

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 specialising. 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.

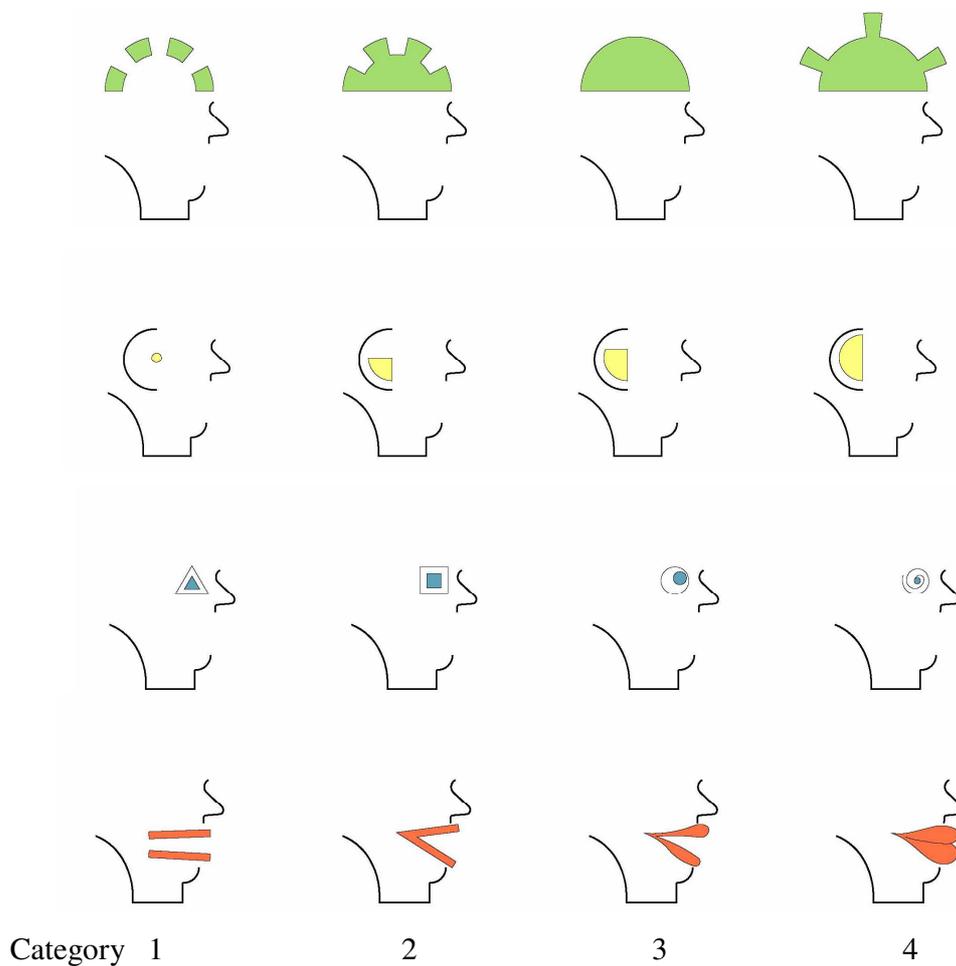


Figure 7.1 *Illustration of the four categories of each component of the mathematics profile*

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

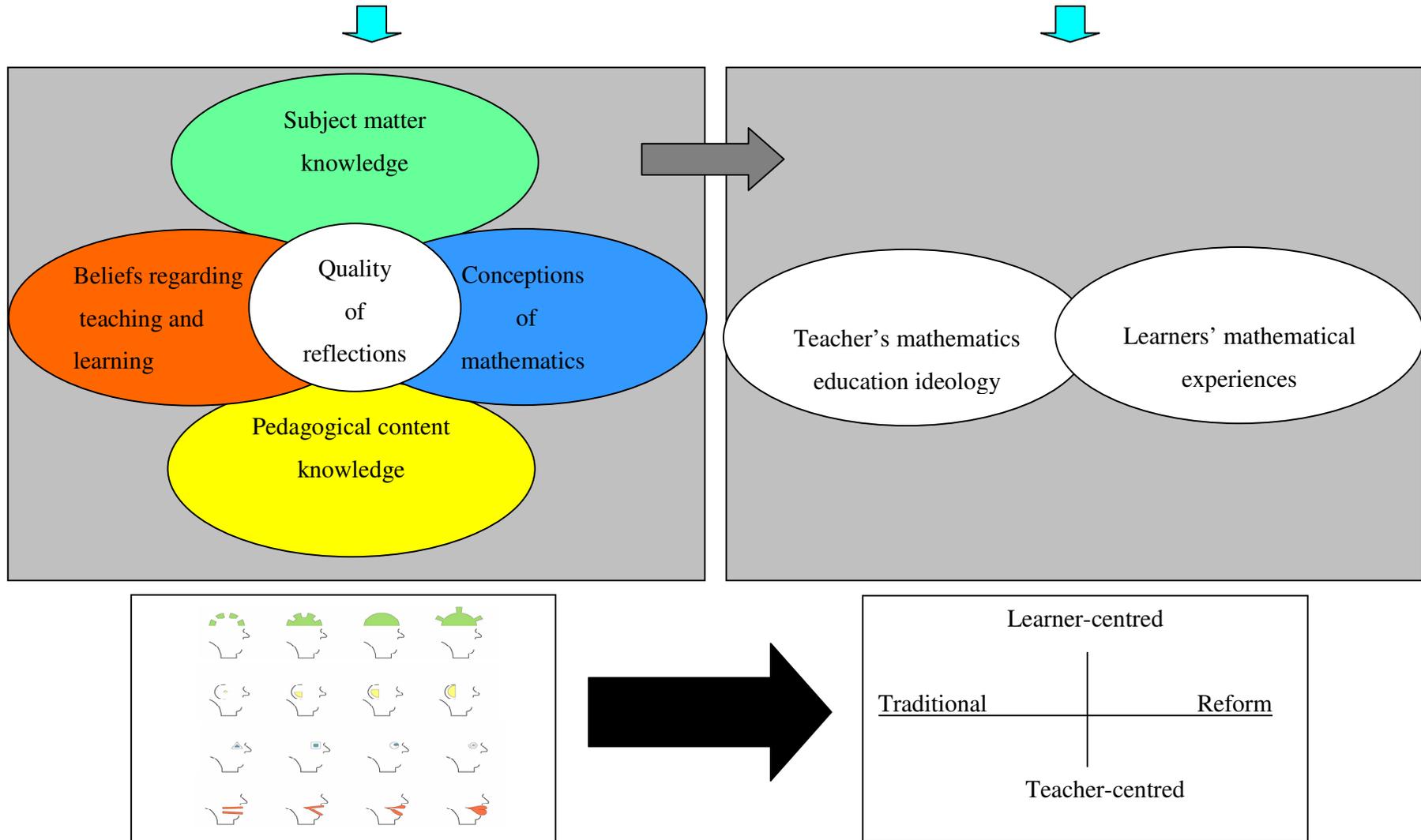


Figure 7.2 Adapted conceptual framework

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

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

products of their mathematisation, and interpret 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).

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.

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.

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

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.

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):

- All students can learn and succeed, but not all in the same time or in the same way.
- Successful learning promotes even more successful learning.
- 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 disabling 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.