade 9 learners and even beyond. Most astonishing was the fact that there was nothing special about this learner, in fact, she was typical of the very average learner in a very average socio-economical area - but she was in grade two. She had therefore never encountered

this work before. This illustrated that it cannot be tolerated to waste valuable learning time (class time) to transfer knowledge because learners are able to and should

(according to the critical outcomes) collect, analyse, organise and critically assess such information or knowledge through other resources available not needing to wait for someone or even the syllabus to reveal or expose it.

d. If *drill* and *practice* are needed to acquire a specific skill which is necessary to solve the problem, it is the learner's responsibility to *do* the drilling and practicing - through instruction manuals or other resources from which the learner will be able to work independently and until the necessary proficiency is obtained. The facilitator cannot, in any case, do the drill or practice for or on behalf of the learner. The learner has to take responsibility for this and no valuable quality learning time ("class time") should be spent on this. This makes it possible for learners even to immediately drill and practice the most recent required competencies when they become known, not needing to wait for someone or the curriculum to demand it.

2. Learning task feedback (LTF)

Learning is maintained through the principle of continuous feedback. Throughout the learning process, be it individual or cooperative, the FOL needs to make certain that the learners keep on learning. Every Feedback (FB) action of the FOL during maintaining learning has to cause the learners to become more independent. That is why the FOL realises that he/she should not give answers to learners' questions and/or become a source of information. This will make the learners dependent and will prevent them from maximising their potential.

The FOL has to observe all the learning activities very carefully during maintaining learning, to be able to FB in the most appropriate way, and so ensuring the best possible quality of learning. In this, the FOL is relentless: He/she would not stop with the actions of facilitating learning described here until the highest possible quality of learning has been achieved by the learners themselves. He/she would also not stop with these actions until the learners have made sure that what they have learned is, for the particular time period and the level they operate on, scientifically absolutely correct.

Maintaining learning cannot be designed or planned for because it depends entirely on the actions of the learners, and those are unknown until they actually occur – however, maintaining learning can and should be thoroughly anticipated. That is why maintaining learning is such a highly skilful, demanding and professional facilitating learning action.

a. Emotional encouragement and support

If the learners are learning well and the quality of their learning is sufficient, the FOL gives emotional encouragement and support, by saying things like: "You are really doing well" (encouragement); or "I know you can do it" (support).

b. Asking clarification

If the FOL observes that the learners are getting off track or the quality of their learning is not good enough, or suspects that this is the case, he/she has to determine exactly where the learners are. The FOL will ask questions such as: "What are you doing?", "Why are you doing this?" or "What do you want to do next?" The FOL seeks information to clarify the position of the learner. This is the only case when the FOL obviously wants an answer and waits for it. But this will always be followed by a challenge for learners to metalearn.

c. Challenging learners to metalearn

(i) Reverting learners' questions back to learners

When learners request help of any kind from the FOL through asking questions, the FOL has to return the question back to the learners by asking questions like: "What do you think?", or "What would you do?".

(ii) Requesting reflection from learners for increased quality of learning

Whether the FOL has detected insufficient quality of learning or whether the learner has made it known somehow, the purpose of the FOL is to have learners reflect on what they did, assess it and improve on it. That is why the FOL will ask the questions and then leave without getting an answer. The FOL will ask questions such as:

- ✓ Have you thought of everything?
- ✓ Have you considered all possibilities?
- ✓ Is this the best way of doing it?
- ✓ How many more can you find?
- ✓ Do you understand what you are doing?
- ✓ Do you understand why you are doing it?
- ✓ Is this enough?
- ✓ How will you improve this?
- ✓ How sure are you?
- ✓ How will you make sure?
- ✓ How well do you think you did?
- ✓ What is the meaning of this for your future?

(iii) Reference to resources

If learners cannot solve the problem in spite of previous actions from the FOL, he/she should refer learners to resources where they might find some information to help them, by asking questions such as: "What do you need?" and "Where will you find what you need?" Obviously the FOL will have made provision for such a possibility and would have made sure that the resources are accessible in the most realistic and appropriate way.

(iv) Auto-education

If learners are still at this point seriously lacking in knowledge and/or skills to enable them to solve the problem, the FOL, as a last resort, will have made provision for a whole spectrum of educational methods, tools, materials and resources for the learners to access on their own, in order to acquire the necessary knowledge and/or skills through auto-education. Note that, although learners are acquiring knowledge and/or skills, this acquisition is meaningful because they have realised that they are lacking it and that they need it to solve the problem. They also learn how and where to acquire knowledge and skills when they need it. Lastly, they have become more independent, because they had to acquire the knowledge and skills through their own efforts.

(v) Edutainment

One of the most important criteria for life in general, and obviously for learning is efficiency. Efficiency is determined by the combination of time it is taking to complete a task, the effort that was exerted in completing the task and the accuracy with which it has been completed. If for any reason time and or accuracy and/or effort becomes paramount for efficient learning, then, and only then, may facilitating learning require a special kind of intervention: , which may result in what has been called "teaching" in the old paradigm: Supplying information, demonstrating or illustrating something, showing something to be imitated, telling something to memorise, explaining something to be "understood", engaging in a Q and A discussion or the demand to become proficient in

a particular skill through drill and practice. This will happen **only under very special conditions**. These conditions appear when learners are busy with LTE and the problem they need to solve demands at a particular time that a particular piece of information or a particular skill is a necessary precondition for being able to continue with solving the problem. The facilitator also knows that, acquiring this particular piece of information or skill through the authentic learning process, will take up so much time and/or may require so much effort to produce the accuracy required, that the learners will be distracted from achieving the actual learning outcome that will compel them to fully utilise their potential in the most efficient way. It means that acquiring this intermediate piece of information or skill, is not an aim in itself, but serves only as a means to achieve the intended outcome in the most efficient way. Only under these very special conditions may the FOL employ the particular activities that will justify learning methods and strategies aimed at regurgitating and repeating like watching, listening, imitating, memorising, drill, practice, etc. But under these conditions, these facilitating learning activities are called edutainment.

Edutainment is a very important part of facilitating learning. Edutainment is prompted by the real disposition of the learners. It is created by a need from the learners - the learners govern - or knowing full well that the learners will need the information/data or skill at a particular point in time for a "higher" purpose. There are very important prerequisites for implementing edutainment: The facilitator of learning will edutain only when there is no other possible way that learners will be able to obtain the information/data or acquire the skill they need right now within the reality of the time limit allocated or reserved to solve the problem. Whether edutainment will be implemented or not will be guided by the question whether edutainment will be the most efficient way for learners to obtain the necessary information/data and/or acquire the necessary skill? If learners are left to obtain the information or acquire the skill in any other way, will time, accuracy and effort unnecessarily be wasted in which much more important learning could have been done? Will this cause the learners to become distracted in solving the actual problem at hand efficiently? Is the learning process of obtaining the information or acquiring the skill a crucial learning experience or are they rather only a means to get to the solution of the current problem more efficiently for potential to be maximised? Whenever a decision has been made to implement edutainment, the format in which it is done is also crucial. As far as possible, it should be done in the dramatic style through the Socratic method and the purpose of the edutainment is always to:

Provoke; disturb; create disequilibria; cause uneasiness and discomfort; stir; shake; touch the emotions; bring into sharp focus; rock the boat; unsettle; deceive; mislead; impact; stun;be radical;have learners really reflect and think critically and creatively!

There is, however, a circumstance under which learning a skill as quickly as possible (through demonstration, imitation, etc) is justifiable. This is when job creation to solve an immediate economic need becomes inevitable. But, this short-term learning has to articulate with the potential of long-term development – it means that, although it is an aim in itself in the short term, it can be only a means to eventually fulfil the aim of education. Important to note again is that learning a skill in this way, focuses on the skill itself and not how it relates to conditions, circumstances, and the environment. And since circumstances, conditions, and the environment is in a continuous mode of dynamic change, it also continuously requires new skills, and it simply becomes futile for a learner not to be challenged through facilitating learning to maximise his/her potential.

3. Learning task consolidation (LTC)

Learning is maintained through LTC at the end of the learning period. A few minutes before the end of a particular learning period, the FOL has to request learners to consolidate what they have learned up to that point and to present it to the entire group of learners. It is of the utmost importance:

a. To ascertain the rate of the learning progress

The FOL demands from learners to share what they have learned up to that particular point in time with the entire group, and, learning from what how far their peers have progressed, the FOL and learners can ascertain the rate of learning progress.

b. To assess the quality of learning

Not only does a simple sharing of what learners have learned take place, but rather a critical assessment of what has been learned by the peers and the FOL. This determines the quality of the learners' learning.

c. To determine the next challenge

Having established the progress and the quality of learning up to that particular point in time provides the opportunity for learners to realise what they have achieved during that particular learning period and to envision what still need to be achieved to fulfil the required outcomes. For the FOL this is also available, and, in addition it allows the FOL to determine what the challenge for the next learning period should be and how it should be executed.

EDUCATING STUDENTS TO BECOME EXCELLENT FACILITATORS OF LEARNING

There could be little doubt that the future increasingly demands learners who are able to take responsibility for their own learning and are therefore able to plan, execute, monitor and assess their own learning to become active, effective, independent, lifelong learners through fully utilising their potential to acquire the fundamental life skills. It should also be clear that this could only be achieved through facilitating learning as has been described in the previous paragraphs. However, at the moment we are currently dealing with a particular education practice of which the requirements are still much rooted in another paradigm. For this reason, the PGCE programme will take as its point of departure four education paradigms of which the quality of learning has been identified to progressively increase from one paradigm to the other. The PGCE programme will therefore be structured in such a way that students progress from one paradigm to the next until they have fully utilised their potential to facilitate learning in the transcendental paradigm in an extraordinary way. The details of this progression will be indicated in a next section. The essential characteristics of each of the education paradigms as they have been initiated by, amongst others, Dewey (1944), Piaget (1952;1958) and Vygotsky (1978) and substantiated by Joyce, Weil and Showers (1992), Miller (1996), Arons (1997), Freiburg and Driscoll (2000) Miller (2003) and Engelström (2004) has been summarised as follows. It should be obvious that the summary indicates distinctive characteristics and therefore portrays what would be dominant in its implementation in practice.

FOUR EDUCATION PARADIGMS / *VIER ONDERWYSPARADIGMAS*

ONDERWYSPARADIGMA EDUCATION PARADIGM / EDUCATION COMPONENT *ONDERWYSKOMPONENT*	Transmission *Transmissie*	Transaction Transaksie	Transformation Transformasie	Transcendental Transendensie
Aim **Doel**	To impart knowledge *Om kennis oor te dra*	To understand *Om te verstaan*	To apply knowledge *Om kennis toe te pas*	To generate knowledge *Om kennis te genereer*
Education mode **Onderwysmodus**	Direct teaching *Direkte ondderrig*	Interactive teaching *Interaktiewe onderrig*	Project education *Projekonderwys*	Facilitating learning *Fasilitering van leer*
Focus **Fokus**	Factual knowledge *Feitelike kennis*	Factual understanding *Verstaan van feite*	Application *Toepassing*	Creative construction of meaning (knowledge) *Kreatiewe konstruksie van betekenis (kennis)*
Educator action **Onderwyseraksie**	Tell, illustrate, demonstrate, explain *Vertel, illustreer, demonstreer, verduidelik*	Questioning, discussing *Vraagstelling, bespreking*	Give assignments, projects, guidance, help *Gee opdragte, projekte, leiding, hulp*	Confront the learners with a real life challenge they have to resolve themselves *Konfronteer leerders met 'n lewenswerklike uitdaging wat hulle self moet oplos*
Learner action required **Leerderaksie verwag**	Absorb, memorise, drill, practice *Absorbeer, memoriseer, dril, inoefen*	Answering questions, discussing *Beantwoord vrae, bespreek*	Exploration, discover, experimentation, *Eksploreer, ontdek, eksperimenteer,*	Creatively constructing new knowledge *Kreatiewe konstruksie van nuwe kennis*
Learning mode **Leermodus**	Receptive *Reseptief*	Interactive *Interaktief*	Self-active *Selfaktief*	Self-directive *Selfgerig*
Learner autonomy **Leerder outonomie**	None *Geen*	Some *Min*	Much *Heelwat*	Total *Totaal*
Level of learning **Vlak van leer**	Shallow *Vlak*	Insight *Insig*	Deep *Diep*	Transcendental *Transenderend*
Learning outcome **Leeruitkoms**	Cognitive Kognitief	Social *Sosiaal*	Multiple *Veelvuldig*	Holistic *Holisties*
Outcome **Uitkoms**	Core concept reproduction *Kernkonsepreproduksie*	Core concept understanding *Kernkonsepbegrip*	Enriched curriculum *Verrykte kurrikulum*	Living real life *Leef die werklikheid*
Learning quality **Leerkwaliteit**	Low *Laag*	Medium *Medium*	High *Hoog*	Maximum *Maksimum*

The transmission, transaction and transformation education paradigms are regarded to be traditional education paradigms in which lessons are planned and presented. It is only the transcendention paradigm which require authentic learning in the holistic sense of the word and the corresponding LTD and LTO as it is demanded in facilitating learning. This does not mean that some actions described as facilitating learning actions are not or cannot be used during the implementation of the other education paradigms. In fact, it should be encouraged that as many as possible of the facilitating learning actions be used in lesson plans and presentations so that composite competence in facilitating learning is enhanced as students move towards the transcendental paradigm.

THE FOUNDATION OF EDUCATING FACILITATORS OF LEARNING IN THE PGCE PROGRAMME.

To become facilitators of learning students need to be educated to execute all the actions of facilitating learning described in the previous paragraphs, and fully utilise their potential to become excellent facilitators of learning. However, the way in which students are educated to do this has to be as unique as the education paradigm of facilitating learning is. The fundamental goal of the PGCE programme is to educate each student to become a professional Facilitator of Learning (FOL). This requires student FOL's to engage in a continuous professional development programme through which they construct their own practice theory of and for Facilitating Learning (FL) on which their entire professional education practice is based.

a.   Professional practice and practice theory

The traditional goal of teacher education is "to teach expert knowledge (resulting from psychological, sociological, and educational research) to student teachers, who can then use this expertise in their practice …. This view leads teacher educators to make a priori choices about the theory that should be transmitted to student teachers. Research shows that this approach has very little effect on practice" (Korthagen, 2001:255) and does not resolve the age old rival dichotomy between "theory" and "practice". In fact, this scientific understanding of education (episteme – see table 4) does not produce the fundamental change in education that is necessary for an ever increasing uncertain future that is emerging. What is necessary, rather, is practical wisdom (phronesis – see table 4) (Korthagen, 2001: 24). Education is a professional practice and as such requires professional praxis knowledge rather than disciplinary based theory. Professional knowledge is derived from practice. Korthagen's (2001: 261) research has shown that it is when student teachers are exposed to and challenged with living through new experiences and continuously reflect on them, that they understand the principles that cause their practice to be successful. Only then are they able to consciously construct new conceptions and internalise fundamental change in their own learning and the way they educate learners. This construction represents the theory of their practice and is known as a practice theory. It is a principle-centred, context-dependent theory that forms the solid foundation, which guide their instantaneous decision making to solve the problems of their professional practice and improve subsequent practices. (Korthagen, 2001; Furlong, 2000) The entire PGCE programme revolves around student FOL's constructing their own practice theory from case studies (reported research on cases in practice) and practical experience, and then using that practice theory as a solid foundation from which they design and execute their own unique professional practices, reflect upon it and improve it.

Table 4   Types of knowledge (Korthagen, 2001:20-31)

Knowledge as episteme	Knowledge as phronesis
Expert, scientific knowledge (theory)	Individual practical knowledge
Needs scientific understanding	Needs practical wisdom
Knowledge of universal principals	Knowledge of concrete particulars
Locus of certitude: Principles	Locus of certitude: Particulars
Knowledge is conceptual	Knowledge is perceptual
Knowledge is rigid	Knowledge is flexible
The principle (concept) dictates the practice	Uses the practice to discover a guiding rule/principle/procedure/method
Knowledge learned (memorised) and "applied"	Knowledge acquired through enough, appropriate and proper ***experience*** (perceiving, assessing, judging, choosing

	actions, execute them, be confronted with its consequences and learn from them)
Provides principle	Provides holistic insight
Teach the student concepts - avoid will, emotions, etc they disturb	Help the student see - celebrate will, emotions, etc they provide insight

b.   Practice Theory

What it is:

> The "practice" (Afr. praktyk) in practice theory refers to each individual student FOL's education practice (Afr onderwyspraktyk): What student's do when they are preparing to facilitate learning during learning task design (LTD) and when they are actually facilitating learning in practice during learning task operation (LTO).
> The "theory" in practice theory refers to the body of systematised knowledge about and for each individual student's practice as facilitator of learning.
> Each individual student's practice theory is therefore the theory of that individual's practice derived primarily from the student's personal practice experience. It is therefore a theory.
> It is continuously informed and enriched by each individual student's practice as such (through reflection by the student on his or her own practice and/or action research of her or his own practice) but also by other practices of other facilitators of learning as well as other already existing theories (research) in education.
> It is therefore in a continuous process of development.

What its function is:

> Each student's practice theory is the foundation from which he or she operates in practice.
> It tells the student what to do and how to operate in practice.
> It therefore determines all the student's actions in your practice.
> It provides all the reasons why the student is operating in practice the way the student does.
> It provides the rational for what the student is doing as facilitator of learning.
> When student's are asked questions about their practice they need to student able to explain everything in terms of their practice theory.

Practice theory in the format of a concept map (and explanatory notes)

A concept map is a creative (colourful, playful, animated) construction of the relationships between a set of (selected) concepts indicating the nature, distance, and relatedness of the relationships between the concepts. A self-constructed concept map is reveals a learner's understanding of what the concept map represents (as opposed to a mind map). It reflects the differentiation between the concepts, as well as the nature and structure of the contextual relationships between the concepts as it manifests in an integrated meaningful whole. It reveals the learner's ability to construct meaning through identification, exposition and definition of distinguishable meaningful units, and recognising, discovering and creating relationships.

Concept maps are considered to student a valuable tool for assessment because they provide an explicit and overt representation of the students' knowledge and promote meaningful learning (Mintzes, Wandersee & Novak, 2000; Novak & Gowin,1984; Novak, 1998). Pearsall, Skipper & Mintzes (1997) reports that concept maps provide a unique window into the way learners structure their knowledge, offering an opportunity to assess both the prepositional validity and structural complexity of their knowledge base. What is also crucial is that concept maps provide a means to capture, elicit and represent qualitative aspects of students' knowledge (Novak & Gowin 1984). Since concepts maps deal with concepts, there is no discipline in which they may not student used. They have been used widely for a variety of educational purposes and functions (Jonassen, reeves, Hong, Harvey & Peters, 1997; Novak 1990) as a curriculum organisstion guide, as an instructional tool, as a tool to promote meaningful learning and as an assessment tool (Mintzes, Wandersee & Novak, 2000; Trowbridge and Wandersee, 1998)

As a learning tool, concept maps can serve to help students to learn, to create and to use knowledge (Gouli, Gogolou and Gigoriadou, 2003: 216-217; Novak,1998: 45-67). In this sense it is consistent with

constructivist epistemology and cognitive psychology (Edmondson, 2000). The concept mapping process:

    a.   promotes and assists meaningful learning (Hill, 2004: 4; Fisher, Faletti, Patterson, Thornton, Lipson & Spring, 1990; Novak 1998; Novak 1990) by encouraging students to identify concept meanings, to establish their own relationship between concepts, to rearrange the existing relationships, to relate new concepts to prior concepts, to organise the concepts in a hierarchical and integrated manner and to refine the completed map;

    b.   helps students to organise knowledge in meaningful related chunks (Novak, 1998), promoting better knowledge organization in memory, better retention, retrieval and utilisation of knowledge in new situations;

    c.   Helps students to realise that learning requires their active and constructive involvement, to understand better the content and the process of effective, meaningful learning (Edmundson, 2000) and to learn how to learn by bringing to the surface cognitive structures and self-constructed knowledge (Novak & Gowin, 1984)

Concept maps as assessment tool can also reveal to both students and teachers the quality and the level of the development of their conceptual understanding for any domain at any grade level (Novak, 1998). Novak & Gowin (1984) found that concept maps gave teachers and researchers more accurate and more authentic insights into students' thinking than traditional methods of testing (Walker & King, 2002). A concept map also provides a better gauge of what students know than most other assessment tools because it allows free response and it provides insights into the students' knowledge structure (Gouli, Gogolou & Gigoriadou, 2003). Not only are concept maps reliable and valid, but they also measure aptitudes not commonly assessed by typical objective tests. These positive effects have been shown also by lots of research studies in different age and culturally diverse students (Horton, McConny, Gallo, Woods, Senn & Hamlin, 1993; Novak, 1990, 1998).

The preceding paragraph is self-explanatory regarding the reason for the preference that the practice theory should student constructed in the form of a concept map (with explanatory notes - where it studentcomes inevitably necessary).

To qualify as a concept map, the following criteria should student observed:

➢ A concept map consists of concepts – meaningful units which, in itself, has meaning.
➢ A concept map consists of at least two concepts.
➢ Each concept in a concept map has to student linked to at least one other concept by a line that indicates a relationship between the two concepts. Any one concept, however, may have a relationship with many other concepts.
➢ An arrowhead has to indicate the relatedness between the concepts. There may student a reciprocal relationship between two concepts that should student indicated by an arrowhead directed to each of the two concepts.
➢ The nature of the relationship between two concepts should student indicated with a written linking word on the linking line.
➢ The distance of the relationship should student indicated by the length of the linking line.

On the next page, a concept map of metalearning is depicted. Please note that some software programmes may have unfortunate detrimental limiting consequences for the ultimate construction of a concept map as in this particular case regarding some criteria. Whatever the medium, concept maps should comply to all essential criteria.

CONCEPT MAP OF METALEARNING

Metalearning

requires

Control over consciousness

through

Continuous reflection

exploring

MIQ	EQ	SQ

through — *and/or* — *through*

Thinking
(To solve existing problem)

Creativity
(Improve quality of life)

using — *during* — *using*

Modes of thinking — Creative problem solving

Planning

through

Design questions — *during* — Objective finding
Fact finding
Opportunity finding

Monitoring

through

Thinking tools — *during* — Idea finding
Solution finding

Assessing

through

Novel assessment tools — *resulting in acquiring* — Acceptance finding
Implementation

Intrapersonal lifeskills

c.   The curriculum

To become competent professional practitioners, the students will engage in a professional and specialisation curriculum.

d.   The professional curriculum

As the name indicates, the professional curriculum aims at equipping the Students with professional competence in education. The following modules form part of the specialisation curriculum:

FCL 420	Facilitating Learning
LNT 410	Learning Theories
ASS 410	Assessment
GPE 410	Global Perspectives in Education Learners with special education needs
FOE 410	Foundations of Education
COE 410	Social Context of Education (d) Diversity (a) HIV/Aids
PEL 410	Professional Ethics and Law
PPF 420	Professional Portfolio
ICT 410	Information and Communication Technology

The absolute foundation of the professional curriculum is the module of facilitating learning (FCL). FCL is the basis of the professional curriculum. Being a professional means, in the most practical sense, the following:

a) Professionals exercise a professional **practice**.
b) They design unique professional practices from a self constructed **principle centred practice theory**.
c) The practice theory has been derived from **practical experience**.
d) Professionals are competent in many skills (strategies, methods and techniques) – but this is exactly what an artisan (a skilled worker) is competent in.
e) Professionals, however, are competent on a much higher level: They are able to **make the best possible founded choices** from existing skills to design a unique practice.
f) More importantly, they are able to **creatively design new skills** to achieve the best possible outcome.
g) Professionals are able to **monitor** what they do every step of the way, to ensure the best possible outcome at all times.
h) This means that professionals are able to make the most appropriate, responsible and accountable **instantaneous decisions at any required moment** to pursue the best possible outcome despite what has been designed.
i) Professionals are able to **critically assess** all their actions and its consequences against a solid foundation in a reflective mode to:
  ❑ precisely pinpoint the very instances of his/her success, failure or uncertainty;
  ❑ accurately diagnose its cause;
  ❑ correctly identify - but even much more importantly - creatively generate alternative possibilities;
  ❑ confidently make the best possible choice for follow up action;
  ❑ and boldly engage in the improvement of the original attempt.
j) Professionals are **independent** and do not **rely** on anyone else to do the job.
k) **No one else** but a professional can do the professional's job.

5.   The aim of the professional curriculum

The professional curriculum provides the professional foundation for facilitating learning. The module, Facilitating Learning, is therefore foundation of the professional curriculum. All the other professional curriculum modules (excluding ICT and PPF) are service modules for FCL and as such all other modules should eventually be effectively integrated into FCL. The aim of the professional curriculum is to construct a practice theory of and for facilitating learning, which the students implement to ensure

the highest possible quality of facilitating learning practice. All other professional curriculum modules (except ICT and PPF) therefore have this as its aim. The assumption therefore is that all other professional curriculum modules (except ICT and PPF) will have the students construct a (practice) framework of any appropriate kind of the particular module ONLY in so far as it DIRECTLY impacts facilitating learning practice. That is why the professional curriculum modules should not be entertained as stand-alone modules (disciplines), but the students need to experience their delivery directly contributing to the quality of their facilitating learning practice. . The construction of such a framework and its continuous assessment as suggested above for each professional curriculum module (except ICT and PPF) is more than sufficient to gauge students' understanding of the essential principles, foundational concepts and their interconnectedness, and to contribute effectively to their facilitating learning practice. Lecturers of the professional curriculum modules are requested not to give additional assignments to students – especially assignments to be completed during students' school based education periods unless such assignments theory-practice integration of your module and holistically and directly integrated with students' facilitating learning practice. All assignments should be completed and submitted during the last scheduled contact session.

5.   Suggested delivery of the professional curriculum (except FCL, ICT and PPF)

The delivery principal is that all contact sessions with students should be learningshop sessions: A learningshop is when students present their attempt at the construction of the required framework (or aspect thereof). They then actively participate in the learning process sharing their own contributions and critically assess their own and the others' contributions as it is being shared solely to improve the learning quality and subsequently the quality of the end product outcome of each individual's learning regarding the framework. With each contact session an increase in the quality of the construction of the framework is expected which should be influenced especially by what they have learned through their facilitating learning practice during their school based education periods. What follows is a recommendation on how this principle could be implemented:

a.   From the field that constitute your module, identify only those prominent areas that correlate most appropriately with the foundation and philosophy of the PGCE programme.
b.   Carefully select learning material that would appropriately represent these identified areas to not exceed 140 pages – the student may (and should be encouraged to) consult additional relevant material within limits.
c.   The students are divided by the programme manager into cooperative learning (CL) groups of four in each group. Divide the learning material into as many equal bits as there would be CL groups. During your first contact session with the students, provide all students with all the learning material, but indicate to each CL group, which is their bit of learning material which they need to prepare for presentation to the entire PGCE student group.
d.   Negotiate a schedule during which time each CL group will do their presentation. All students study the learning material that would be presented at a particular time because they need to ask the presenters clarifying and probing questions during and/or after the presentation.
e.   The presentation is in the form of a concept map or any other appropriate structure that would allow for only the absolute essence of the material to be presented in a meaningfully, holistically integrated format. The CL group supplies a copy of their presentation to all the students.
f.   The presentation is self –assessed, peer assessed, and assessed by the lecturer and the mark thus accumulated by the CL group is allocated to each member. In addition, each individual member of the CL group assesses each other member's contribution confidentially and the mark each individual received is accumulated with that which the group attained which gives an aggregated individual mark.
g.   As each CL group presents their material a cumulative concept map (or any other appropriate structure) is constructed collaboratively by the entire group, facilitated by the lecturer, and it is elaborated and improved each contact session time, until, at the end, everyone posses a high quality concept map (or any other appropriate structure) of the module.
h.   The mark accumulated for each student regarding these presentations could serve as the first semester mark – you are reminded that you have to allocate a first semester and a second semester mark for each student of which the average is the final mark.
i.   What could fit well into the PGCE programme as theory-practice integration of your module and holistically and directly integrated with their facilitating learning practice the following example from the Learning Theories module is supplied: Students need to video record some of their LTO's as part of the module Facilitating Learning. For the Learning Theories module (or any other

professional curriculum module for that matter) the students may use one (or more) of these video recordings to identify the learning theories that are in operation, justify its use and assess the quality of its implementation to subsequently improve their facilitating learning practice. This assignment should be assessed and a mark allocated.

j. The mark for the assignment indicated in i. above, could serve as a second semester mark.

RESPONSIBILITIES OF PROFESSIONAL CURRICULUM LECTURERS:

Lecturers appointed/allocated to the professional curriculum are responsible for the following:

(i)   Design of the curriculum for the module which includes the compilation and/or upgrading of a study guide.

(ii)   Development, assessment, evaluation, and quality assurance of the curriculum on an on-going basis.

(iii) Delivery of the module as suggested above according to the scheduled timetable .

(iv)   Accumulating a first semester mark for each student as a progress mark and providing it ***directly to the administrative officer*** at the academic administration of the Faculty of Education responsible for the PGCE in the required format on the marking list and on the required date (information obtainable from Me Melinda Joubert: 420-5590; mjoubert@hakuna.up.ac.za) ***and you keep a hard and electronic copy*** for your own safekeeping.

(v)   Accumulating a second semester mark for each student, which, together with the first semester mark - in whichever formula of aggregation you deem most appropriate - serves at the same time as the final year mark, the examination mark, and the final achievement mark. You also provide these marks ***directly to the administrative officer*** at the academic administration of the Faculty of Education responsible for the PGCE in the required format on the marking list and on the required date (information obtainable from Me Melinda Joubert: 420-5590; mjoubert@hakuna.up.ac.za) ***and you keep a hard and electronic copy*** for your own safekeeping.

(vi)   Availability during the final assessment period to assess at least 10 student's professional development portfolio defences and interviews.

6.   The relationship between the Professional and Specialisation Curriculum

The entire Professional Curriculum and in particular the comprehensive, integrated, holistic practice theory of facilitating learning in the form of a concept map informs (is the foundation of and supports) the specialisation curriculum in which the actual professional practice is manifest. But how the particular field of specialisation is practiced, depends on the nature and structure of that particular specialisation. The specialisation curriculum therefore focuses on the identification of the nature and structure of the field of specialisation and the identification and selection of the relevant support mechanisms from the constructed generic practice theory of facilitating learning to the specialisation practice theory – ***however, it is not necessary to construct a practice theory of facilitating learning in the form of a concept map for a specialisation***, because the __***LTD and LTO***__ for the particular specialisation, will actually ***represent its practice theory***. __**BUT**__, what is of pivotal importance is that **EVEY SINGLE LT** has to be designed and operationised __**ACCORDING TO THE BE's PRACTICE THEORY OF FACILITATING LEARNING IN THE FORM OF A CONCEPT MAP THAT WAS CONSTRUCTED IN FCL – This is the only practice theory that we are referring to.**__ This manifests the relationship between the Professional and Specialisation curriculum. In the most literal sense, you as specialisation lecturer has to demand that the students design LT's with their practice theories next to them and they have to justify every design element by referring to their practice theory. When students operationise their LT's, assessment has to be based on how the student justifies his/her actions according to his/her practice theory – again, the practice theory serves as the pivot for the assessment discussion. This characteristic will be at the centre of the specialisation curriculum assessment, meaning that the LTD and LTO has to be assessed against the students constructed practice theory. This, therefore forms the basis from which the Students will conduct their practice. The major focus of assessment in the specialisation is the assessment of their actual education practice during their school based education (SBE) at the schools regarding the students learning task design (LTD) and learning task operation (LTO) when students have the learners execute the designed learning tasks (LT's). Additional particulars about assessment in the Specialisation follows a little later.

8.   Suggested delivery of the specialisation curriculum

Following is a summary of how the programme is designed to operate *for each of the 2 specialisations* where applicable **OR** *per semester* where only one specialisation is offered. Since Specialisation lecturers have only a compulsory 1 hour contact session during each indicated time slot for the Specialisation, this time should be utilised wisely in learningshop format to compel students to be meaningfully occupied for the remaining time scheduled on the timetable when the Specialisation lecturer may not be present.

Contact session number	Length (hours)	Purpose
1	1	Orientation to the Specialisation
2	1	Establishing the nature and structure of the Specialisation and how this determines its facilitation of learning.
3-4	2	• Analysing the programme students received at the school which they need to take responsibility for during the SBE to determine the range of the outcomes to be achieved. • Making a provisional time allocation: Fitting the required outcomes to a time schedule within the available allotted time of the SBE.
5-7	3	Obtaining all available materials from which learning tasks can be designed for the achievement of all the required outcomes. This allows determining the scope, possibilities, limitations and implications of the particular required outcomes to be achieved.
8-14	7	*Learning Task Design (LTD)* by students LT's with the facilitating aid of the Specialisation lecturer. The designing of the required LT's according to the SBE programme is used as the meaningful point of departure to explore the broader and deeper substantive (content/product) and syntactical (methodology/process: skills, strategies, techniques) structure of the Specialisation as it determines its education in a just in time (JIT) learning principle.
15-16	2	Constructing a plan of action for the improvement of each BE during the remainder of the SBE.
34 DAYS OF SBE		*Learning Task Operation (LTO)*: The SBE session is allocated to the Specialisation with the focus on LTO where BE's present learners with a designed LT which they – the learners – have to execute. This is also the time during which the *Specialisation lecturer will assess each BE at least 2 times.*

Designing and operationing LT's according to the required demanding criteria constitutes the essence of what FOL's do. These are the essential and meaningful activities students should be involved in during their education as FOL's.

Assessment of the students regarding the Specialisation consists only of their work in practice at the schools during SBE: *Per semester per student*, it consists of at least 2 formal assessments of the Specialisation lecturer, at least 4 formal assessments of the Mentor Educator on different occasions, at least 2 formal peer assessments also different from the Specialisation lecturer and the Mentor Educator, and at least 4 formal self-assessments on different occasions than all the others – a total of 12 formal assessments. You as Specialisation lecturer are responsible to collect all the grading from the respective assessment agents and compile from them a final grading for the specialisation – you determine the weighting of each assessment category of which your assessments have to carry at least a 50% of the total weighting.

Only when and if ALL the categories of competences (learning outcomes) regarding the particular learning area/programme/subject *are not covered* within the programme the students need to follow at their schools, it is suggested that they do design LT's to incorporate those, but they operationise them with their peers and it should be assessed as if it was part of their practice at a school. This adds one other additional category of assessment which should be incorporated in the students' final grading with a weighting according to your discretion.

Students need to progress effectively through all the education paradigms by becoming competent in each one before moving on to the next. Progressing through the paradigms is suggested in the following way:

➢ During the first semester students are not required to operationise LT's in the transcendental paradigm. They are, however, required to plan and present lessons in the transmission and transaction paradigms and experiment at least once with transformation paradigm. However, during the first semester, students need to at least design one LT in the transcendental paradigm. This LTD should be assessed and the mark allocated for it should at least weigh 25% of the semester mark. Mark accumulation for the first semester: 50%-Specialisation lecturer assessments; 25%-Mentor assessment of the LTD in the transcendental paradigm; 25%-Mentor assessments+peer assessments+self-assessments.
➢ During the second semester the students should design and operationise at least 4 LT's in the transcendental paradigm of which two have to be assessed by the Specialisation lecturer and the two others by the Mentor educator. The mark accumulation for the second semester should be: 50% Specialisation lecturer assessments; 25%-Mentor assessments of the 2 LT's in the transcendental paradigm; 25%-All other Mentor assessments+peer assessments+self assessments.

RESPONSIBILITIES OF SPECIALISATION CURRICULUM LECTURERS:

Lecturers appointed/allocated to the specialisation curriculum are responsible for the following:

(i) Design of the curriculum for the module, which includes the compilation and/or upgrading of a study guide.
(ii) Development, assessment, evaluation, and quality assurance of the curriculum on an on-going basis.
(iii) Delivery of the module as suggested above with at least one face-to-face contact hour with the students per scheduled timetable session.
(iv) Ensure the effective progression of students through all the education paradigms by approving all lesson plans and the education paradigm it has been designed in according to the progression through the paradigms indicated above.
(v) At least two lesson/LT assessments during school practice at the school per student per semester.
(vi) Accumulating a semester mark for each student each semester (where appropriate) and providing it *directly to the administrative officer* at the academic administration of the Faculty of Education responsible for the PGCE in the required format on the marking list and on the required date (information obtainable from Me Melinda Joubert: 420-5590; mjoubert@hakuna.up.ac.za) *and you keep a hard and electronic copy* for your own safekeeping.
(vii) Accumulating a final mark from the two semester marks for each student and providing it *directly to the administrative officer* at the academic administration of the Faculty of Education responsible for the PGCE in the required format on the marking list and on the required date (information obtainable from Me Melinda Joubert: 420-5590; mjoubert@hakuna.up.ac.za) *and you keep a hard and electronic copy* for your own safekeeping.
(viii) Assessment of each student's professional development portfolio.

9.   Development of a Professional Development Portfolio

The students will compile a professional development portfolio. It will incorporate the development of their practice theory for facilitating learning and a very carefully verified selection of all their work supported by substantial and meaningful reflections which should portray their professional development as facilitator of learning. The format of the portfolio should make provision for the incorporation of all required and appropriate items that could also include original physical objects, but it should also portray students' professional competence in implementing multimedia, multifaceted, multiformatted, dynamic systems. Since it is now hopefully much clearer what the intention is with each module and how the entire curriculum relates in context, the suggested format for the Study Manual for each module and what should be incorporated in its content, will be helpful.

D. STUDY MANUAL

> **A cover with the following information:**

UNIVERSITY OF PRETORIA
Faculty of Education

Professional Curriculum
or
Specialisation Curriculum

Study Manual
for
Module Name and Code

Responsible PE's name

Date of compilation

The inside with the following information

Disclaimer

Please take note that any part or the entire Study Manual may change at any time due to the rapid change and development of education in South Africa and worldwide and the fact that this entire programme is at this stage subject to research and in that regard a developing programme. However, you will be informed of the changes in good time so as not to have any negative influence on your own professional development as facilitators of learning.

A.   Organisational Component

1.   Professional Educator Information

- Name
- Building
- Office number
- Office tel no
- Email address

2.   Sources

Under this heading you need to include all the learning materials the BE's (Beginner Educators) will need to study. Give complete and correct bibliographical details of the 3-4 substantial practice theory articles published or to be published in refereed and/or accredited journals. This would be the prescribed sources. You may add some sources to study for enrichment, but you need to keep this to a minimum because the total prescribed sources for the proper professional curriculum alone already amounts to 32 articles. Also remember, the BE's may only work on your module for the corresponding notional hours.

3.   Assessment

Describe under this heading the following:
- What will be assessed?
- Details of how will it be assessed (the format of assessment practice).
- How each aspect will be graded.
- How the final grade will be accumulated.

4.   Timetable

See Timetable for BE's

5.   Structure of the module

Construct a diagramme (mind map or concept map) of the outline of the module with each study unit.

B.   Study Component

1.   Purpose of this Module

State the purpose

2.   **Study Unit Number**

We suggest a study unit for every contact session or series of contact sessions. Supply a descriptive title for the study unit

3.   **Learning outcomes**

Formulate the learning outcomes for this study unit in terms of end product outcomes.

4.   **Sources**

Indicate the exact sources from the inventory in the organisational component to be used to achieve the learning outcomes of this study unit.

5.   **Workshop**

Describe the nature of the workshop in the following way:

> How will you facilitate the *initiation* of the BE's learning, or what is the problem that you will pose for BE's to solve?
> What will be expected of BE's to do (the *learning* process) to solve the problem themselves?
> How will you facilitate the *maintenance* of the BE's learning, or what will you do to ensure that the BE's achieve the highest possible learning quality?
> How will you facilitate the *consolidation* of the BE's learning, or what will you do ensure that the BE's obtain the best possible learning outcome as a reinforced point of departure for their subsequent learning experiences?

6.   **Self-activity(s)**

Formulate any number of activities that the BE's will need to execute on their own in writing that will not be assessed, but is a necessary prerequisite to enable them to execute the assignment(s). It should also represent a challenging and dynamic preparation for a contact session.

7.   **Assignment(s)**

Formulate an assignment to be executed by the BE's that is a comprehensive integrated challenge. It may be something in addition to the self-activity(s) that should be executed for a contact sessions or it may be given as an assignment after a contact session.

8.   **Assessment criteria**

Indicate the assessment criteria that will be employed to assess the assignment(s).

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UNIVERSITY OF PRETORIA
Faculty of Education

SPECIALISATION CURRICULUM

Study Manual
for
Mathematics
IPH 402
SPH 402
VWS 400

"The main concern of mathematics education is to provide pupils with opportunities to construct their own mathematical ideas." (Moodley, 1992)

"it would be difficult to lead a normal life in many parts of the world in the 20th century without making use of some kind of mathematics"

"mathematics provides a means of communication which is powerful, concise and unambiguous" (Cockcroft, 1982)

Hayley Barnes
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Disclaimer

Please take note that any part or the entire Study Manual may change at any time due to the rapid change and development of education in South Africa and worldwide. The entire programme is at this stage subject to research and for that reason a developing programme. However, you will be informed of the changes in good time so as not to have any negative influence on your own professional development as facilitators of learning.

A. ORGANISATIONAL COMPONENT

1. PROFESSIONAL EDUCATOR INFORMATION

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CONSULTING HOURS: By appointment

2. SOURCES

PRESCRIBED SOURCES
These can all be downloaded and printed from the websites indicated below:

(i) Paul Ernst "The impact of beliefs on the teaching of Mathematics". Can be retrieved from http://www.people.ex.ac.uk/PErnest/impact.htm

(ii) Martin van Reeuwijk " The role of realistic situations in developing tools for solving systems of equations". Can be retrieved from http://www.fi.uu.nl/publicaties/literatuur/4763.pdf

(iii) Linchevski et al. "Indispensable Mathematical Knowledge (IMK) and Differential Mathematical Knowledge (DMK) – Two sides of the Equity coin". Can be retrieved from: http://academic.sun.ac.za/mathed/Malati/Files/PME20001.pdf

(iv) Richard Skemp "Relational understanding and Instrumental understanding". Can be retrieved from: http://www.tallfamily.co.uk/david/skemp/pdfs/instrumental-relational.pdf

(v)   Alwyn Olivier "Handling pupils' misconceptions". Can be retrieved from:
http://academic.sun.ac.za/mathed/Malati/Files/Misconceptions.pdf

(vi)   Vicky Inman "Questioning their mathematics". Can be retrieved from:
http://0-web.ebscohost.com.innopac.up.ac.za/ehost/pdf?vid=1&hid=107&sid=0fc19c85-8296-467b-ae28-4af891748a79%40sessionmgr107

RECOMMENDED SOURCES

(a)   The Revised National Curriculum Document for Grades R – 9 for Senior Phase and Grades 10 – 12 for FET students.
(Available in the reserved section of the Groenkloof AIS or on the internet at the following site: http://education.pwv.gov.za)
You may also be able to purchase a copy directly from the Department of Education at the following address:
Sol Plaatjie House
123 Schoeman Street
Pretoria
Tel: 012 312 5911

(b)   Paul Andrews "Mathematics is like football". Can be retrieved at:
http://0-web.ebscohost.com.innopac.up.ac.za/ehost/pdf?vid=2&hid=103&sid=b2dfbe0b-3fa3-47b5-a695-dadc46ab830e%40sessionmgr108

It is also recommended that you consult school textbooks on mathematics that are relevant to the phase you intend teaching. Try to use textbooks that were published after 1999. A variety of textbooks and teacher guides is available in the AIS for loan or you can purchase some at Juta Books in Hatfield Centre of Protea Books in Burnett street.

3. ASSESSMENT

In this specialisation, you will mainly be assessed on your professional development as a mathematics educator. This relates to issues such as your content knowledge, your lesson planning, facilitating of learning of mathematics, and using relevant literature to substantiate and defend your approach to the teaching and learning of mathematics.

The sources listed above are will assist you in grasping and comprehending the WHY, WHAT and HOW of the basis of your intended profession as a mathematics educator. It is highly recommended to read the recommended sources in order to accelerate and enhance your own frame of reference and thinking, and be in a position to critically engage in the construction of your own accountable practice theory.

- **What** will be assessed?
  - ❑ Your professional practice as a mathematics educator in the context of the classroom.
  - ❑ Your mathematical subject knowledge and pedagogical content knowledge in the relevant phase of your professional practice.
  - ❑ Your knowledge of the unique nature, structure and methodology of this specialisation area.
  - ❑ Your critical account for the selection and use of support and assessment mechanisms within the domain of mathematics to facilitate teaching and learning.

- **How** will it be assessed? (format)
  - ❑ Professional growth is the ultimate aim of all the assessment.
  - ❑ Formal assessment for promotion purposes will mostly (60%) take place during the school-based teaching session at the schools, although there will be some assessments (40%) that will be conducted outside of the school context.
  - ❑ The following weighting system will be applied in compiling your final mark for this module:

	Peer & self assessment	PE
School practice assessment	10%	50%
Other assessment	10%	30%

- A rubric stating the marking criteria will be made available to you for all assessments.
- The final mark for this module will be calculated from the marks you receive for practice teaching from your mentors' as well as assessments conducted by myself.
- Additional informal assessment will also take place during contact sessions. The format will centre around actively participating in workshops, discussions and practical sessions.
- Although you will not always be given a formal mark for each of these sessions, you will receive feedback (from myself and your peers) as to your present level of proficiency and competency as described in the learning outcomes.
- If necessary, as determined through a process of self-reflection, peer assessment and other assessment, I may request to meet with you in order to improve the identified area(s) which require further improvement, growth and development.

4. STRUCTURE OF MODULE
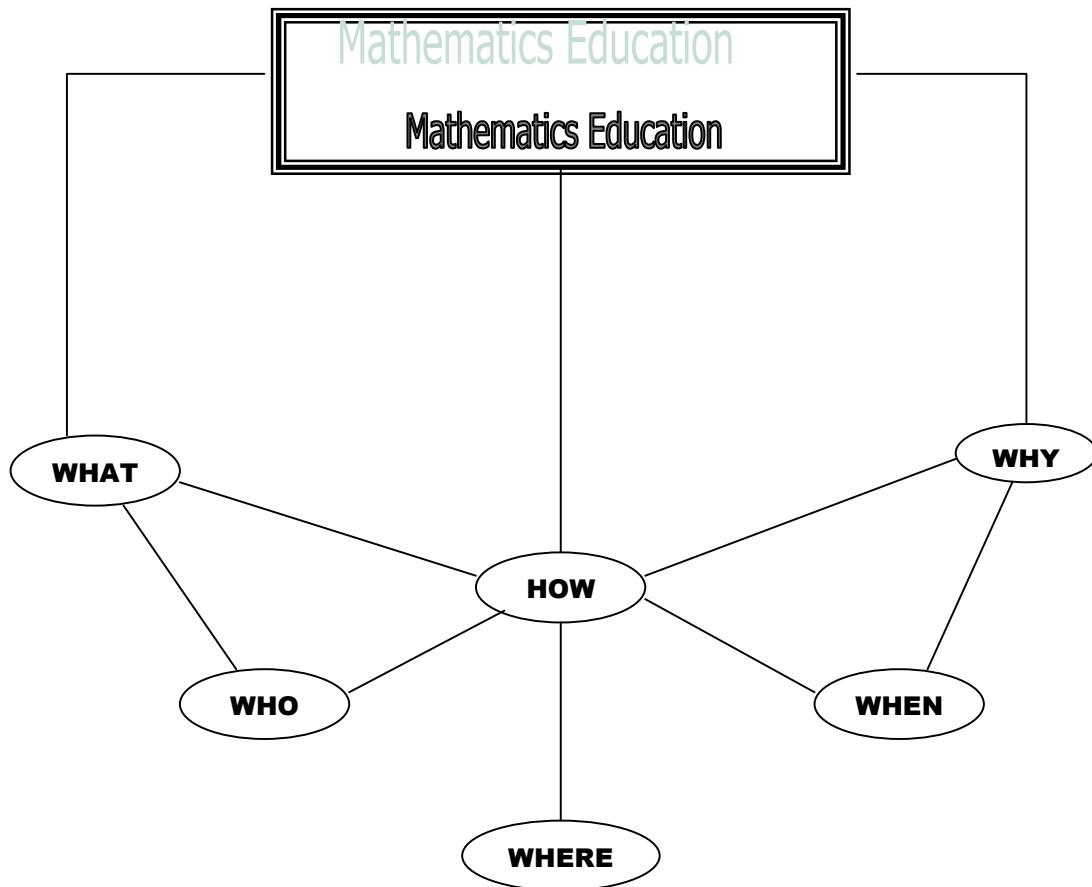
5. TIMETABLE 2007

FET students to attend both SPE 1 and SPE 2 sessions

| Session	SPE 1	SPE 2	Time	Hrs
1	Tuesday 26 Feb	Thursday 28 Feb	13:30 – 15:30	2
2	Tuesday 4 March	Thursday 6 March	13:30 – 17:30	4
3	Monday 10 March	Tuesday 17 June	14:30 – 17:30	3
4	Tuesday 11 March	Wednesday 18 June	14:30 – 17:30	3
5	Wednesday 12 March	Thursday 19 June	14:30 – 17:30	3
6	Thursday 13 March	Friday 20 June	13:30 – 17:30	4
7	Friday 14 March	Monday 23 June	13:30 – 17:30	4
8	Monday 17 March	Friday 27 June	13:30 – 17:30	4
9	Tuesday 18 March	Monday 14 July	13:30 – 17:30	4
10	Monday 31 March	Wednesday 16 July	13:30 – 17:30	4
11	Tuesday 1 April	Thursday 17 July	13:30 – 17:30	4
12	Friday 4 April	Friday 18 July	13:30 – 17:30	4
13	Monday 7 April	Monday 21 July	13:30 – 17:30	4
14	Wednesday 9 April	Tuesday 22 July	13:30 – 17:30	4
15	Monday 5 May	Monday 4 August	14:30 – 17:30	3
16	Monday 19 May	Monday 18 August	14:30 – 17:30	3

B. *STUDY COMPONENT*

1.   THE PURPOSE OF THIS MODULE

The purpose of this module is, according to the seven roles for educators, to demonstrate competence in selecting, using and adapting teaching and learning strategies in ways that meet the needs of all learners and the context concerned. This is specific to the learning area of Mathematics.

The course also seeks to afford you the opportunity to improve your content knowledge, conceptual understanding and pedagogical content knowledge required to be a competent mathematics educator in your relevant phase. It is important that you realise that times have changed since you were a learner. You are therefore encouraged (and urged) to avoid the temptation of restricting yourself to attempting to teach mathematics as you were taught it.

Outcomes – based education has been implemented in South Africa during the last few years. This course does not seek to make you an "OBE convert". It does however aim to give you the opportunity to explore theories and approaches to the teaching and learning of mathematics other than the traditional approach of "chalk and talk" and rote learning that has been the norm in South Africa for so many years. The course will also equip you with alternative assessment strategies other than traditional tests and exams to allow you to incorporate assessment as a learning tool in the teaching of mathematics.

It s hoped that the course will not only make you more positive about the learning area of mathematics but that you will in turn want to make it as accessible and applicable for the learners you will one day teach. You are therefore required to keep an open mind to the design and implementation of the course. Use this experience to your advantage and take up the challenge of stepping outside your comfort zone and trying something new. You are encouraged to integrate existing literature with your own experience in the classroom and that of other mathematics educators in order to create your own dynamic practice theory that will continuously be challenged, reflected on and developed throughout your career as an educator.

MENTOR TEACHER /EDUCATOR → PRACTICE THEORY ← Nature, structure and methodology of Mathematics education

PROFESSIONAL EDUCATOR (lecturer) → PRACTICE THEORY ← School-based teaching

← Pedagogical content knowledge

← Own learning and experiences
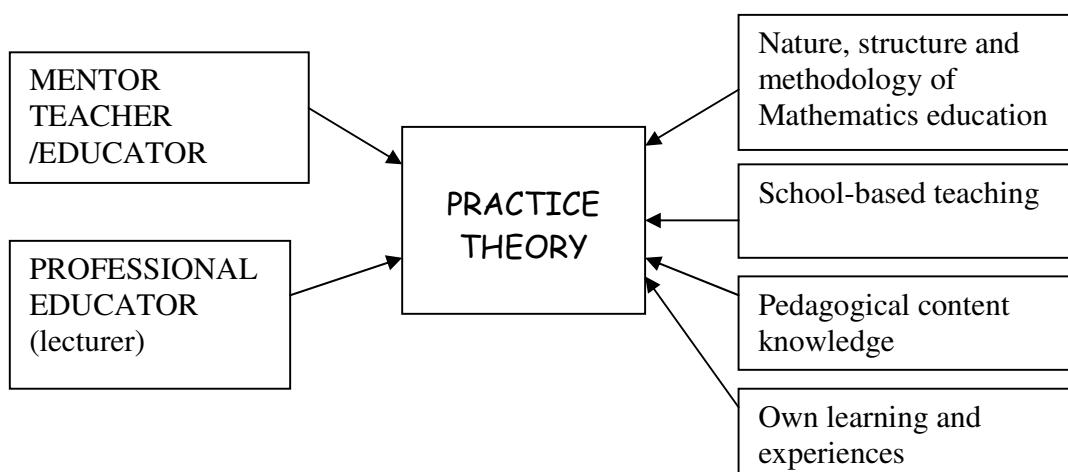
2. OUTLINE OF TOPICS COVERED

The WHAT and WHY of Mathematics Education

What:
- What is mathematics education?
- What do I have to teach learners?
- What do I as a mathematics educator need to know in order to teach mathematics to learners?
- What do I want to assess in mathematics?
- What is my own conceptual understanding of the content I will be required to teach learners?

Why:
- Why do I want to teach mathematics?
- Why do learners need to learn mathematics?
- Why do we assess learners?

The HOW of Mathematics Education

How:
- How can I effectively facilitate the learning of mathematics?
- How can I prepare a learning task design for a mathematics lesson?
- How can I assess learners in mathematics?
- How can I use collaborative learning effectively in the mathematics classroom?
- How can I work with different ability groups in the mathematics class?

The WHO of Mathematics Education

Who:
- Who will I be teaching? (which phase will I be focussing on)
- Who am I within my role as a mathematics educator?

The WHEN of Mathematics Education

When:
- When should I assess learners?

The WHERE of Mathematics Education

Where:
- Where can I go to learn more about mathematics education once I am qualified?
- Where can I teach mathematics?

3.   LEARNING OUTCOMES

• Generate your own practice theory on Mathematics as a learning area
• Design the best mathematical practice according to your general practice theory.
• Critically execute, monitor and assess your practice of mathematical education against the mentioned theory.
• Continually improve the quality of your subsequent mathematical practice.

In order to attain these outcomes BE's will also need to demonstrate:

• Knowledge as well as conceptual understanding of the mathematical content required to be competent educators in their relevant phase
• Knowledge of the structure, nature and methodology of the learning area of mathematics
• Knowledge and application of the new revised curriculum statement in mathematics relevant to their phase
• That they understand and can demonstrate various ways of solving mathematical problems to learners in their relevant phase
• Knowledge and application of applying an outcomes-based approach to the teaching of mathematics
• That they are able to prepare and implement a learning task design on any given mathematics topic for their relevant phase
• Knowledge and application of classroom assessment in mathematics relevant to their phase
• That they are able to use the internet as a source of information

4.   WORKSHOPS

The workshops will take the form of discussions, reflections, assessments and feedback and presentations. Contact time will generally be restricted to two hours at a time.

5.   ASSIGNMENTS

Assignments for the year will be issued and discussed during the sessions.

6.   ASSESSMENT CRITERIA

Assignments will be accompanied by a marking rubric that clearly defines the assessment criteria.

7. GENERAL

Correspondence between students and myself is often carried out via email. Please therefore ensure that you regularly check your email so that you are up to date on requirements, class times, discussion topics etc. Articles or documents that you are required to read will also be sent out via email so that you can print them. Please keep all of these in a file so that you can refer back to them as necessary. When I have attended a lesson of yours, I will always provide feedback via email within 48 hours. You will then be expected to respond to this email, with your reflections on aspects of the lesson (as requested by me) as well as a proposed mark for the assessment. Please also try to do so within 48 hours of receiving my email.

8. INDIVIDUAL APPOINTMENTS

You will each be requested to have an individual appointment with me sometime during your specialisation to discuss various aspects of being mathematics educator, with regard to your specific phase, needs, expectations etc. Please feel free to ask any questions during this meeting or to discuss any issues you would prefer not to work through in any of the group sessions. Please come and see me sometime in order to book a time (approximately 45 minutes) when this meeting can take place.

ENJOY the CHALLENGE!

UNIVERSITY OF PRETORIA
Faculty of Education

Professional Curriculum

Study Manual
for

Professional Portfolio
PPF (400)

LIFE CAN ONLY BE UNDERSTOOD BACKWARDS:
BUT MUST BE LIVED FORWARDS.
Sören Kierkegaard

Prof D M de Kock
Johannes A Slabbert

Revised and Updated December 2003

Disclaimer

Please take note that any part or the entire Study Manual may change at any time due to the rapid change and development of education in South Africa and worldwide and the fact that this entire programme is at this stage subject to research and in that regard a developing programme. However, you will be informed of the changes in good time so as not to have any negative influence on your own professional development as facilitators of learning.

A. ORGANISATIONAL COMPONENT

1. Professional Educator Information

Name	Prof DM de Kock	Prof Johannes A Slabbert
Building	Aldoel	Aldoel
Office number	E 214	F 205 A
Office tel no	420-2758	420-2773
Email address	dmdekock@hakuna.up.ac.za	jslabber@hakuna.up.ac.za

2. Sources

KORTHAGEN FAJ (ed.) 2001 *Linking practice and theory* Lawrence Erlbaum Associates, Publishers London. Chapters to be announced

ASKEW & CARNELL 1998 *Transforming Learning: Individual and Global Change* Redwood Books London

3. Assessment

Ways of assessment in this project
Assessment comprises
- Self-assessment
- Peer assessment
- Cooperative learning assessment
- Assessment by lecturer.
of
- Tasks
- Assignments for classroom discussions
- Participation in discussion
- Teamwork
- Teaching practice observation and reflection
- Logbook
- Seminar presentation

Final assessment

Final assessment for awarding qualified teacher status is based on Project A
- presentation of a continuous assessment profile and
- the final, developmental profile exposing growth of practice theory construction.

Continuous assessment criteria are
- the quality participation in discussions
- the quality of questions
- the quality reporting of research and reflective practice
- the ability to analyse and construct theory
- the design and management of a logbook
- the quality of critical self assessment and peer assessment
- creative input, enthusiasm, problem solving skills and the ability to identify theoretical principles and construct a reliable facilitating learning theory

The final, formal examination
- based on interpretation and selection of the logbook entries to finally report and display on personal growth, understanding and knowledge of the professional educators task and constructed practice theory.

4.   Timetable

See the official general timetable for the PGCE

5.   Structure of the module

UNIT 1 PRACTICE THEORY? LEARNING HOW TO REFLECT	
	UNIT 2 DOING ACTION RESEARCH

UNIT 4 Session 1 THE LOGBOOK ASSESSMENT Session 2 THE LOGBOOK ASSESSMENT	
	UNIT 6 PRACTICE THEORY SEMINAR
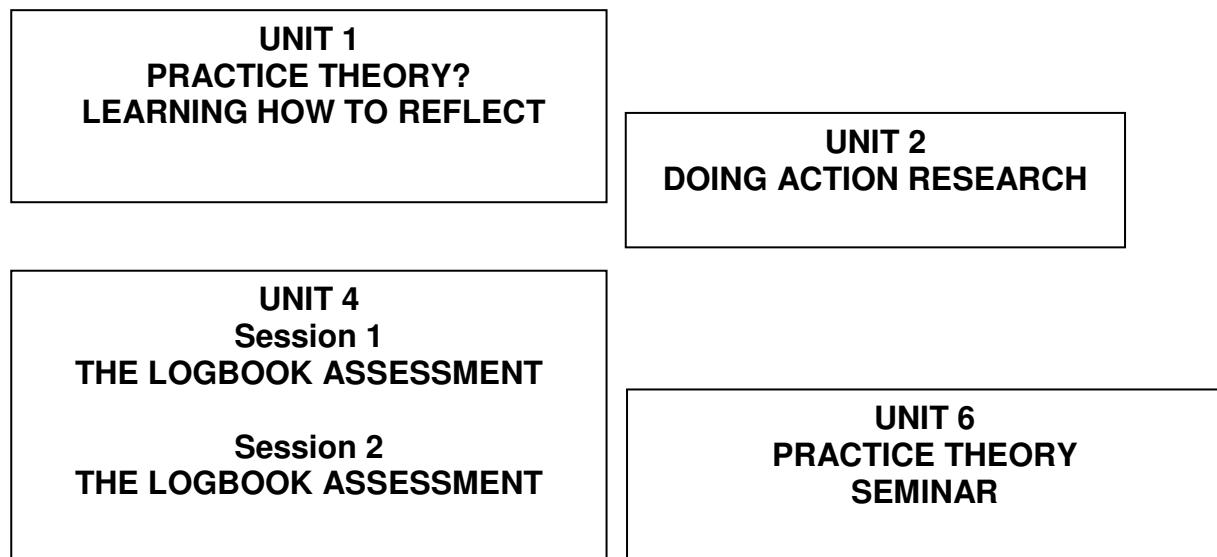
B.   STUDY COMPONENT

Purpose of this Module

- To enable educators to analyse, discuss, evaluate and change their own practice adopting and analytical approach to facilitating learning
- To foster educators' appreciation of the social and political contexts in which they work, supporting them to recognise that facilitating learning is socially and politically situated and that the educator's task involves appreciation and analysis of context.
- To enable educators to appraise moral and ethical issues implicit in classroom practices, including the critical examination of their own beliefs about quality learning facilitation.
- To encourage educators to take greater responsibility for their own professional growth and to acquire some degree of professional autonomy;
- To facilitate educators' development of their own practice theory understanding and developing a principled basis for their own classroom work
- To empower educators so that they may better influence future directions in education and take a more active role in educational decision –making.

(adapted from Korthagen 2001:53)

STUDY UNIT 1		
SESSION 1 **PRACTICE THEORY?**	**&**	**SESSION 2** **LEARNING HOW TO REFLECT**

What is practice theory?
When is theory relevant?
Why a practice theory?
How do you construct a practice theory?

What is reflection?
When do you reflect?
Why do you reflect?
How do you reflect?

1. Learning outcomes

To fullfill the role of researcher and independent lifelong learner
To interpret concrete experiences and confidently motivate actions

2. Sources

KORTHAGEN FAJ (ed.) 2001 : Linking practice and theory Lawrence
Erlbaum Associates, Publishers London.
Excerpts from Chapters 1 & 2.

3. Workshop

SESSION 1
Choose a topic and design an opportunity for learners to learn.

1   Sharing in groups by explaining your design
2   Group members listen and compose a list of questions
3   Using the lists of questions discuss the designs
4   Choose the best design.
     Student 1:Describing the design to the whole group
     Student 2:Motivating your groups choice.
     Student 3:Indicate how it can be improved
     Student 4:Indicate the principals governing the design that you as a group
     derive from this experience?

5   Information session
     ➢ Introducing the logbook.
     ➢ What is a Logbook?
     ➢ Short exercises to follow

6.   Self-activity(s)

Using this experience of session 1 formulate answers to the questions asked at the
beginning of this unit in your logbook

7.   Assignment(s)

Read, analyse and interpret the prescribed notes. Indicate what relation it has to the
workshop activities.
Give a one page written report in your logbook.

SESSION 2

Compiling Assessment standards
- Groups set the assessment standard
- Peer assessment of assignments in groups
- Individual students list what they have learnt from this session.

Is reflection action learning?
- Whole group discussion

Study the following
- ASKEW & CARNELL 1998 Transforming Learning: Individual and Global Change Chapter 5

How do you reflect?
- Compile a definition for reflection?
- Design your own model for reflection?

Final assignment for this Unit

Study
- KORTHAGEN's Notes taken from Chapter 7, 8 & 11 then critically analyse and compare his reflection model to the one you have designed.
- Record your insight in your Logbook

> **UNIT 2**
> **DOING ACTION RESEARCH**

What distinction is there between action learning and action research?
What is action research?
How do I do action research?
Why do I do action research?
What evidence can be used?

1.   Learning outcomes

To fulfill the role of researcher and independent lifelong learner
To create a vehicle for professional development
To operate with confidence in the context of the classroom, learning and education as a whole.

2.   Sources

KORTHAGEN FAJ (ed.) 2001 : *Linking practice and theory* Lawrence Erlbaum Associates, Publishers London.
Excerpts from Chapters 11
ASKEW & CARNELL 1998 *Transforming Learning: Individual and Global Change* Chapter 5 and 9
Notes to be handed out

3.   Workshop

Does action research bring about changes in your practice?
Do you gain confidence through action research ?
How are you going to prove this?

a.   Self-activity(s)

Design your action research for term 2 at the schools
Plan how you are going to record your work?

b.   Assignment(s)

Implement your action design during term 2
Reflect continuously using the model you have designed in Unit 1
Conclude with an essay on your constructed knowledge supported by a practice theory
Prepare your logbook for assessment during the June contact sessions

c.   Assessment standard

Clarity, logic, evidence, reliability, insights, quality management, relevancy, understanding

ADDITIONAL LEARNING MATERIAL

PRACTICE THEORY

What it is:

➢ The "practice" (Afr. praktyk) in practice theory refers to your education practice (Afr onderwyspraktyk. What you do when you are preparing to facilitate learning (LTD) and when you are actually facilitating learning (LTO).

➢ The "theory" in practice theory refers to the body of systematised knowledge about and for your practice as facilitator of learning.

➢ Your practice theory is therefore the theory of your practice derived primarily from your practice (it is a theory).

➢ It is continuously informed and enriched by your practice as such (through reflection on your practice and action research of your practice) but also other practices of other facilitators of learning as well as other already existing theories (research) in education.

➢ It is therefore in a continuous process of development.

What its function is:

➢ Your practice theory is the foundation from which you operate in practice.

➢ It tells you what to do and how to operate in practice.

➢ It therefore determines all your actions in your practice.

➢ It provides all the reasons why you are operating in practice the way you do.

➢ It provides the rational for what you are doing as facilitator of learning.

➢ When you are asked questions about your practice you need to be able to explain everything in terms of your practice theory.

Practice theory in the format of a concept map (and explanatory notes)

A concept map is a creative (colourful, playful, animated) construction of the relationships between a set of (selected) concepts indicating the nature, distance, and relatedness of the relationships between the concepts. A self-constructed concept map is reveals a learner's understanding of what the concept map represents (as opposed to a mind map). It reflects the differentiation between the concepts, as well as the nature and structure of the contextual relationships between the concepts as it manifests in an integrated meaningful whole. It reveals the learner's ability to construct meaning through identification, exposition and definition of distinguishable meaningful units, and recognising, discovering and creating relationships. The preceding paragraph is therefore self-explanatory regarding the reason why the requirement is that the practice theory should be constructed in the form of a concept map (with explanatory notes - where it becomes inevitably necessary).

To qualify as a concept map, the following criteria should be observed:

➢ A concept map consists of concepts – meaningful units which, in itself, has meaning.

➢ A concept map consists of at least two concepts.

➢ Each concept in a concept map has to be linked to at least one other concept by a line that indicates a relationship between the two concepts. Any one concept, however, may have a relationship with many other concepts.

➢ An arrowhead has to indicate the relatedness between the concepts. There may be a reciprocal relationship between two concepts that should be indicated by an arrowhead directed to each of the two concepts.

➢ The nature of the relationship between two concepts should be indicated with a written linking word on the linking line.

➢ The distance of the relationship should be indicated by the length of the linking line.

On the next page, a concept map of metalearning is depicted. Please note that the electronic medium has an unfortunate detrimental limiting consequence for the ultimate construction of a concept map regarding most of the criteria. Concept maps should rather be constructed on large poster size paper through low-tech means.

CONCEPT MAP OF METALEARNING

Metalearning

requires

Control over consciousness

through

Continuous reflection

exploring

MIQ

EQ

SQ

through

and/or

through

Thinking
(To solve existing problem)

Creativity
(Improve quality of life)

using

during

using

Modes of thinking

Creative problem solving

Planning

through

Design questions

Objective finding
Fact finding
Opportunity finding

during

Monitoring

through

Thinking tools

Idea finding
Solution finding

during

Assessing

through

Novel assessment tools

Acceptance finding
Implementation

resulting in acquiring

Intrapersonal lifeskills

REFLECTION

What it is:

➤ Reflection is a critical assessment conducted at the end of an event that you were part of or that you observed.
➤ The kinds of events that you will be doing reflection on during your education to become the best FOL you possibly can.
➤ But since your career is that of FOL, the major events that you will do reflection on would be how well you were facilitating learning.
➤ Reflection is of crucial importance for your professional development and is a meaningful stand-alone instrument for doing so.
➤ Reflection conducted on its own (outside the process of action research) is a critical assessment of a practice episode ***through your own subjective observations***.
➤ Action research always includes reflection: Reflection then is conducted ***only on the data you have collected***.

The process of reflection:

• State the intended outcome: What did you want to achieve?
• Describe the planned event for achieving the outcome: How did you want to achieve it?
• Describe the actual event: What did actually happen?
• Interpret the event: Why did it happen?
• Assess the event: Was what happened good or bad regarding the intended outcome?
• What did you learn?
• How can you improve?

THE REFLECTION PROCESS
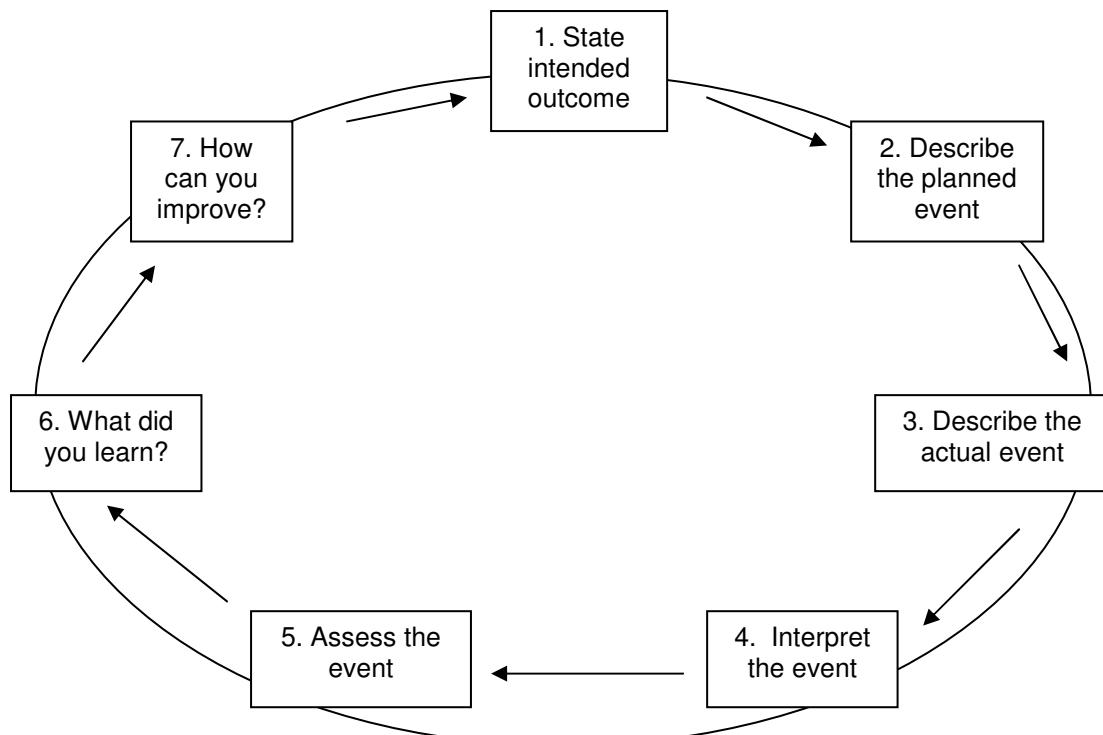
ACTION RESEARCH

What it is:

➢ The "research" in action research indicates that it is a RESEARCH process of systematically gathering the most appropriate DATA for providing HARD evidence of the actual reality of what you are investigating (and not simply the reality as you have subjectively observed it by yourself).

➢ The "action" in action research refers to action being taken by you to improve a particular aspect of your practice.

➢ The "action" in action research is taken in a continuous (cyclic) process of PLAN, ACT, OBSERVE, REFLECT, REVIEW which, at the same time, results in the new PLAN that restarts the process. This process is then taken through a number of such phases (cycles).

➢ You are challenged to take your action research through at least 4 such cycles (phases)

The process of action research:

➢ PLAN what particular aspect of your practice you want to improve on through action research (During this term it would be your LTF of maintaining learning): What, how, when, where, and why?

➢ ACT by executing your plan.

➢ OBSERVE in this context means to collect your data while you are executing your plan (During this term it would be the data you are collecting to determine how well you are executing your LTF of maintaining learning). You may have, and in some cases it may be necessary to have someone else collect your data for you. The way in which your data is collected should also represent a proper classification thereof. If this is not the case, you need to classify your data after it has been collected.

➢ REFLECT through conducting a critical assessment ***only of the data you have collected!***

➢ REVIEW your original plan according to the result of your reflection indicated by the data you have collected and adapt your plan to improve your performance (of your LTF during this term) accordingly. RESTART commences with the reviewed plan as the starting point of the next cycle (phase).

How you should conduct your action research:

➢ You are likewise advised to make video recordings as a means through which to collect your data. This will result in at least 4 video recordings corresponding to 4 LT's and 4 learning periods.

➢ You are advised to video record your initiating learning together with your maintaining learning for a particular LT for the length of at least one learning period, which will include your LTF. The reason for this is to retain the appropriate LT context and not to video record only your maintaining learning part in isolation. However, you need to ensure that the length of the recording of your maintaining learning part is sufficient to provide enough data for trustworthy evidence for your LTF. Video record a consecutive learning period of your LTF if there is a possibility that you may not have collected enough data in one learning period.

➢ In the unlikely but possible event that you will initiate less than four LT's, you are advised to video record the necessary amount of consecutive learning periods of your maintaining learning to ensure that an appropriate amount of data for your LTF is collected.

ONE CYCLE (PHASE) OF ACTION RESEARCH
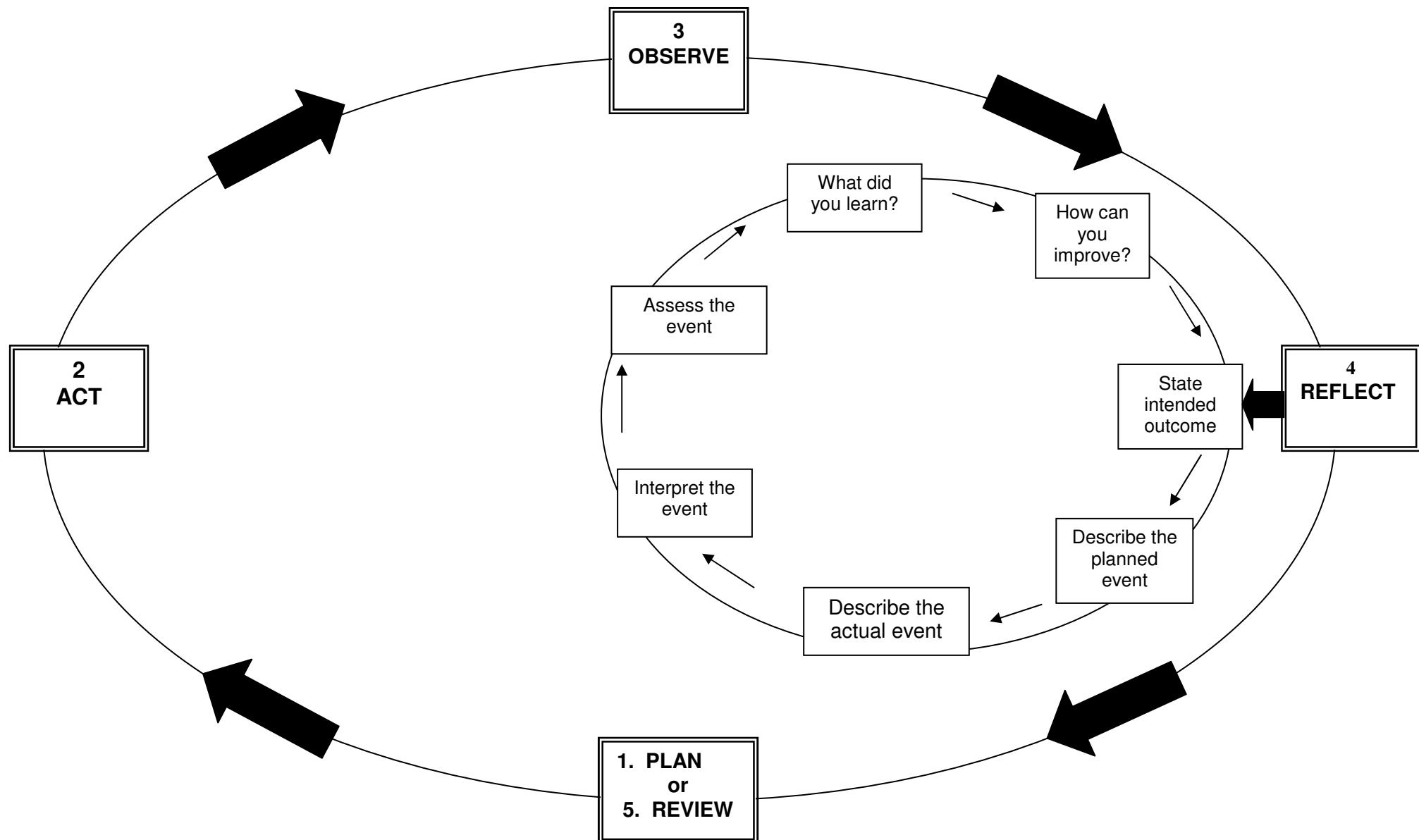
PROFESSIONAL DEVELOPMENT

- It is your development for IMPROVEMENT.
- It consists of an increase of knowledge of WHAT and HOW.
- But much more importantly, it consists of an increase in the knowledge of WHEN, WHERE, WHY and WHAT IF.
- It therefore consists of the ***internalisation*** of PRNICPLES determining your actions.
- These principles recognised by the fact that it gives direction for continuous increased improvement.
- The development is professional in that it demonstrates an implementation of the internalised principles through a continuous increased improvement which cannot be accomplished by someone else outside the profession.

Appendix C - Paradigms of learning

FOUR EDUCATION PARADIGMS / *VIER ONDERWYSPARADIGMAS*

ONDERWYSPARADIGMA EDUCATION PARADIGM / EDUCATION COMPONENT *ONDERWYSKOMPONENT*	Transmission *Transmissie*	Transaction Transaksie	Transformation Transformasie	Transcendental Transendensie
Aim **Doel**	To impart knowledge *Om kennis oor te dra*	To understand *Om te verstaan*	To apply knowledge *Om kennis toe te pas*	To generate knowledge *Om kennis te genereer*
Education mode **Onderwysmodus**	Direct teaching *Direkte ondderrig*	Interactive teaching *Interaktiewe onderrig*	Project education *Projekonderwys*	Facilitating learning *Fasilitering van leer*
Focus **Fokus**	Factual knowledge *Feitelike kennis*	Factual understanding *Verstaan van feite*	Application *Toepassing*	Creative construction of meaning (knowledge) *Kreatiewe konstruksie van betekenis (kennis)*
Educator action **Onderwyseraksie**	Tell, illustrate, demonstrate, explain *Vertel, illustreer, demonstreer, verduidelik*	Questioning, discussing *Vraagstelling, bespreking*	Give assignments, projects, guidance, help *Gee opdragte, projekte, leiding, hulp*	Confront the learners with a real life challenge they have to resolve themselves *Konfronteer leerders met 'n lewenswerklike uitdaging wat hulle self moet oplos*
Learner action required **Leerderaksie verwag**	Absorb, memorise, drill, practice *Absorbeer, memoriseer, dril, inoefen*	Answering questions, discussing *Beantwoord vrae, bespreek*	Exploration, discover, experimentation, *Eksploreer, ontdek, eksperimenteer,*	Creatively constructing new knowledge *Kreatiewe konstruksie van nuwe kennis*
Learning mode **Leermodus**	Receptive *Reseptief*	Interactive *Interaktief*	Self-active *Selfaktief*	Self-directive *Selfgerig*
Learner autonomy **Leerder outonomie**	None *Geen*	Some *Min*	Much *Heelwat*	Total *Totaal*
Level of learning **Vlak van leer**	Shallow *Vlak*	Insight *Insig*	Deep *Diep*	Transcendental *Transenderend*
Learning outcome **Leeruitkoms**	Cognitive Kognitief	Social *Sosiaal*	Multiple *Veelvuldig*	Holistic *Holisties*
Outcome **Uitkoms**	Core concept reproduction *Kernkonsepreproduksie*	Core concept understanding *Kernkonsepbegrip*	Enriched curriculum *Verrykte kurrikulum*	Living real life *Leef die werklikheid*
Learning quality **Leerkwaliteit**	Low *Laag*	Medium *Medium*	High *Hoog*	Maximum *Maksimum*

UNIVERSTIY OF PRETORIA – EDUCATION FACULTY
PGCE BASELINE ASSESSMENT

The following exam was set for a Grade 10 Mathematical Literacy class. You are required to set the memorandum for the exam. You are not permitted to use a calculator in setting up the memorandum. Please remember to include your name on the memorandum. You have two hours in which to complete this.

QUESTION 1

a)   Write down a number to replace each letter so that the answer is **always 45.**
        For example: $a = 5$

$$40 + a$$

$$50\% \text{ of } b$$

$$450 \div c$$

$$= 45$$

$$¼ \text{ of } d$$

$$142 - e$$

(4)
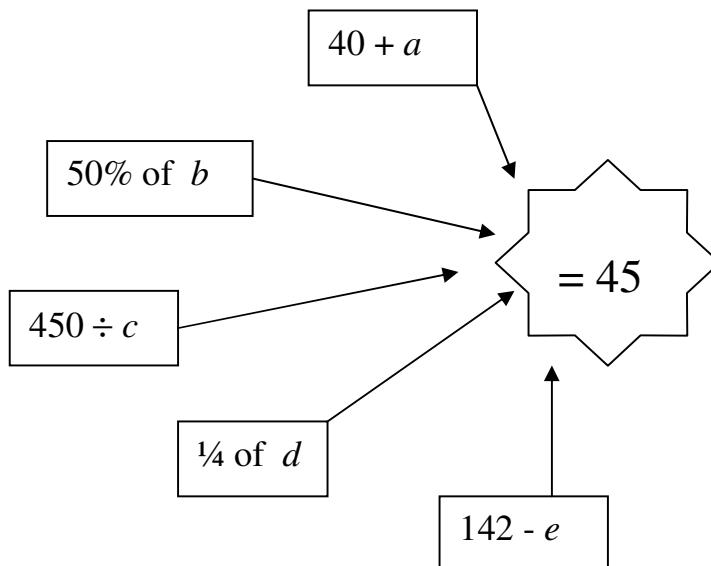
b)   Calculate:

   (1) $-1^2 \text{ x } (-5)^2$

   (2) $6^2 + (-1)^2$

   (3) $-1\,023 - (-248)$

   (4) $-902 + (-65)$

   (5) $\sqrt[3]{-216}$ (5)

c)   Write down the decimal form of $21\dfrac{1}{4}$ (1)

d)   Write the decimal 1,4 as a fraction   (1)

e)   Simplify: (2)

$$7 - \left(2\frac{1}{4} + 1\frac{1}{3}\right)$$

f)   Write down whether the following statements are TRUE or FALSE:

    (1)   12 is a multiple of 24.

    (2)   1 is an even number.

    (3)   26 is a multiple of 13.

    (4)   The product of 11 and 10 is 110.

    (5) $x + x + x = 3x^3$

    (6) $a \times 3a = 3a^2$

    (7) $x = \dfrac{1}{2}$ if $14x = 7$

                                                                                   (7)
                                                                                   [20]

QUESTION 2

a)   Write the letter of the correct expression next to the matching number:

(1)	x increased by 10	A)	xy
(2)	The product of x and y	B)	$x \div 2$
(3)	The sum of a certain number and double that number	C)	$x - 2$
(4)	Half of a certain number multiplied by itself	D)	½ x^2
(5)	Ms Barnes' age in x years' time	E)	$35 + x$
(6)	Two less than x	F)	$x + x + 2$
(7)	A certain number multiplied by itself	G)	x^2
(8)	Two consecutive even numbers	H)	x^{35}
(9)	$x + x + x + \dots$ to 35 terms	I)	$x + 2x$
(10)	$x.x.x.x.x\dots$ to 35 factors	J)	$x + 10$
		I)	$35x$

                                                                                   (10)

b) Simplify the following expressions:

(1) $-2x - 7x$ (1)

(2) $-3y + 2x + 11y - 8x$ (2)

(3) $(-5a)(-a)^2$ (2)

(4) $10^4 + 10^4 + 10^4 + 10^4 + 10^4$ (2)

(5) $2^3 \times 2^2$ (1)

(6) $-5p \times 6q \times (-2p)$ (2)

(7) $5x^2 - (-7x^2) + x^2$ (2)

(8) $-x^2 + 3x - 5x^2 - x$ (2)

(9) $2(x + 1) - (x - 2)$ (3)

(10) $(-5 + 2)(-3 - 4)$ (2)

(11) $\dfrac{4x^3 y^4}{8x^2 y^5}$ (2)

(12) $\dfrac{2x}{6} + \dfrac{x}{2}$ (2)

(13) $\dfrac{-3x^2 + x^3 - x}{x}$ (3)

(14) $[-2(2a^2 b^3)]^2$ (2)

(15) $4y^0 \times \left(\dfrac{y}{2} + \dfrac{y}{4}\right)^2$ (4)

[42]

QUESTION 3

a) The following equation was solved by a Grade 9 learner. Rewrite the equation into your exam scripts and circle any mistakes (there may be more than one). Then redo the equation correctly:

$-2(x + 1) - 2 = x + 1$
$\therefore -2x + 2 - 2 = x + 1$
$\therefore \qquad -2x = x + 1$
$\therefore \qquad -2x + x = x + x + 1$
$\therefore \qquad -x = 1$
$\therefore \qquad x = -1$ (5)

b) Solve the following equations:

(1) $x + x + x + x = 12$ (1)
(2) $x.x.x = 27$ (1)
(3) $2x - 8 = 4$ (1)
(4) $4x + 7 = 9$ (2)
(5) $-3x + 10 = 3x - 14$ (3)
(6) $2 - 2(x - 2) = -3(x + 4) + 1$ (5)

c) If $x = 2$ is the solution to an equation, make up any equation to suit this solution. (2)

d) Solve for a and b:

a x a x b x $b = 36$ (2)

e) Two numbers, m and n are multiplied to give an answer of -12;
that is m x $n = -12$

(1)   If m is 3, what must n be?   (1)
(2)   Write down all the integer/*heelgetalle* values that m and n can have?   (3)
(3)   If m is 0, will there be a value for n that can make the equation true?   (2)
Explain your answer.

[28]

QUESTION 4

a)   Calculate the sizes of the angles marked with small letters:

(1)


(2)

(2)

(2)

(3)

(4)

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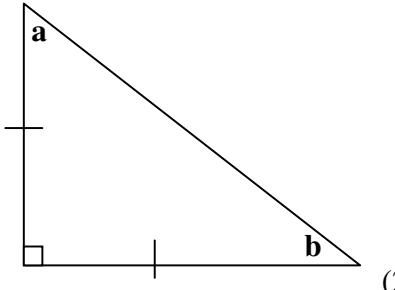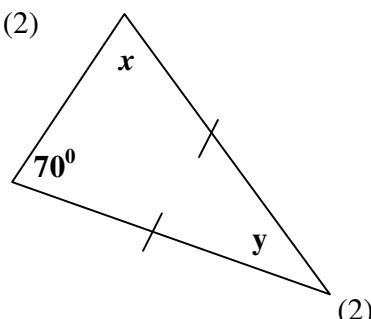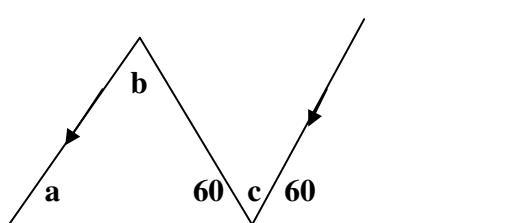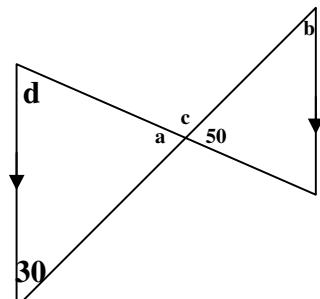
b)   Calculate the value of the missing angles in the following sketch and provide
      reasons for your answers.

(6)
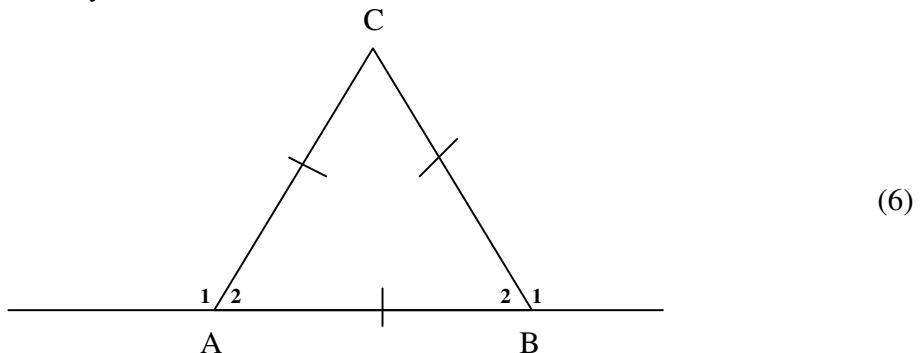
c)   The following triangle is a right-angled triangle.

      AB is equal to 12. AC is equal to 16. B = 90°

      (1)   Draw the triangle and label it correctly.   (2)
      (1)   Calculate BC, correct to two decimal places.   (2)
      (2)   Calculate the perimeter/*omtrek* of the triangle.   (2)
      (3)   Calculate the area of the triangle.   (2)

                                                                            [25]

QUESTION 5

a)   Fill in > ; < or =

      (1)   -18 _____ 18

      (2) $-4x$ _____ $-11x$

      (3)   1.5 _____ 0.15

      (4) $\dfrac{10}{10}$ _____ 1

      (5) $3\dfrac{1}{2}$ _____ $\dfrac{7}{6}$ (5)

b)   Answer the following questions:

      (1)   Change $\dfrac{18}{30}$ into a percentage.   _____   (2)

(2) A shirt costs R108 but the store manager offers you 10% discount. What must you pay for the shirt? (2)

_____

c) If 1 cm represents 20 m,

(1) how many metres will 15 cm represent? (1)

(2) how many centimetres must you draw to represent 200 m? (1)

d) Find the formula for the following:

(1)

x	y
2	4
3	6
4	8

$y =$ _____ (2)

(2)

x	y
2	5
3	6
4	7

$y =$ _____ (2)

[15]

QUESTION 6

A scientist is comparing the weights of the four molecules listed in the table below:

WEIGHTS OF MOLECULES

Molecule	Weight (in kilograms)
Salt	9.350×10^{-28}
Pure water	2.879×10^{-26}
Hydrochloric acid	5.832×10^{-22}
Potassium hydroxide	8.976×10^{-24}

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Which of these molecules is the heaviest? **[1]**

QUESTION 7

A wholesaler is offering two different package deals of roses and carnations to florists. One package contains 20 dozen roses and 34 dozen carnations for R504.00. The other package contains 15 dozen roses and 17 dozen carnations for R327.00. This information can be represented by the system of equations below, where r represents the cost of one dozen roses and c represents the cost of one dozen carnations.

$$20r + 34c = 504$$

$$15r + 17c = 327$$

Solve the system of equations to find the cost, in rands, of a dozen roses. **[4]**

QUESTION 8

Kelly went for a drive in her car. During the drive a cat ran in front of the car. Kelly slammed on brakes and missed the cat. Slightly shaken, Kelly decided to return home by a shorter route. The graph below is a record of the car's speed during the drive.

Kelly's drive
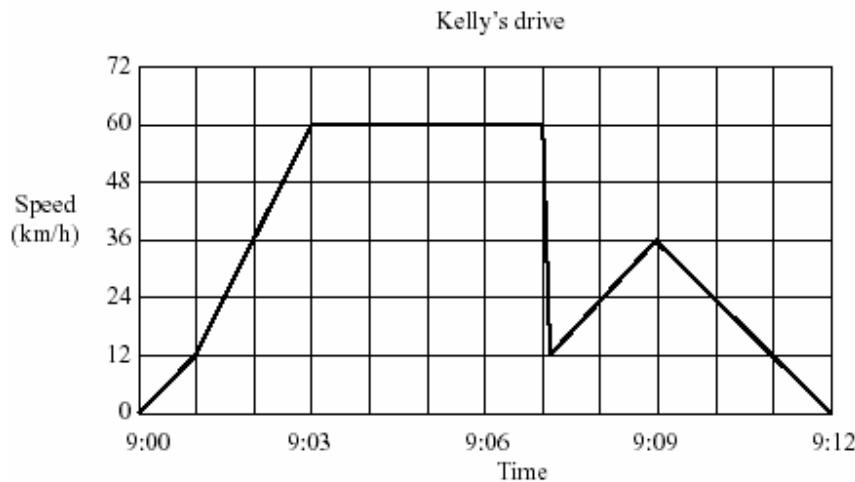
a)   What time was it when Kelly slammed on the brakes to avoid the cat?   (1)

b)   Explain what you think was happening between 9:03 and 9:07
        according to the graph.   (2)
                                                                              [3]

QUESTION 9

A school club is planning a bus trip to the Kruger National Park. A bus which will hold up to 45 people will cost R1500 to hire and the daily admission into the Park is R30 each. If the cost of the trip, including bus and admission ticket, is set at R80 per person, what is the minimum number of people who must participate to ensure that the costs are covered?
                                                                              [2]

QUESTION 10

The following two advertisements appeared in a newspaper in the country "Zorbodia" where the currency used are *zeds*.

BUILDING A
Office space available

85 - 95 square meters
475 *zeds* per month

100 - 120 square meters
800 *zeds* per month

BUILDING B
Office space available

35 - 260 square meters
90 *zeds* per square meter
per year

If a company is interested in renting an office of 110 square metres in Zorbodia for a year, at which office building, A or B, should they rent the office in order to get the lower price? Explain your answer.

[4]

QUESTION 11

This picture shows a cube with one edge marked. How many edges does the cube have altogether?
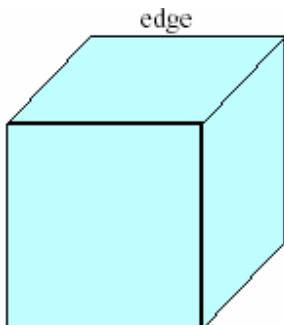
[2]

QUESTION 12

The figure consists of 5 squares of equal size. The area of the whole figure is 405 cm^2.

a)   Find the perimeter of the whole figure.   (2)
b)   Find the length of one side of one square.   (2)
[4]
Final total: **[150]**

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