Tracing the use of Pedagogical Content Knowledge in Grade 6 Mathematics Classrooms in KwaZulu-Natal

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ABSTRACT

The aim of this study was to explore the concept of pedagogical content knowledge, or PCK, and its use in the practice of teaching. Teacher knowledge is a significant factor in determining learner gains in all school subjects. However, little is known about the role of the different types of knowledge that teachers are supposed to possess in particular in a developing world context. PCK was introduced by Lee Shulman in 1986 and has since been the subject of much research in teacher education. Pedagogical content knowledge is thought to be a highly specialised form of teacher knowledge that intertwines subject matter (content) knowledge and general pedagogic knowledge.

In this study, I examined the levels of PCK of 39 mathematics teachers; I tried to determine how they used PCK in their teaching of mathematics; what determined their PCK; and to what extent PCK influenced the mathematical achievement of their learners. The methodology that I used was lesson observation of 42 video-recorded grade 6 mathematics lessons from various schools in the greater Umgungundlovu district of Pietermaritzburg in KwaZulu-Natal. These schools were selected through random stratified sampling to participate in a larger regional achievement study, designed to investigate the factors which influence learning in schools. I was part of a research team that analysed the videos of the mathematics lessons, with the intention of getting the 'big picture' of mathematics teaching and learning in South Africa. Using the data from my observations, I developed a PCK instrument and attempted to measure the teachers' PCK. I then tried to link these PCK scores to other variables in my study, which included a teacher's test and learner tests. I tested the consistency of my instrument and the teachers'

PCK scores appeared fairly consistent across lessons, but that more research is needed to interrogate that.

My initial findings suggested that all teachers possess PCK in some form, though their observed PCK levels were limited. The opportunity to develop proficiency, the use of examples and some engagement with learners' prior knowledge though mostly in the form of checking homework were the areas most prevalent. The focus was mostly on procedural aspects. Only a minority of the teachers used representations, showed more than one method, displayed longitudinal coherence or engaged in more substantial ways with learner thinking (misconceptions and errors).

Crucially, it emerged that a sound teachers' knowledge of mathematical content was necessary for a high PCK rating, but there was no significant relationship between teachers' PCK and learner gains in mathematics. It is likely that there are other factors which have a greater impact on learners' learning than effective teachers, factors such as the socio-economic backgrounds of the learners. Given the random sampling of the schools in the study, and various attempts to ensure consistency in my coding and analysis, I hoped that these results would be valid for the greater KwaZulu-Natal area. However, because I used mainly the video analysis of lessons, and only a part of the teachers' test, to determine the teachers' PCK, it is possible that I may not have been able to get the full picture of the teachers' PCK as I would have if I had also interviewed them.

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DECLARATION

I, Virendra Ramdhany, declare that this thesis is my own work and has not been submitted previously for any degree at any university.

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LIST OF ACRONYMS

HSRC	Human Sciences Research Council
TIMSS	Third International Mathematics and Science Study
PUFM	Profound Understanding of Fundamental Mathematics

CHAPTER 1: INTRODUCTION

1.1 Rationale and Motivation

"What makes the greatest difference to the learning outcomes of students?"
On the surface, this may seem a simple enough question and many people may believe the answer to be simple as well. The reality is anything but simple. Success for school-going children depends on many factors, including but not limited to:

- What learners bring with them from their social backgrounds (ie, their homes and families)
- The types of schools they attend
- How well their schools function and how effective their teachers are, and
- What happens in their classrooms in terms of teaching, learning and assessment.

The factors listed above influence student learning to varying degrees, some more than others. It would be near impossible to single out the biggest influence, but with so many conditions to satisfy, and few of them met for many of our learners, it is little wonder that the vast majority of school-going learners in our country suffer every year with minimal academic success.

My thesis aims to isolate just one of the factors, that of teachers' effectiveness based on their pedagogical content knowledge in mathematics, and to investigate how and to what extent this influences learner performance.

In 1995, South African Grade 8 learners took part in the Third International Mathematics and Science Study (TIMSS) to assess the state of Mathematics and Science education in our country. In 1998/1999 the study was repeated [Third International Mathematics and Science Study- Repeat (TIMSS-R)] to assess if any developments had occurred since 1995. The study was conducted by the Human sciences Research Council (HSRC) and the results were sobering.

South Africa ranked bottom out of the 38 countries that participated in the 1995 study for both mathematics and science, with less than 0.5% of the 8 000 South African participants performing at the top level internationally. In 1998, the study was repeated as TIMSS-R (or TIMSS-Repeat). South Africa took part in the study again, along with several developing countries such as Thailand, Chile, Morocco and Tunisia also participated in the study. South Africa's average score of 275 out of 800 points was well below the average of 487 points. The other African countries, Tunisia (448) and Morocco (337) performed better than South Africa, as did Thailand (467) and Chile (392). Analysis of the results exposed the stark realities of life for the multitudes of South African learners. Many learners come from poor family backgrounds, live in overcrowded conditions, often report late to school, are frequently absent and are raised by uneducated or illiterate parents or care-givers. At many of their schools, at least 27% of the mathematics teachers were not formally qualified to teach the subject and many more suffered with low confidence in their teaching abilities (Orkin, 2000). It was something of an understatement then when the President of the HSRC stated that "in general, conditions for learning science and mathematics in South Africa are not favourable, compared to other countries in the study" (Orkin, 2000).

Drawing on my own experiences of 15 years of teaching in the public school system, and witnessing the continual curricular changes after the demise of apartheid education, I feel there is an urgent and desperate need to assess the knowledge levels of our teachers. During the apartheid era, mathematics education research originating from South Africa was not known in international circles, and since the turn of the century most teacher education research focusing on mathematics has been located in higher education institutions (Parker & Adler, 2005). An exhaustive search through the databases – including Sabinet, MathEdu and Google Scholar - yielded precious little on South African teachers' pedagogical content knowledge (PCK), the main focus of this thesis. I am therefore confident that my study will contribute significantly to the literature on teacher mathematical knowledge in South African schools.

My study forms part of a larger research project, the HSRC-Stanford Regional Study. It is a follow-up to a pilot study of Grade 6 Mathematics lessons in the Gauteng province.

The HSRC together with the University of Botswana, the School of Education at Stanford University in partnership with the Universities of KwaZulu-Natal and Cape Town, focused on Grade 6 Mathematics to investigate: a) the impact that school inputs make on gains in learner learning; b) differences in educational policies; and c) the role of such policies in shaping the quality of school inputs. I was part of a research team that analysed the videos of the mathematics lessons, with the intention of getting the 'big picture' of mathematics teaching and learning in South Africa.

In this study, I:

- discuss the knowledge that mathematics teachers need to have, with a special focus on pedagogical content knowledge (PCK);
- attempt to determine to what extent mathematics grade 6 teachers in KZN use pedagogical content knowledge in their teaching, and
- thus lay the basis for interrogating the relationship between teachers' use of PCK and learners' performance in mathematics.

1.2 Research Questions

In my thesis, I seek to understand what the PCK construct is, whether it can be measured with any degree of reliability and to what extent it can affect learners' mathematical achievement. As I attempt to formulate an instrument for identifying teachers' PCK, I hope to be able to place the teachers into groups based on the range and extent of their PCK. To be able to link this to the background variables, I will attempt to provide a measure of the level of PCK; that is to say, do the teachers demonstrate high or low PCK levels in the observed lessons?

My research questions are therefore:

1. What are the levels of pedagogical content knowledge (PCK) demonstrated by grade 6 mathematics educators in KwaZulu-Natal (KZN) in the observed lessons?
2. What is the relationship between teachers' observed level of PCK and learners' mathematical achievement?

1.3 Conceptual Framework

The conceptual framework I used for my study is derived from theories that already exist about teacher knowledge and its resulting effects on teacher preparation and practices. Much of my study draws on the works of Shulman, Ball, Hill, Schilling, Grossman and Ma. According to the authors, teacher knowledge falls into two categories, Content knowledge and Pedagogical knowledge. These two forms of knowledge do not exist in isolation from each other however, but instead intersect during a teacher's practice of teaching. At this point of intersection between content knowledge and pedagogical knowledge is thought to be a highly specialised form of teacher knowledge called Pedagogical Content Knowledge.

Shulman pioneered the concept of pedagogical content knowledge (PCK) in 1986 and others have since taken up this idea and re-worked it in ways to make it sensible to them. Grossman (1990) maintained the PCK moniker but expanded on Shulman's categories. Ball and her colleagues used Shulman's main points to develop their mathematical knowledge for teaching (MKT), while Ma's Profound Understanding of Fundamental Mathematics (PUFM) called for teachers to have a deep and broad understanding of mathematics in order to achieve greater understanding among students.

The PCK that teachers possess is thought to equip them with the skills and abilities necessary to transform (mathematical) content knowledge into forms that are accessible to learners; skills that enable teachers to have a greater understanding of how students learn particular concepts or sections in mathematics; to be able to identify the common errors that students make and understand the reasons for these errors; and to have alterative methods at hand to facilitate student learning when difficulties do arise (Shulman, 1987; Van Driel *et al*, 1998; Deng, 2007).

It is further believed that teachers accumulate this knowledge as they teach the same sections over and over and begin to see patterns in student learning and error-making.

Formal pre-service and in-service content and pedagogical training courses are also believed to have a great influence on a teachers' PCK development; while informal trial-and-error experiences in their own classrooms are also thought to contribute (Sorto *et al*, 2008).

I will begin by reviewing the literature on teacher knowledge, with a particular emphasis on pedagogical content knowledge; I will then describe the methodology of data collection, including the numerous problems encountered; my analysis of the data will lead to a conception of the PCK levels of the teachers in my study; and finally I will try to link the teachers' PCK to the other variables mentioned in the study.

Chapter 2: LITERATURE REVIEW

This chapter focuses on the literature on teacher knowledge, with an in-depth look at the concept of pedagogical content knowledge, or PCK. I will discuss the rationale behind PCK and its usefulness in teaching to enhance learner understanding and ultimately, to improve learner achievement in mathematics.

Teacher Knowledge

To fully understand what PCK entails, one has to first acknowledge the importance of the other "knowledges" that teachers need to have. In 1986, Shulman and his colleagues developed what they felt were the 7 major categories of teacher knowledge. The first four categories were the general dimensions of teacher knowledge, which most teacher education programmes focus a great deal on. These categories are: general pedagogical knowledge, knowledge of learners, knowledge of educational contexts, and knowledge of the purposes and value of education. The last three categories, namely content knowledge, curricular knowledge and pedagogical content knowledge, were what Shulman and his colleagues were most interested in, as they deal with teacher competency and effectiveness. Pedagogical Content Knowledge (PCK) is a specialised amalgam of knowledge that combines subject-specific content knowledge, curricular knowledge and pedagogical knowledge. These forms of knowledge are therefore "inextricably linked" to each other (Deng, 2007).

Shulman (1986) refers to content knowledge as the 'subject matter' or the amount and organisation of knowledge (of facts and concepts) in the teacher's mind, and a sound understanding of the structures of the subject matter. This refers to a deep understanding of "the variety of ways in which the basic concepts and principles of the discipline are organized to incorporate its facts" (Shulman 1986, p. 7). Ball *et al* (2008) divide content knowledge of mathematics into two domains: common content knowledge (CCK) and specialised content knowledge (SCK). Common content knowledge enables teachers to do the work that they assign their students, recognise the errors they make, use the correct terms and notation correctly, and so on. Specialised content knowledge is the knowledge unique to mathematics teachers. SCK enables teachers to look for patterns in student errors, choose appropriate examples for math topics and so on.

Pedagogical knowledge refers to general strategies of classroom management, teaching styles and methods. Curricular knowledge is another component of teacher knowledge that is important for the development of PCK. Teachers with strong curricular knowledge are aware of how topics are arranged both within a school year and over time (Hill *et al*, 2005), and use the full range of programs designed for the teaching of particular subjects and topics at a given level. Effective teachers know and understand curricular materials, such as the strengths and weaknesses of textbooks and other materials (Shulman, 1986; Grossman, 1990; Deng, 2007).

Pedagogical Content Knowledge

In 1986, Lee Shulman introduced the notion of pedagogical content knowledge (PCK) to the world, more than 80 years after John Dewey called for teacher subject matter (content knowledge) and pedagogic knowledge to be developed side-by-side (Dewey, 1904). Up until that point, very little attention was paid to subject matter knowledge compared to pedagogic knowledge, with most teacher education "structured across a persistent divide between subject matter and pedagogy" (Ball, 2000). Shulman however, was interested in

… questions about the content of the lessons taught, the questions asked, and the explanations offered. From the perspectives of teacher development and teacher education, a host of questions arise. Where do teacher explanations come from? How do teachers decide what to teach, how to represent it, how to question students about it and how to deal with problems of misunderstanding? (Shulman, 1986, p. 6).

PCK was considered a special kind of knowledge for teaching which only teachers have, that linked content and pedagogy (Grossman, 1990; Ball, 2000; Ball & Bass, 2000; Ball, Thames & Phelps, 2008; Thames, Sleep, Bass & Ball, 2008), and which can be traced to

Dewey’s (1904) call for teachers to draw upon “both their knowledge of subject matter…and their knowledge of students’ prior knowledge and conceptions” (Dewey, 1904, 8) to make topics more accessible to students. Shulman included in his definition:

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. (Shulman, 1986, p.9).

Shulman believed that pedagogical content knowledge

… also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons. If those preconceptions are misconceptions, which they so often are, teachers need knowledge of the strategies most likely to be fruitful in reorganizing the understanding of learners (1986, p. 10).

He was not simply interested in how many college mathematics courses the teachers took, because he felt that “Mere content knowledge is likely to be as useless pedagogically as content-free skill” (1986, p. 6). More important was to blend the two aspects of a teacher's capacities: the content aspects of teaching as well as the elements of teaching process, because teacher effectiveness depends not only on the amount of knowledge accrued in the mind of the teacher, but also how this knowledge is used in the classroom (Hill, Rowan & Ball, 2005).

Shulman’s original definition of PCK had its limitations, not least of which was the lack of a clear list or catalogue of what this ‘new’ knowledge entailed. There was also the underlying assumption that there existed a difference in the pedagogical content knowledge bases between the novice and expert teachers. As a result, many mathematics researchers have since adapted and expanded his conception, though not necessarily replaced it. Grossman's (1990) four components of PCK resemble Shulman's closely. These include: 1) Knowledge about the purposes of teaching; 2) Knowledge of students' understanding and potential misunderstanding; 3) Knowledge of curriculum and curricular materials; and 4) Knowledge of instructional strategies and representations for teaching particular topics.

Ball *et al* (2008) used Shulman's PCK underpinnings to introduce their Mathematical Knowledge for Teaching or MKT. They believe that MKT is the teacher knowledge needed to "perform the recurrent tasks of teaching mathematics to students". Mathematical Knowledge for Teaching can be divided into 4 domains: 1) Common content knowledge; 2) Specialised content knowledge; 3) Knowledge of content and students (KCS) and 4) Knowledge of content and teaching. KCS is content knowledge intertwined with knowledge of "how students think about, know, or learn particular content" (Hill *et al*, 2008), and is thus based on Shulman's initial definition which includes an understanding on what topics students find difficult or easy to learn.

Baumert *et al* (2004) went even further to divide PCK into two different types, Declarative PCK and Procedural PCK. Declarative is more theoretical where the teachers consider their orientations towards their lessons, the curriculum and their knowledge of students' misconceptions and difficulties. Procedural PCK is determined by the teacher's practice of teaching in the class, and includes actions of responding to students' questions and mistakes.

Liping Ma's Profound Understanding of Fundamental Mathematics, or PUFM, is thought to share many similarities with Shulman's PCK. Ma (1999) believes that PUFM is "…the awareness of the conceptual structure and basic attitudes of mathematics inherent in elementary mathematics…" and that a teacher teaching with PUFM "…has connectedness, promotes multiple approaches to solving a problem, revisits and reinforces basic idea and has longitudinal coherence." (p. 124). This is covered by Shulman's (1986) assertion that teachers "need not only understand *that* something is so, the teacher must further understand *why* it is so" (p. 9). The implication is that teachers' content knowledge must represent a deep understanding of the material (Jordan *et al*, 2008).

In considering these definitions, some common ground becomes evident. According to Shulman, PCK is a uniquely integrated form of knowledge of subject matter, curriculum, pedagogy and students. Central to his definition are: the use of different forms of representations and examples that make topics easier for learners to understand; and an understanding of students' preconceptions and misconceptions which would help teachers anticipate student difficulties (Shulman, 1987; Graeber, 1999; Seymour & Lehrer, 2006). For teachers to be able to understand the conceptions of students - whether pre- or misconceptions - requires teachers to have a keen insight into students' thinking and understanding. Shulman also emphasised knowledge of multiple ways of representing the content to students. Such knowledge "relies on the teacher's understanding of the content, and has as its purpose the transformation of that content into a form that students will understand" (Chick, Baker, Pham & Cheng, 2006). Grossman (1990) mentions that PCK provides teachers with the knowledge to perceive the way students understand or misunderstand topics, as well as the knowledge of representations and instructional strategies. Ball *et al*'s Knowledge of Content and Students enables teachers to "anticipate what students are likely to think and what they will find confusing" (2008, p. 40) while Knowledge of Content and Teaching provides teachers with the ability to use their mathematical content and pedagogical knowledge to choose examples and tasks that would positively affect student learning.

It is clear then that these authors believe a sound knowledge of students thinking and understanding, combined with instructional strategies which include, among others, powerful representations, examples and explanations, are key aspects of a teacher's pedagogical content knowledge. Ma (1999) does not disagree, but while other authors may only imply its importance, Ma stresses vehemently the importance of making connections between mathematical topics and ideas at their most fundamental level. A teacher teaching with PUFM has breadth, depth and thoroughness, which refer to the capacity to make these connections. This is the main reason, Ma feels, for the apparent success Chinese teachers achieve in teaching elementary mathematics.

While literature does not abound with international studies of teachers' PCK, South African literature on PCK is markedly lean in comparison. An exhaustive search through the databases – including Sabinet, MathEdu, Google Scholar - yielded precious little on South African teachers' PCK. Kazima, Pillay and Adler (2008) refer to 'mathematics for teaching (MfT) which is a 'specialised mathematical knowledge that teachers need to know and know how to use in their teaching'. Although this MfT draws on Shulman's PCK, Ma's PUFM and Ball's Specialised Knowledge for Teaching Mathematics, Kazima *et al* (2008) felt it a more 'inclusive notion' necessitated by what they believed to be Shulman's vague distinction between pedagogical content knowledge and subject matter knowledge. It would have seemed logical then to build on the MfT construct rather than go with PCK, seeing that my study focused on the South African context. However, due to my involvement in the larger project which works with PCK, and the fact that I had already done a lot of research on PCK, I decided to go with this.

The importance of developing PCK

If teachers listen to children, understand their reasoning, and teach in a manner that reflects this knowledge, they can and will provide children with a mathematics education better than if they did not have this knowledge. (Dewey, 1904, pp. 29-30)

Research from the United States, China and New Zealand indicates that teachers with so-called high levels of PCK, in whatever form this construct may be conceptualised, are better able to teach in a way as to enhance student understanding (Ma, 1999; An, 2004; Hattie, 2003). For many years now, mathematics education research has focused on ways in which classroom environments can be created so that learners learn mathematics with understanding. When students learn with understanding, they are better able to apply their new knowledge to prior knowledge and to solve new and unfamiliar problems. They are less prepared to do so if they learn each topic as an isolated skill (Fennema & Romberg, 1999; An, 2004).

This has implications for teachers as well, because "teachers need to understand the mathematics they are teaching, and they need to understand their own students' thinking" (Fennema & Romberg, 1999). Effective teachers are those who have an extensive repertoire of powerful and useful representations, examples and counterexamples, helpful analogies and the ability to adapt these representations in multiple ways (Shulman, 1986; Borko & Putnam, 1995; Grouws & Schultz, 1996; Grossman, 1990; Davis & Simmt, 2006; Simon, 1997; Ma, 1999). These teachers also have a deep knowledge of students' development of relevant concepts, which helps teachers to anticipate how students' learning might ensue and progress; anticipate potential misunderstandings of topics; and use this knowledge to re-interpret concepts to promote learner understanding. Teachers with deep and broad PCK, who recognise learning as understanding, realise that knowing is not sufficient and that understanding is achieved at the level of internalising knowledge by connecting prior knowledge through "a convergent process. Here, the teacher focuses on not only the conceptual understanding but also procedural development in which the teacher constantly inquires about students' thinking and makes sure students fully grasp the knowledge and are able to apply the concepts and skills" (An, 2004).

There is evidence that students whose teachers learned about aspects of student thinking and understanding increased their achievement in mathematics (Fennama *et al*, 1996; Ma, 1999; An, 2004). Research suggests that such teacher competence can only exist when there is a combination of skills, knowledge and contextual understanding. Teachers who know about their students' mathematical thinking can support the development of mathematical proficiency (Graeber, 1999; Van der Valk & Broekman, 1999). O'Connor & Michaels (1996) believe that as teachers successfully orchestrate student understanding, by teaching the same topics to students over time, they construct PCK. Effective teachers develop practices tuned to students' interpretations of mathematics.

Little is known about the ways in which teachers transform academic subject matter knowledge into a school subject appropriate for teaching and learning, and how they relate this to students' understanding. According to Shulman, PCK holds the key to the transformation of content knowledge into forms that are "…pedagogically powerful and yet adaptive to the variations in ability and background presented by students." (1987, p. 15). This transformation is shaped and informed by teachers' knowledge and beliefs about the purposes of schooling, about learners, the curriculum, pedagogy and the school context (Deng, 2007; Van Driel *et al*, 1998).

These characteristics of teachers described above make them effective in making connections between mathematical topics and in doing so, enhancing their quality of teaching to promote greater understanding among students. Hill and Ball (2009) noticed that teachers with strong MKT seemed to possess certain characteristics, such as careful attention to mathematical detail and well-explicated reasoning, developing their own knowledge through math-focused teacher development programmes, and the ability to learn from both textbooks and their students. This mirrors Ma's (1999) findings that Chinese teachers attained PUFM by "learning from colleagues, learning mathematics from students, learning mathematics by doing problems …and studying teaching materials intensively" (p. 142).

A measure of PCK

In light of this research, it is clear that developing high levels of PCK within mathematics teachers (and indeed teachers of all subjects) has the potential to yield positive gains in mathematical achievement among learners – though we need research such as this project to interrogate the extent to which this holds in developing contexts. To do this would mean getting an idea of the measure of PCK that teachers possess. However, this is very difficult to do because teachers' PCK is not always explicit. A teacher's PCK is measured based on his knowledge, his actions and his reasons/beliefs, so it is not based entirely on written tests or on behaviours. The questions which remain though are: How do we measure teacher PCK? And: How can we then develop and improve teachers' PCK?

There have been numerous attempts, in the form of small- and large-scale studies and a variety of methods, to measure teacher knowledge in general and PCK in particular, but clear-cut results and answers have been elusive (Thames, 2006; Ball *et al*, 2008; Hill, Ball & Schilling, 2008; Hill & Ball, 2009). This was earlier asserted by Mewborn (2001, p. 29) who stated that in the US, from the 1960s to the turn of the century, studies "that sought to demonstrate a connection between measures of teacher knowledge and student achievement failed to find any statistically significant correlation". These authors believe the primary reasons for this are the multi-faceted nature teacher knowledge in general and PCK in particular, and hence the subjectivity of what is the greatest predictor of mathematical success among students. I believe, after reviewing my results from this study, that if we do have a good, commonly agreed-upon measure of PCK, then a stronger and more definite correlation between PCK and learner achievement might be achieved.

Ball *et al* (2005) were involved in a study that tried to investigate the nature of Mathematical Knowledge for Teaching (MKT). 700 teachers and almost 3000 students took part in a longitudinal study in which the students test scores, students' socioeconomic status, and a teacher questionnaire/test were analysed to look for student gains over the course of one year. The teacher questionnaire contained items which were intended to measure[1] common content knowledge (CCK) and specialised content knowledge (SCK), and asked for background data such as teacher qualifications and experience. Their results found that the students of those teachers who scored higher in their tests, especially on the 'knowledge for teaching' questions, gained more over the course of the year. The researchers were pleased with these results which, they believed, suggested that 'improving teachers' knowledge may be one way to stall the widening of the achievement gap' (2005, p. 44), in particular among those students who come from poor socioeconomic backgrounds. Ma's study, in which she looks for reasons why

[1] See discussion in Christiansen & Ramdhany, forthcoming.

Chinese students "consistently outperformed" their US counterparts in international studies of mathematics achievement, is perhaps the closest example of correlation between teacher knowledge and student achievement. Ma used the International Association for the Evaluation of Educational Achievement (IEA) and TIMMS to show that teachers with a profound understanding of fundamental mathematics (PUFM) are better able to help students make connections between mathematical ideas and concepts, which leads to greater conceptual understanding in mathematics and corresponding good results (Ma, 1999). Yet the study was a small scale interpretivist study and thus cannot be generalized or transferred to other countries where the context is different.

There are very few studies which have measured PCK *per se*. In South Africa, the pilot HSRC-Stanford Regional Study in Gauteng province did not reveal any conclusive link between teachers' PCK and learner performance in mathematics, largely because teacher knowledge was not randomly distributed in the sampled schools, but also due to some recognised validity issues in how PCK was 'measured'. The original study on which the Gauteng study was based (Sorto *et al*, 2008) found that the differences which exist between teachers in different countries (Panama and Costa Rica) are due largely to the teacher preparation programmes in the different countries. Teachers from both countries generally show good pedagogical knowledge but lack the connection with the underlying mathematical concepts. These teachers are also more comfortable with lecturing as the main mode of classroom instruction. In terms of the quality of the mathematics lessons, both countries focus on procedures rather that making the connections that enhance learner understanding and problem-solving skills. The authors generally agreed that, while the teachers in these to countries showed good content and pedagogical knowledge, they lacked a profound teaching knowledge of mathematics.

International studies for the measurement of PCK reveal that researchers usually devise their own instruments for testing. These contain categories of what they feel to be the most important aspects of PCK. For example, Baumert (2003) based his test on his own Declarative-Procedural model which consisted of 26 tests; Jordan's (2008) PCK test contained 3 sub-domains (Knowledge of tasks; knowledge of students' misconceptions and difficulties; knowledge of math-specific instructional strategies) and 10 assessment items. Results are difficult to generalise due to the variety of instruments used and conceptualisations of the PCK construct, while in some tests, the criteria were not specified.

The last twenty years or so has seen a flurry of activity in teacher education circles, set alight by Shulman's (1986) introduction of pedagogical content knowledge (PCK). The attention has shifted from subject matter knowledge and general pedagogical knowledge to a more specialised form of teacher subject knowledge. Opinion in research circles is markedly split as to the validity of the PCK construct, its usefulness in teacher education and the means of measuring such a construct reliably. While giant strides have been made (and continue to be made) in this area of teacher knowledge, there is still much we do not know, and I am hopeful that my study is able to contribute to debate constructively.

I make no secret that this thesis is influenced heavily by Shulman's original conceptualisation of pedagogical content knowledge (PCK). However, I also borrow from Ball's knowledge of content and students (KCS) and Ma's Profound Understanding of Fundamental Mathematics (PUFM) in trying to formulate a construct that relates to our unique conditions in this country. The categories that I drew up, which I use to formulate an instrument to measure teachers' PCK in this study, therefore has elements from all these researchers, although I believe it to be based essentially on Shulman's PCK. From Shulman, I draw on his PCK concept which combines teachers' subject matter knowledge and pedagogical knowledge into a specialised knowledge unique to teachers and their jobs of teaching. The effective use of a wide variety of representations, examples and analogies, as well as the identification of learners' prior knowledge was very important to him. Ball's KCS provides the knowledge that teachers must have to anticipate students' problems, as well as the ability of teachers to identify and address common student conceptions and misconceptions. Ma's PUFM advocates the importance of making connections between mathematical topics and encouraging multiple methods and approaches to solving mathematical problems.

Pedagogical content knowledge or PCK has been around for some time now, yet it is still viewed in many parts of the world with more than a little suspicion. I believe that if understood properly, PCK has the power to transform the lives of teachers and their students, especially in (but not limited to) mathematics. Central to Shulman's PCK is the student's understanding. What should teachers do, how should teachers teach, in order to ensure that the student understands best? What are the best types of representations or examples to use? How does the teacher make connections between topics to enhance understanding? PCK provides answers to these questions.

In the next chapter, I will give details of the larger study to which my study is attached, describe the data collection and its related difficulties encountered by the research team, and introduce the instrument which I developed for the purpose of trying to measure the PCK of the teachers in my study.

Chapter 3: METHODOLOGY

In this chapter, I will discuss the data collection methods we used in this study and describe some of the problems we experienced and validity issues we addressed. In particular, I will highlight the instrument I developed in the hope of measuring the teachers' PCK. I will also provide details of the internal validity of the instrument.

3.1 Regional Achievement Study

As I have mentioned briefly in chapter one, I was part of a research team involved in a regional achievement study in KwaZulu-Natal. The purpose of the study was to explore and establish the relationship between teachers' mathematical content knowledge, teachers' practice and learner outcomes in grade 6 mathematics classrooms. The study involved assessing teachers' mathematical content knowledge, teachers' pedagogical content knowledge (PCK) and teachers' practice in mathematics classrooms.

This was a replication, with substantial modifications, of a study already conducted in Latin America (Sorto *et al*, 2009) and piloted in Gauteng by a research team led by the Human Sciences Research Council (HSRC), in conjunction with Stanford University, the University of Botswana, the University of Cape Town (UCT), University of Witwatersrand (Wits) and University of KwaZulu-Natal (UKZN).

The original study in Panama and Costa Rica examined the relationship between mathematical knowledge for teaching, the preparation of and classroom practices of third and seventh grade teachers in these two countries. Some significant relationships were found between aspects of teacher knowledge and characteristics of the teachers (Sorto *et al*, 2009, p. 251).

3.2 Data Collection

The data collecting team consisted of nine members of the School of Education and Development staff and eleven research assistants who included Masters students and unemployed graduates with experience in data collection. The data collection in the study was conducted in 3 phases:

Phase 1 took place between May and August 2009, and involved administering a learner questionnaire and test to approximately 1800 grade 6 learners in 39 public schools. This questionnaire included questions on learner biographical details, their family and socio-economic status, language and their perceptions about school violence. The test comprised items from the grade 5 and grade 6 mathematics curriculums which, based on the pilot study conducted in Gauteng, had been prepared by the Joint Education Trust (JET). This test was developed for more generalised testing and the instrument itself was tested in line with the national curriculum.

Phase 2 was conducted between August and September 2009 and involved videotaping teachers teaching in their grade 6 mathematics classrooms. It also involved administering a teacher and a principal questionnaire. The teacher questionnaire had a general component and a mathematical knowledge component. The general component included their biographical information, education and training, socio-economic status, home language, curriculum coverage, supervision, school violence and questions on absenteeism. The mathematical knowledge component included questions that required teachers to identify common errors made by learners in primary mathematics, and other similar tasks. The principal questionnaire included questions related to those asked of teachers about language, curriculum coverage, school violence, absenteeism and supervision.

The second phase of the study also included examining learners' books in each class as a way of measuring the "opportunity-to-learn". This was aimed at providing sufficient information to assess how much content was covered during the year, and thus how much opportunity the learners had to learn mathematics.

Phase 3 of the study was conducted in October and November and involved conducting the learner questionnaire as a post-test to assess whether there were any gains that learners made when compared to the pre-test.

3.3 My part in the study

As part of the research team, several Masters students were tasked with analysing the videos. One student coded for the subject content matter covered in each lesson, another for the mathematical proficiencies that the educators endeavoured to develop in the learners. A third student coded for the level of cognitive demand that each lesson made of the learners, while I coded for teacher knowledge.

The instrument that I was given to use for the purpose of identifying teacher knowledge was a simple one, consisting of three main columns, Core knowledge (subject matter), general Pedagogical knowledge and Pedagogical Content knowledge. The columns for each category were further divided into 5-minute clips, in which I had to state either Present (P) or Not Present (NP) for that category. Needless to say, there was much debate over the rather simplistic (I thought) Present or Not Present coding system, so for my own research, I concentrated only on pedagogical content knowledge (PCK) and developed my own instrument which I used to analyse the videos. This instrument can be seen later in this chapter.

3.4 Sampling

Forty primary schools were sampled from the Umgungundlovu Education district in KwaZulu-Natal, using stratified random sampling. Umgungundlovu is one of 12 education districts in the province and comprised a total of 219 807 learners in 2009. In terms of the matriculation pass rate in 2008, the Umgungundlovu district had a 63% pass rate which was the second highest in the province. Thus we expected the results from the Grade 6 learners and teachers in this study to be slightly better than the results in other districts.

All schools categorised by the Department of Education as Quintiles 1, 2 and 3 were recoded into quintile 1 for this study, representing poorer schools, and schools usually categorised as quintiles 4 and 5 were recoded into the new quintile 2, representing affluent schools. Approximately 76% of KZN grade 6 schools fall within the study's quintile 1 (old quintiles 1, 2, 3) and 22% fall in the new quintile 2 (old 4 and 5), while 2% still need to be updated. In order to maintain the provincial representivity of schools, sampling was done within these strata. A random number of all sampled schools was generated and sorted in an ascending order. A rank was assigned to each school on the basis of this ascending order. 2 lists of schools were generated representing quintiles 1 and 2 respectively. The first 30 schools were selected from the list of quintile 1 schools and the first 10 from the list of quintile 2 schools. Thus the study sample was stratified to comprise 75% of less-resourced schools and 25% of better-resourced schools.

Approximately 78% grade 6 schools in KZN are rural, 18% urban and 4% not yet demarcated. The project did not use the rural-urban field as a variable for sampling because the senior researchers believe that there is a strong relationship between rural schools and schools in the lower socio-economic quintiles, and urban schools and schools within higher socio-economic quintiles.

Although the intention was that 40 schools be sampled, four schools did not wish to participate and had to be replaced. The final number of schools in the study was 39. From these 39 schools, the fieldworkers videotaped at least 62 grade 6 mathematics lessons, with as many as 5 lessons from some schools. The final numbers in my data set were 42 videos in which 39 teachers appeared. There were 3 teachers who appeared in two videos each. Of these 39 teachers, 26 wrote the teacher's test.

I resisted the urge to include a copy of the original teacher test here, as this thesis is part of a larger project and the test will, in all probability, be used in other studies. I therefore did not want it in the public domain. In my study, I focused mainly on the analysis of the videos and used the results of the PCK questions of the teacher test to support what I observed in the videos. A fairly comprehensive summary of the teacher test results for the PCK items can be seen in Table 5.1 in the Appendix.

3.5 Validity issues in data collection

Data collection was delayed in cases where some schools refused to participate in the study. Four of the initially selected schools had to be replaced. Another challenge was that some of the primary schools identified in the Departmental records as having grade 6 classes only went up to grade 4. Those also had to be replaced. Thus, representivity could have been slightly altered in the process. Some teachers were not comfortable with being videotaped, and often had to be reassured of the confidentiality of the whole process. However, a few teachers refused to participate in this part of the study, limiting the data set. Teachers tended to be suspicious of the writing of the test and in particular the video taping, and voiced their discomfort about not knowing how these videos would be used, and about whether or not the learner performance would be used in a punitive way. There were also cases where teachers interfered with the study: In one case, the field workers established that teachers had given them grade 7 learners to write the test and lied that it was a grade 6 class; In another case, a teacher was found ‘translating’ questions into isiZulu in such a way that the answer was strongly hinted at.

One of the challenges in conducting the learner tests was that grade 6s were also required to write mathematics tests that were set by the department of education. Teachers therefore felt this was an added pressure their learners had to go through. Learners generally completed the tests, but it is uncertain if their efforts would have been different if the test results had mattered to them. The questionnaires were lengthy and it is uncertain to what extent learners’ answers reflect their home situation – for instance, does the child in grade 6 know the highest level of education of her/his parents? The learners were not asked about more ‘intimate’ aspects of their home situation, such as whether their parents are ill (HIV infection rates in KwaZulu-Natal are the highest in the world), if they care for their parents or siblings, or if they have been sexually abused (South Africa also ‘tops’ the statistics in this respect).

Further problems were encountered during data collection, which posed challenges in terms of validity issues. In a few cases, there were mismatches between the first and second learner tests, such as the learner names not matching each other, or a total absence of learner names on the tests, or a large drop in the number of learners taking the second test compared to the first. In cases like this, one has to wonder what the reason was for the large drop in number - and, is the first or the second learner number the true reflection of the class? Why were the names not matching? Did different learners write the first and second tests? Or are some schools haunted by great learner movement – we do know that farm workers often migrate every six to twelve months? These questions raise serious validity issues, especially in light of the fact that the study hoped to assess student gains, if any, between the first and second tests. In the end, only 76% of the learners (47 of 62 classes) in the study wrote both tests.

3.6 My PCK instrument

Attempting to develop a measure for PCK opened several debates as to what should be in the domain. This is due to the fact that pedagogical content knowledge (PCK) is a very difficult type of teacher knowledge to categorise or indeed measure, owing to the gradual evolution of PCK brought about by various authors who have subsequently engaged with Shulman's original construct (Grossman, 1990; Ball, 2000; Ball & Bass, 2000; Ball, Thames & Phelps, 2008; Thames, Sleep, Bass & Ball, 2008). Indeed, even my conceptualisation of PCK may differ from others'. However, without some form of instrument, it is not possible to say whether a teacher shows evidence of PCK or not. For this reason, it was imperative for me to develop an instrument so that I could analyse the videos with a fair degree of confidence that I would be covering as many bases as possible.

Initially, and strongly informed by my literature review, I formulated questions which encompassed what I believed to be the most important aspects of PCK, although I do not suggest it is a comprehensive framework. The questions were grouped under headings which formed the categories of PCK in my study (See Appendix: Table 3.1).These

The instrument I designed and used for analysing the videos:

Time	PEDAGOGICAL CONTENT KNOWLEDGE								
	Prior knowledge identified	Level appropriate	Progression of lesson (Sequencing/ pacing)	Longitudinal coherence (prior, future connections)	More than one method shown	Representations/ examples	Identifies errors/ misconceptions (Q,L,T)	Addresses errors/ misconceptions	Learner opportunity to develop proficiency

questions were then summarised into my instrument as shown on the previous page. I will expand on the content of the codes and details of the coding process below.

3.7 Coding the videos

Although there is a column ‘Level appropriate’ in the instrument, I do not mention it in my analysis. This was necessary for the larger project, and not integral to the focus of my study. It was intended to be used to observe if the educators who took part in the project were in fact teaching their particular mathematical topics at the appropriate grade level. When the videos were coded in a large group, it was noted that all lessons were pitched at the appropriate levels according to the national assessment guidelines for the subject.

Time

As I analysed each video, I divided each lesson into 5-minute intervals or clips. After each 5-minute interval, I would stop the video and write brief notes in the categories of my instrument. For example, if I identified what I thought was prior knowledge in the first 5-minute clip, I would note ‘homework correction’ or ‘types of angles’ or ‘short mental test’, and so on. This does not mean, however, that the entire 5-minute clip was spent in this way - it simply means that the teacher tried to assess the learners’ prior knowledge at some time during this interval, even if only for a minute or two. When the learners were busy with a class work activity, then the entire 5-minute clip was generally spent in this way. At the end of the lesson, I worked out the frequency of teacher actions as a percentage of the entire lesson. If the lesson was 50 minutes long, then that is a total of 10 intervals. If I filled in ‘prior knowledge’ in two time intervals, then the percentage would be 20% - that is, the teacher spent at most 20% of the lesson trying to assess or ascertain the prior knowledge of the learners. It could of course be less time, when less than the entire 5 min interval was spent on that particular activity.

While a more detailed analysis would have been preferable, I also had to be pragmatic, given the large amount of data. I believe that if I worked consistently through the 42 videos, then I would get a fairly accurate picture of what went on in the classrooms. If say, Teacher X addressed a learner's errors just once (that is, in only one 5-minute clip) in a 40-minute lesson (13%), and teacher Y addressed learners' errors three times (or in three different clips) in a 40-minute lesson (38%), and this reflected a pattern in these teachers' classroom practices (see internal validity discussion on p. 35 ff), then it would be reasonable (rather than hopeful) to expect a difference in the learners' test scores, as well as in the teachers' test scores.

In the sections below, I will discuss the process of coding, thereby clarifying and exemplifying the categories of the instrument, in particular their boundaries, as well as indicating some of the difficulties I experienced in assigning codes to video-recorded classroom events.

Prior knowledge identified

I felt it fairly easy to see if the educators tried in some way or other to identify the levels of their learners' prior knowledge. Most of the lessons began with a recap or review of a lesson or piece of work done previously, be it the previous day or week. The educators would usually check the previous day's homework, followed by corrections and then move on to new work for the day. Some educators asked questions to ascertain prior knowledge: "Do you remember what the parts of a division sum are called?"; "What are 2D/3D shapes?"; "How many operations are there in mathematics?" Other educators would ask the class to count in ½'s form ½ to 5 (in unison), while a few opted to quiz their learners for 5 minutes of so: what is 13 x 13; what is 20 x 5 - 50? One educator began her lesson with a ten-minute mental test. Any of these examples listed was recorded as the teacher 'identifying the learners' prior knowledge'. This did not usually take up a great deal of time- an average of 13% or 6 minutes at the start of the lesson.

I also experienced little difficulty in identifying those lessons in which the educator did not spend any time on prior knowledge, but rather went straight into the day's lesson. This happened on four occasions, where the educators began the lessons by announcing the topic for the day - “Good morning, today we are looking at the addition of fractions. What do we call the shaded area of the diagram on the board?” In another example, the educator began the lesson by giving the learners ten minutes to complete a group activity. The learners worked in total silence. Only after ten minutes did I discover that the activity consisted of multiplication story sums. I could not tell if the learners had done it previously, to classify it as prior knowledge, so I did not code it as such.

Retrospectively, after careful consideration and deliberation, I realised that correcting of homework can only be considered as ‘identifying prior knowledge’ if that homework is used as a platform for the present day’s lesson. If the homework is not used as a starting point for the present day’s work, then it is simply identifying and addressing errors. Unfortunately, when I analysed the videos, I did not make detailed notes of what the homework was that was being corrected, so I could not determine if the homework and the present lesson were in fact related or not. This would have been a useful distinction to make, because there may well be a difference in terms of the support of new content provided by such revisions. It is something which might be picked up in future work, with more careful analysis of the progression of the content.

There were instances where I was not sure if what I saw could be regarded as longitudinal coherence or not. In one particular lesson, the teacher began by reviewing the three types of graphs covered by the class in a previous lesson (prior knowledge). The teacher then asked the learners for their homework, which was to collect data of 5 of their friends’ birthday dates. The entire lesson was then based on the information that the learners has collected. At the end of this same lesson, the educator asked the learners to collect data on the political parties in their areas, which was to be used in the following day’s lesson. This is the point of contention: “yesterday’s homework used for today’s lesson, today’s homework used for tomorrow’s lesson”- is this making connections between new knowledge and prior and future knowledge? And if so, is it an example of longitudinal coherence? As the homework was about collecting information but not engaging conceptual links, I did not code this as an example of longitudinal coherence.

Progression of lesson (sequencing and pacing)

Sequencing

Sequencing is the "stringing together" of individual classroom activities in some sort of chronological order, in other words the order in which the lesson progresses. Does the educator begin the lesson with simple examples and then move on to the more difficult and complex examples? Does the educator move from the known to the unknown, by introducing new work that is related to prior knowledge? (Goldsmith, 2009). Positive answers to these questions would suggest that there is evidence of sequencing based on the teacher's actions.

Some of the examples of sequencing, which I coded as such, included the following:

- A lesson in which the learners were first asked to estimate distances; then they were shown different measuring instruments; they then used these instruments to measure their estimated distances; and finally were asked to convert from one unit of measurement to another. This is what I coded as the *presence* of progression, as it was clear that the learners began with simple tasks and moved on to more demanding tasks.
- Another lesson saw the educator asking the learners for their ideas of what a budget was; then the learners had to work out a budget in groups; and finally they had to work on an exercise individually.

Pacing

Pacing is the rhythm and timing of classroom activities and units that the teacher uses for the various parts of the lesson. That is to say, how much of time is used for review, prior knowledge, introducing and explaining new work, learner application and marking/correction of learners' work – and thereby gives an indication of the pace with which new concepts and ideas are introduced. This is largely determined by the teacher's ability to know when the right time is to change to another activity or sub-activity (Goldsmith, 2009). The Government Gazette (2008, p. 19), which contains details of the Foundations for Learning Campaign 2008-2011, includes a section for daily teacher activities during mathematics time. This is a suggested pacing and sequencing for a typical grade 6 mathematics lesson and goes something like this: Oral & Mental work - 10 minutes; Review and Correct homework - 10 minutes; Teacher introduces concept of the day's lesson - 20 minutes; Problem solving and learner engagement - 15 minutes; and Homework for the day - 5 minutes. (Note the implied teaching approach, as opposed to starting with an activity from which concepts are then drawn.)

In the videos, there was the *presence* of pacing by the teachers, and each teacher used different amounts of time for each part. Some teachers used more time than others on explaining, especially if the section was a difficult one for the learners to understand; other teachers spent the largest part of the lesson on application. A lot depended on the length of the lessons. If the lessons were 45-50 minutes long, then the teachers had the freedom to spend more time on say, explaining than if the lessons were 30 minutes long.

It is important to note that I did not represent the category of sequencing and pacing (ie progression of lesson) as a percentage of the lesson as I did with the other categories. This is because pacing is an area of study in its own right. To do so would have meant timing (in minutes) how long the teacher took to go over homework, then to introduce the new topic for the day, then how much time the educator would assign for an application exercise, correction of the learners' work, and so on. In this case, I decided to assign the code *present/ not present* in terms of general progression of the lesson based on the 'quality' of sequencing and pacing. In other words, if I felt the sequencing and pacing was good, I indicated *present*, but if not, then I indicated *not present*.

Longitudinal coherence

Effective teachers are those who are able help the students make connections between mathematical topics, as well as being able to connect new knowledge to prior knowledge and to future knowledge (Ma, 1999; Seymour & Lehrer, 2006). In other words, teachers must not teach content of a specific grade in isolation, but rather have an understanding of the entire mathematics curriculum. Longitudinal coherence is therefore the connections made when a teacher reviews "crucial concepts that students have studied previously." (Ma, 1999, p. 122) and, knowing what the student is going to learn later, taking "opportunities to lay the proper foundation for it" (ibid.). Ball (1991) concurs with

Ma and calls for teachers to know “the relationships among…topics, procedures and concepts” (p. 7). This is the educator’s deep understanding of mathematical concepts which is crucial in making these connections.

In coding for these categories, I decided that the identification of prior knowledge cannot be *automatically* regarded as longitudinal coherence simply because, in most cases, prior knowledge was dealt with mainly in the first five minutes or so, and thereafter no reference was made to it. It must therefore not be regarded as irregular that I coded 38 educators as ‘identifying prior knowledge’ while only 11 as showing longitudinal coherence. These 11 educators referred back to prior knowledge *during* their lessons and *not only* in the first 5-minute clip. They also made references to work that they would be covering in future and that this day’s work would relate to that in some way.

For example, one educator linked the day’s lesson on 2D and 3D shapes to something she did with the learners two grades before, and at the end of the lesson asked them to collect objects which would be used in future lessons related to the one they just had. In another lesson on tessellation, the educator related parts of the current lesson (parallel lines of rectangle) to previous lessons in another learning area (have the same properties as parallel lines learnt about in geography). She also gave the learners a worksheet to complete which combined questions based on the present day’s work and on work done in previous lessons. These are just two examples, but they show how some teachers do not teach topics in isolation from other topics. This is the basis of longitudinal coherence. It must be noted that there could be times where the teacher was laying the foundation for future work that I perhaps have not identified, because it remained implicit. For instance, working with both sharing and measuring in division lays a necessary foundation for division by fractions.

More than one method shown

It is widely acknowledged that educators who have at their disposal a wide variety of teaching methods are able to promote greater understanding among their learners (Shulman, 1986; Borko & Putnam, 1995; Grouws & Schultz, 1996; Grossman, 1990;

Davis & Simmt, 2006; Simon, 1997; Ma, 1999). Teachers must also be able to encourage learners to try to solve problems in more than one way, by themselves demonstrating multiple ways to solving problems. In my analysis of the videos, I coded the following examples as "Teachers showing the learners more than one method to working out a problem":

- In 2 different lessons on area and perimeter, the educators first showed the learners the 'long way' of working out perimeter ($s+s+s+s$) and area (drawing 1 cm squares in the shapes and counting the squares). Once the learners showed a proficiency in this, the educators solicited an 'easier' method from them and eventually introduced the idea of the formulae for area and perimeter.

However, one could argue that this is simply guiding the learners towards one particular method, and thus is more about providing a conceptual underpinning for the preferred method. More straightforward was the situation where the teacher showed the learners that they could give their answer to long division problems either with a remainder or with a fraction.

Certain difficulties arose when the educators announced that there are two different methods to solving a problem, but I could not see the essential differences between the two. For example, adding two numbers such as 2 435 345 and 1 438 275 by taking each place value and adding them one at a time, and finally adding the seven sub-totals, is essentially the same as using the algorithm of writing the numbers one below the other and adding, starting with the units column. One educator however distinctly separated them into two methods, and for that reason I coded it as such – though I still doubt the fairness of this decision. One could argue that it is the same for s+s+s+s versus 4xs, but when two different operations were used, it would draw on different concept images for the learners and therefore I felt more confident coding this as two different methods.

The use of representations and examples

A lot of PCK literature refers to the power that educators wield when they are able to use an array of useful and appropriate representations and examples in their teaching (Shulman, 1987; Graeber, 1999; Seymour & Lehrer, 2006). This has been shown to have positive impacts on learner understanding, in particular when linking the representations to the mathematical concepts being taught (Grossman, 1990; Borko & Putnam, 1995). Most of the educators in the study used many examples in their teaching, but not as many used non-symbolic representations.

Many examples were related to the learners' own experiences to promote understanding. For instance, in a lesson on decimal fractions, the educators asked the learners to think of items from their homes which used decimal fractions such as 1,5 kg, 1,25l, 2,5kg and do on. The learners soon realised that items which they see and use everyday (1,25 *l* cool drink, 2,5 kg flour/sugar) use decimal fractions which they only now understood. In another lesson on 2D and 3D shapes, the educator come to class with a box filled with homemade prisms and pyramids. Each learner had to complete a table (number of faces, number of edges) by physically counting on the models. In this lesson, the learners were able to understand easier the differences between a prism and a pyramid.

Identifying and addressing errors and misconceptions

In terms of *identifying* errors and misconceptions, I looked out for specific questions and/or tasks from the educators which would have given an indication that the teacher had realised that the learners were experiencing any difficulties. These were then coded as 'identifying'. In one example, the educator asks the class to draw the (homework) angle on the board (S20W). After five minutes, he draws the angle on the board and turns to the class, asking," Have all of you written it like this? Raise your hands if you have written it like this." When the class did not respond, the educator realised that the learners did not do their homework and actually they, the learners appeared to have no idea what to do.

In other instances, I coded for 'identifying' as the educators walked around the class as the learners worked through an exercise. Here, the educators would stop and interact with the learners and discuss something from their answers. It must be noted that at these times, it was not always possible to hear what was actually being said between the learner and educator.

Not all situations of identifying errors or misconceptions could be located, as the teacher may well have engaged learners while working on a task individually or in groups. On the video, it is not possible to see or hear enough to know what form the interaction takes. However, I did give the educator the benefit of the doubt in these cases, on the assumption that the educator would not be discussing any other issue with the learners other than the task at hand.

Addressing misconceptions and errors was slightly easier to code than *identifying* was. The most obvious was correcting of homework at the beginning of the lesson. Here I coded for 'addressing' errors even though I may not have coded for 'identifying', especially where the educators simply called learners to the board to write down the answers to the homework. As I mentioned with *identifying* above, I also coded for 'addressing' often when the educator walked around the class as the learners were busy with an exercise. Event though I could not hear what was being said on many occasions, I assumed that the educator was in fact addressing something that was identified as a mistake or misconception. In one lesson, after the educator walked around the class a few times, he stopped all the learners and addressed a common error that he had noticed (the learners could not work out the cost of 3 pairs of shorts @ R15-00 each). This was an obvious case of identifying *and* addressing an error. It also lent credibility to my assumptions that the educators were in fact identifying and addressing errors or misconceptions as they walked around the class.

An important point to note is this: on many occasions, the educators would ask questions to the class, like: "What is 15 x 15?" or "What is 25 x 10 000?" When the learners called out the answers, the educator would ignore any incorrect answers and only acknowledge the correct answers. In these instances, I did *not* code for 'identifying' or 'addressing'.

A further indication of the difficulties I experienced during the coding of the videos is the fact that, initially, I had coded four (4) lessons where the educators had a zero rating for identifying errors/ misconceptions, but had a 'score' for addressing errors/ misconceptions. This apparent mismatch was not obvious to me at first. How can an educator address an error if he did not identify it in the first place? In one lesson, the educator asked the class to draw a grid of 1 cm squares, and reminded the learners not to use the lines of their books as these lines were not 1 cm in width. I coded this as *addressing* without identifying, because the educator made this statement *before* the learners begin their work. In another lesson, the educator seemed to ignore the source of the learners' errors and simply gave the correct answers to their incorrect ones. These two videos and a further two were viewed again and I subsequently decided to change my coding of them. I ended up with a situation where every lesson either had a zero rating for *both* identifying and addressing, or a score for both categories.

Learner opportunity to develop proficiency

Kilpatrick *et al*'s (2001) idea of mathematical proficiency has five strands: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning and productive disposition. Ideally, as students proceed from one grade to another at school, they should develop each of these strands and become more proficient in mathematics. These five strands refer to the following:

- Conceptual understanding, which is the comprehension of mathematical concepts, operations and relations;
- Procedural fluency, the skill in carrying out procedures flexibly, accurately, efficiently and appropriately;
- Strategic competence, the ability to formulate, represent and solve mathematical problems;
- Adaptive reasoning, which is the capacity for logical thought, reflection, explanation and justification; and
- Productive disposition, which refers to the habitual inclination to see mathematics as sensible, useful and worthwhile. (Kilpatrick *et al*, 2001, p. 116).

Coding for mathematical proficiencies was part of the bigger study, and has been engaged by another of the researchers (see Ally, forthcoming).[2] Here, I am only engaging it in the sense of learners working on an activity, either on their own or in groups. I made

[2] Unfortunately, this study is not yet complete; otherwise it would have been possible to assess the validity of my coding through inter-coder reliability. This will be engaged in the larger project.

no distinction with respect to what strand they were developing proficiency in, or any distinction regarding the quality of the activity, the extent to which it was indeed an opportunity to learn. The latter aspect has been addressed elsewhere as well (see Noubouth, forthcoming). So this code was in essence used to the extent to which the learners had time to work on their own and 'practice,' whether that practice was of a conceptual or procedural nature, problem solving or reasoning. Though I did not code for the different strands of proficiency, I did make some notes about it, but only in relation to the learners' opportunities to work actively.

There is great responsibility on teachers to engage their learners in mathematical activities which would address all strands of mathematical proficiency. Teachers need to design activities to help learners understand the mathematical concepts and ideas, and to engage students in learning. Classroom application and homework exercises are usually designed and given with the intention of review and practice, reinforcing knowledge of the lesson that had just been taught and helping the teacher to check for learners' understanding (An, 2004). In the videos that I studied, any form of classroom activity related to the day's lesson was coded as the teachers providing an opportunity for the learners to develop some sort of proficiency. This usually took the following forms: 1) an exercise that the teacher writes on the board, 2) a worksheet exercise given by the teacher, 3) learners being called to the chalkboard to work out (and explain) sums and problems and 4) any homework given by the teachers. In addition, any questions which the teachers asked to the class as a whole, or to individual learners, as well as when the learners were asked to recite the 13-times table, or to count in multiples of 3, 5, 10 and so on, were also coded as opportunities to develop mathematical proficiency.

My primary concern in coding learner activities as opportunities for proficiency was that I could not see the actual workbook of worksheet exercise that the learners were working with. I naturally assumed that it was an application exercise of the day's topic of the lesson. Because of this, it was difficult to ascertain the strand of mathematical proficiency that was being developed. As far as I could tell, from any questions that the teacher asked or from the chalkboard work, most of the activities focused of procedural fluency. I did experience difficulty in trying to determine if the other strands were being developed, insofar as I did not know what types of teacher behaviour would specifically develop these strands.

3.8 Validity and Trustworthiness of my analysis

As I have mentioned previously, the instrument which I have developed for the purpose of my study is by no stretch of the imagination the most comprehensive one there is. I have chosen to include categories which I felt would present opportunities for me to identify the specialised teacher knowledge central to PCK, though only as it manifested in the classroom interactions.

Due to the fact that I was part of a fairly large research team, there were many occasions when we coded several videos in a group. We did this until we had almost complete inter-coder reliability, but on occasion I did need to consult with my supervisor regarding boundary cases. However, the coding can and may have 'shifted' over the course of the process.

Quite fortuitously, it must be said, there were three teachers who were each recorded in two different classes and teaching two different lessons. This provided the ideal opportunity for me test for consistency of the teachers' PCK as 'measured' by my instrument. That is to say, do the teachers show the same 'levels' of PCK in all the classes they teach? If they do, then this could mean that teachers do in fact possess PCK, however varied their levels may be. If the same teacher's PCK is inconsistent from one class to the next, then several validity issues arise. This could raise questions like: Does PCK really exist? Are my categories of identifying PCK suitable? Was I consistent in my coding and analysis of the videos? Most importantly: if it turns out that my instrument was not measuring PCK only, but other aspects of teacher knowledge to a greater degree than PCK, then whatever I did measure was pretty constant over the lessons.

The figures below show the results of three teachers (A, B and C) who were recorded in two different classes and teaching two different lessons. Figure 1 and figure 2 show remarkable consistency in the categories of PCK favoured by the educators, as well as the frequency of these categories as a percentage of the lessons. The results for Teacher C (Figure 3) are not as consistent as Teachers A and B, but not significantly inconsistent as to suggest major flaws in my instrument or in the coding process. I am mindful, too, that my instrument and the codes may not have measured what they were intended to measure. For this reason, it should not be a surprise that Teacher C's results were different in the two lessons that I observed. Finally, it is of course possible that the PCK varied with the topic or simply that this teacher is not always teaching in the same way. Hill *et al* (2008, p. 376)) found in studies that PCK among mathematics teachers differ with respect to the topic being taught. For example, teachers who were familiar with students' problems with division of fractions experienced difficulty understanding students' problems with algebra. This suggests that PCK can indeed vary with the topic being taught.

In terms of validity however, I believe that these comparisons do to a degree strengthen my assertion that all teachers possess some 'level' of PCK, and suggests that I was quite consistent in my analysis of the videos. To some extent, it also lends credibility to the instrument I developed for the purposes of ascertaining the levels of PCK demonstrated by the teachers in the lessons analysed in this study.

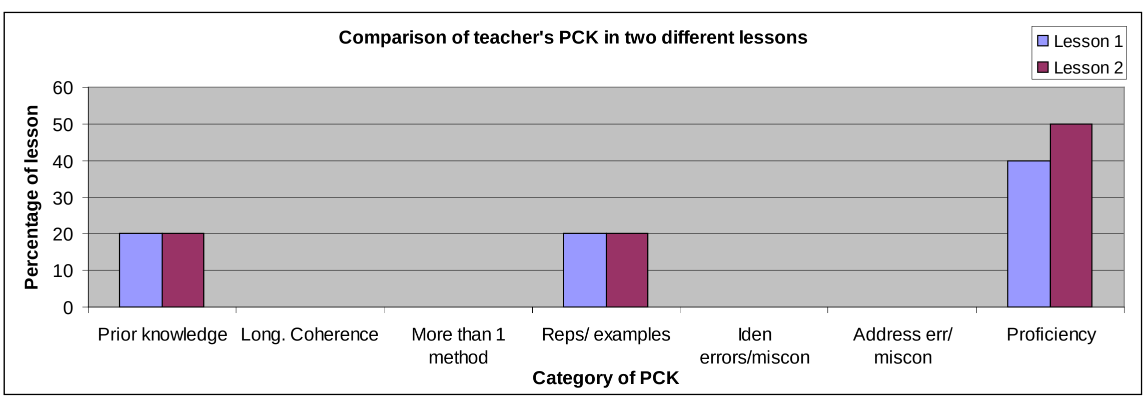


Figure 3.1- Comparison of Teacher A's PCK in two lessons

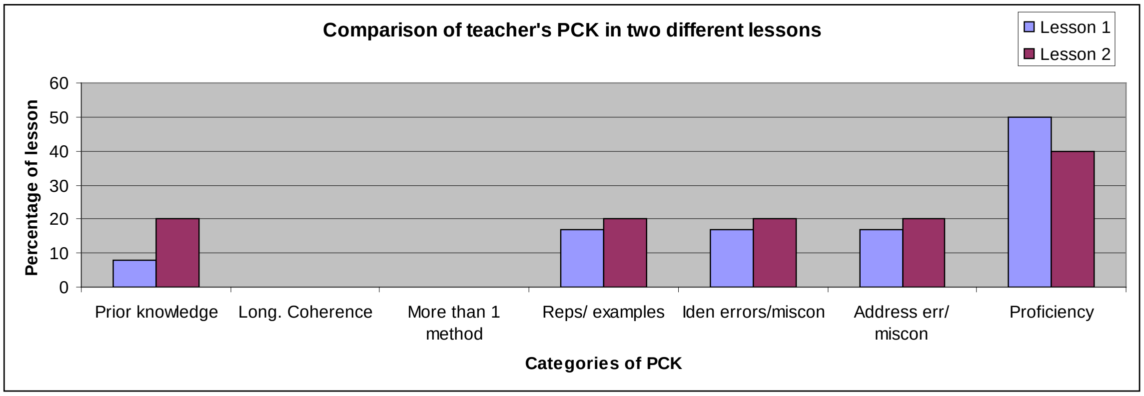


Figure 3.2 - Comparison of Teacher B's PCK in two lessons

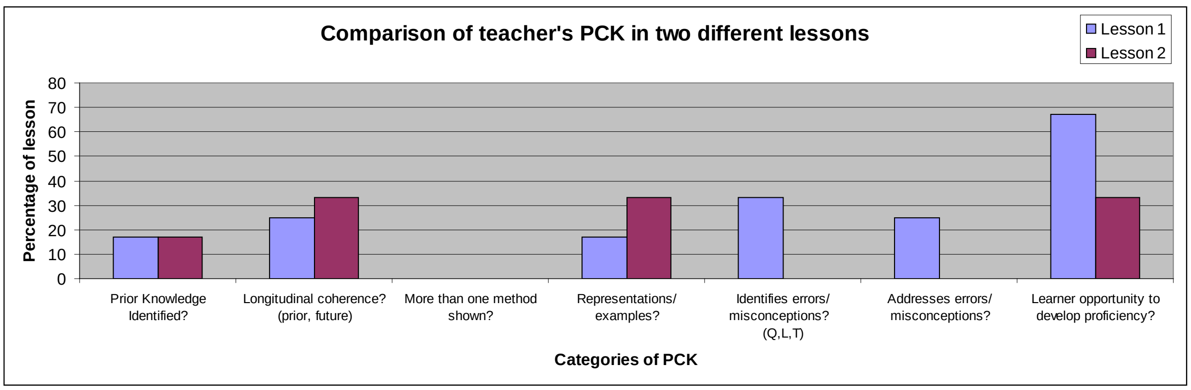


Figure 3.3 - Comparison of Teacher C's PCK in two lessons

Given these findings, I feel that the results of my codings are sufficiently valid that it makes sense to relate them to the remaining data in the study.

Chapter 4: ANALYSIS OF PCK CATEGORIES

In this chapter, I will describe in detail the video analysis of the lessons and especially the actions of the teachers. I have chosen to analyse certain categories of my PCK in conjunction with others which I felt were related in some way. For example, identifying prior knowledge and longitudinal coherence were combined, due to the fact that both categories deal with the connections that teachers make in their teaching. When both categories are represented in one graph, it is very easy to see how many teachers try to connect learners' prior knowledge to the present day's lesson and how many teachers connect new knowledge to learners' prior knowledge and lay the foundations for their future knowledge.

My data set comprised 42 videos in total, but three educators appeared in two videos each. This therefore means that I analysed the teaching of 39 teachers. The two lessons of each of those teachers were in different classes and the educators taught different lessons in each class. For my purposes, I decided that the fairest way to proceed was to find the average of these teachers' 'scores' and represent them just once in my analysis. As discussed in the previous chapter, this only made a difference in the one case, as their PCK codings were quite similar across classes.

Identifying prior knowledge and connecting to prior and future knowledge (Longitudinal coherence)

According to Figure 4.1, 90% (35 of 39) of the teachers in this study spent time identifying the learners' prior knowledge before going on to a new or another section of work. This usually took the form of introductory questions, such as "What are 2D/3D shapes?", "Do you remember the 3 types of common fractions that we did last week?" or the correction of homework given in the previous lesson which would lead on to the current lesson. Most of the educators did not spend too much of time on this. On average, teachers spent 13.4% of the lesson (an average of 6 minutes, at the beginning of the lesson) going over aspects of work previously covered. 10% or 4 teachers in this study did not spend any time on this, but rather went directly into the day's work.

At least 11 teachers (28%) spent 20% or more of the lesson (ie 29%, 33% and 43%) going over previously covered work. The reasons for this varied: one lesson was used exclusively for revision of term 3 work, to prepare the learners for the upcoming tests, while another educator seemed to experience great difficulty in trying to explain the addition of mixed fraction to his learners, and had to keep referring to a previous exercise in order to ensure the learners understood.

11 educators (28%) spent any time on what I considered to be longitudinal coherence. Many of the lessons covered topics which the educators did in isolation, and no connections to prior or future knowledge were even hinted at. One educator stood out in this respect, however. She linked the lesson on 2D and 3D shapes to something she did with the learners two grades before, and at the end of the lesson asked them to collect objects which would be used in future lessons related to the one they just had.

28 educators, or 72%, made no connection to previous or future lessons or sections. All their lessons were done in isolation. Again, a possible reason for this could be that the educator may have abandoned his normal lesson plan to prepare a particular lesson for the purpose of being video-recorded, but that would not exclude making references to previous learning. Another consideration is that in some schools, a teacher teaches only one grade, and therefore does not know what was covered in previous grades. This, however, does not exclude making links to content covered previously in the same grade. Thus it is fair to say that when no continuity could be discerned, it is possible or even likely that this reflects the teacher's practice.

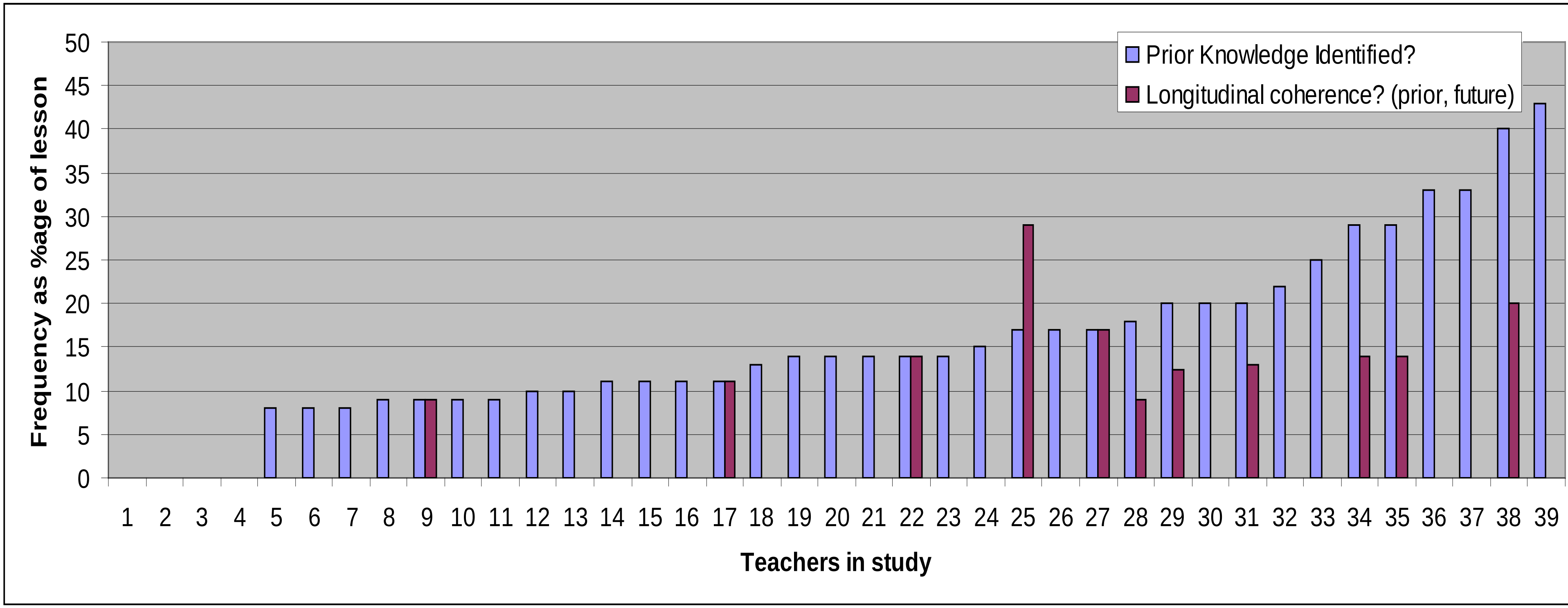


Figure 4.1: The frequency of connections via prior knowledge and longitudinal coherence for each teacher (numbered).

Multiple methods to a solution and the use of varied representations and examples

Figure 4.2 shows that while most of the educators used representations and examples of some sort in their teaching, very few educators explained key ideas in various different ways or showed learners more that one method to arrive at a solution.

Of the 39 educators studied, only 5 (13%) showed their classes more that one method of arriving at a solution. These included for example, a long and then short method of simplifying fractions; addition of large numbers using two methods; and working out the perimeter of a square using (first) the formula $s+s+s+s$ and then the shorter *side x 4*. While these examples may not blow most people away, some learners were indeed excited to discover that there was more that one way of arriving at a solution.

As I have mentioned previously, there were certain cases which filled me with doubt and may have skewed my analysis somewhat. In a lesson entitled "Adding fractions with unlike denominators", the educator gave the class an example: $\frac{5}{4}+\frac{3}{5}$. He then used an algorithm to work out the lowest common denominator (LCD), and got $\frac{25}{20}+\frac{12}{20}=\frac{37}{20}$. After he was satisfied that the learners understood this, he told them that there was *another method*. Once again, he wrote $\frac{5}{4}+\frac{3}{5}$, and in the next step $\frac{(\ +\ )}{20}$. Then he asked the learners "4 into 20, how many times? 5 times - so you multiply the numerator by *that 5* and you get 20. He repeated the procedure with the next fraction until he arrived at $\frac{(25+12)}{20}$, and eventually the same answer as previously. I did not code this as being 'multiple methods to arrive at a solution' because I felt that they were essentially the same thing and not two different methods.

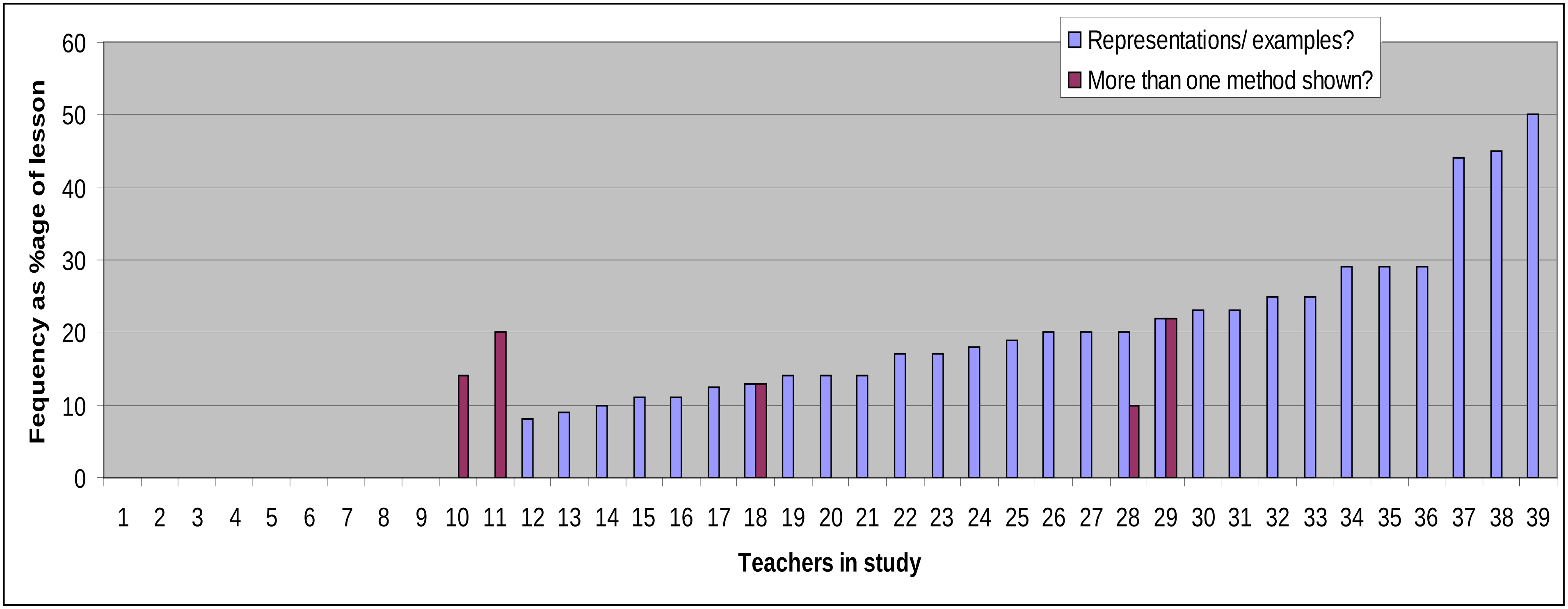


Figure 4.2: The number of teachers who used representations and examples, and more than one method in solving problems.

The use of representations and examples was more widespread than was a variety of methods, but again only an average of 16,1% of a lesson was utilised this way, by 74% of the educators. Examples were more widely used than representations. Many educators cited everyday examples to enhance learner understanding of concepts like perimeter (walking around a soccer field), tessellation (puzzle pieces fitting together), units of measurement (1,25 *l* cooldrink, 500 g block of margarine) and so on. Representations were scarce indeed, with only 4 teachers of the 39 using representations during their lessons. One educator stood out here, with her vast collection of 3D cardboard prisms and pyramids to help learners get to grips with the shapes and properties of these figures.

23% (9) of the educators failed to use any form of representations or examples in their teaching, and these same 9 educators did not show their learners more than one method to arrive at a solution. The topics for these lessons included additive inverse, units of measurement and multiplying by 10, 100, 1000 and 10000. As concept images are constructed as much if not more through examples as through definitions and rules, this is a worrying finding which needs further investigation.

Identifying and addressing errors and misconceptions

Nearly half of the educators in the study made an attempt to identify learner errors or misconceptions, and used an average of 8,2% of their lesson time to do so. These educators either asked questions of the learners or gave them tasks to complete. Most often, the educator would walk around the class as the learners completed an activity. At this time, the educators would usually stop and ask learners to explain how they arrived at a solution. Some interaction would take place and the educator would move on to another learner. It was often unclear whether the educators did in fact identify an error or misconception, especially if he did not continue to interrogate the learner in question. Poor sound quality (at times) and an inability to understand isiZulu also hindered my complete understanding of the educator-learner interactions.

The other half of educators showed no discernible attempt to identify the errors or misconceptions made by the learners. In other words, the educator did not ask questions of the learners regarding the topic for the day, either while at the board or while walking around monitoring the learners' progress as they worked at an exercise.

Figure 4.3 shows that the results for educators addressing learners' errors and misconceptions are identical to identifying them. 50% of the educators addressed, or tried to address, the situation when a learner made an error. This usually took the form of further questions until the learner realised his error and solved the problem himself. Another method of addressing any problems was the educator walking form learner to learner as they completed an activity, and assisting learners in obvious distress. There were even a few instances where an educator simply gave the correct answer after the learners failed to do so - this was not regarded as addressing the error/s, however.
The other half of the educators did not attempt to address the misconceptions or errors made by learners. In fact, of the 39 educators that I viewed on tape, I made the following notes:

- Educator does not correct learner error despite opportunity to do so - 12 times
- Educator ignores wrong answers and only acknowledges correct answers - 8 times
- Unclear/ not sure if educator addresses misconception or error - 5 times
- Educator simply gives the correct answer - 6 times

Too often, in my view, an educator would ask a question, receive a wrong answer, simply ignore the learner's wrong answer and move on until he/she got the correct answer or explanation. The learners who made the error were forgotten. Many educators, after several failed attempts, simply gave the correct answer to an incorrect one and moved on, without explaining to the learners why their answers were wrong.

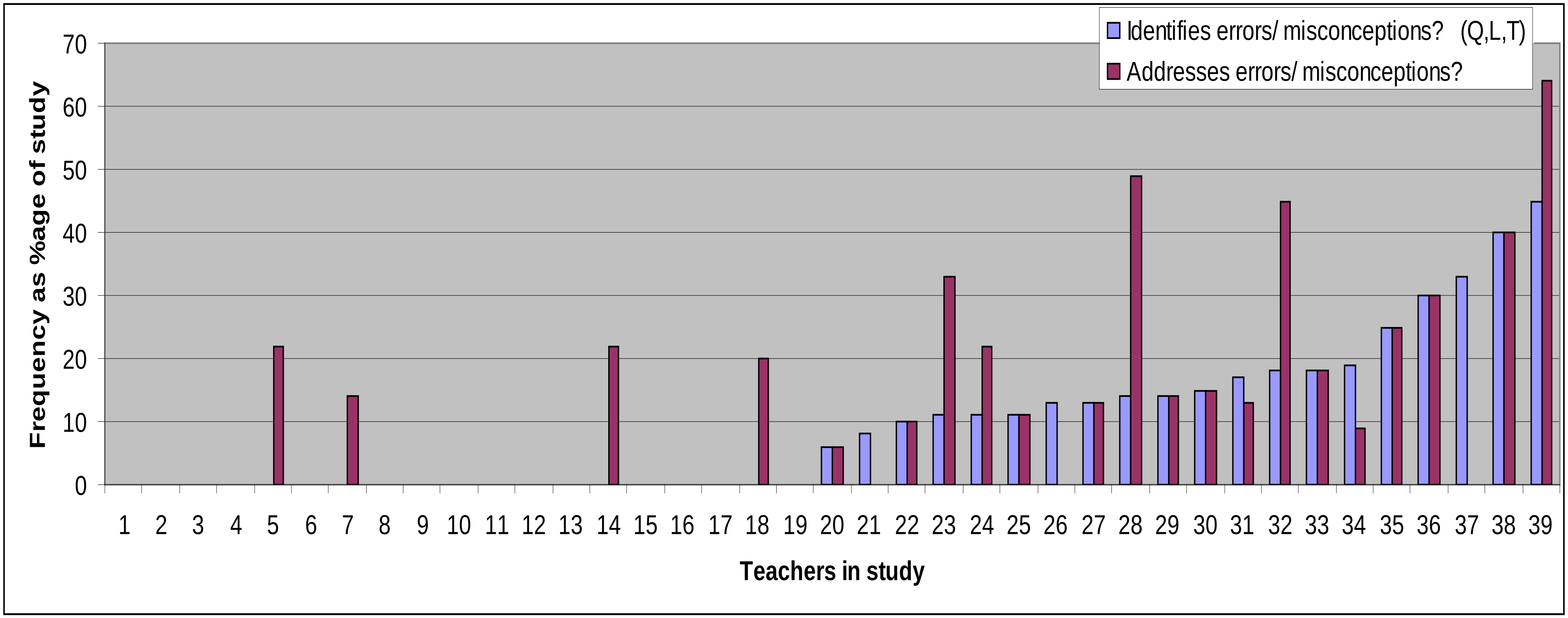


Figure 4.3: The number of teachers who identified and addressed errors and misconceptions.

Learner opportunity to develop proficiency

Figure 4.4 shows that in the 39 lessons studied, the learners spent an average of almost 45% of their lessons engaged in some activity. Many of the educators favoured calling learners to the front of the class to demonstrate on the chalkboard how to complete an example or work out a problem (observed 18 times in the 42 videos - in some lessons, observed 2 or even 3 times). The rest of the time, the learners were engaged in either a worksheet or workbook activity. This usually started around mid-lesson and went on to the end of the lesson. The activities often appeared to be designed to help learners gain proficiency in the section that they had just been taught, in particular procedural proficiency. During the course of the lesson, it was common for the educator to walk around, monitor progress and assist where and when necessary. Before the end of the lesson, the educator would explain the homework to the learners. This was usually another exercise/activity related to the day's lesson.

Although my analysis of the videos did not extend to the five different strands of mathematical proficiency (refer to chapter 3: Coding the videos), it is interesting to note that most of the learners were engaged in activities designed (either inadvertently or not) to develop their procedural fluency. This refers to the skill in carrying out procedures flexibly, accurately, efficiently and appropriately. For example, the educator would ask the class to count in multiples of 2, 3, 5 or 10, (and even 1000!) in unison. Or he would ask them to recite the different types of graphs covered in an earlier lesson. In unison ("There are three types of graphs - bar graphs, pie graphs and line graphs!"). Or she would ask the learners to practice long division in their workbooks. These types of activities are also typically associated with lower levels of cognitive demands of mathematical tasks, commonly known as *memorization* and *procedures without connections*. Memorization is the recollection of facts, formulae and definitions; while procedures without connections involve performing algorithmic type of problems and have no connection to the underlying concept or meaning (Stein *et al*, 2000). This is explored further as part of the larger study.

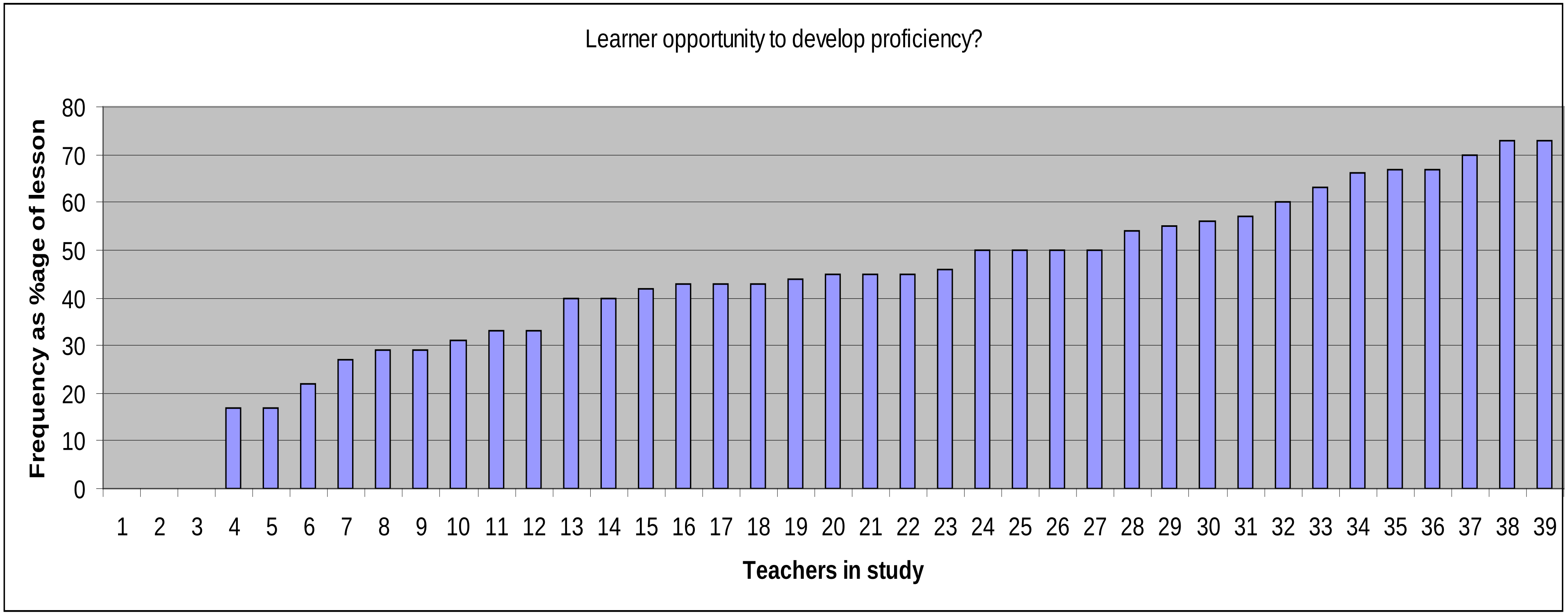


Figure 4.4: The percentage of the lessons used by teachers to develop learner proficiency

It is also worth mentioning that there were lessons, albeit very few, in which the learners enjoyed the lesson to such an extent as to suggest that they were developing a productive disposition towards mathematics. These included a lesson in which the learners were given models of prisms and pyramids and were able to explore the properties of the shapes and the relationships between them. Another lesson saw the educator getting the entire class involved in measuring - using different methods and instruments (including their shoe sizes!) - the length of the classroom floor, the height of the cupboard, bookcase and so on. It was my opinion - from observing the engagement on the video - that the learners in these classes found mathematics to be worthwhile, useful and actually very enjoyable.

There were three lessons which I coded as zero for this category. In one 35-minute lesson, the educator introduced the topic of measurement, moves on to units and explained terms (length, height, width, distance, depth) to the learners. The educator then gave each learner a blank page and asked them to fold the pages into 4 quadrants, in each quadrant to write down mm, cm, m and km. Following this, the educator spoke exclusively in isiZulu for the last 5 minutes of the lesson before the bell rang. The lesson ended and the learners did not do any activity other than folding their paper. In another, 18-minute lesson, the educator stood at the board and discussed lines, line segments and rays, all the while drawing examples on the board. The lesson ended with the passive learners engaging in no discernible physical task. No questions were asked which could have opened the doors to mental engagement, and which would then be seen as a strand of proficiency. In the third zero-rated lesson, the educator spoke about data collection and types of graphs for the entire lesson, a total of *fifteen* minutes. A few questions were asked of the learners, regarding types and uses of graphs, but no formal exercise was given for classwork or for homework.

Progression (Sequencing/pacing) of lesson

As mentioned in the previous chapter, I did not represent progression of the lesson as a percentage of the lesson. I did however, state if sequencing and pacing were in fact present (*contributing to a higher PCK score) or* not present during the course of the lesson. Most of the educators began their lessons with either a recap of the previous day's homework, and then moved on to the present day's work. There was often a clear pattern: introduction to the topic, some simple examples on the chalkboard, then more complex examples, and then a classwork exercise.

There were 4 lessons which I coded as "*not present*" for sequencing or pacing. In the first lesson, the educator spent very little time on the different parts of the lesson. The lesson was devoted to circles. Here, the learners were asked to draw six concentric circles, then draw a pattern in these circles and colour in their patterns. There was no progression from simple to difficult in terms of complexity or otherwise of the work allocated to the learners. Another lesson was entirely revision of term 3 work, in preparation for the September tests. Again, there was presence of pacing ie. the educator did use more-or-less equal amounts of time per revision section, but no progression with regard to complexity. In the third lesson, I coded as *not present* because the learners were given 45 minutes to complete just 5 sums - adding fractions with unlike denominators. Once again, I could not discern an increase in the complexity of the learners' work. This, coupled with what I believed to be poor pacing of the lesson in the sense that no concepts were introduced and the content was insubstantial, earned a *not present* coding. The final lesson to be coded *not present* for sequencing/pacing was a 15 minute lesson in which there was an almost total lack of structure. The educator spoke for the entire 15 minutes, there was no learner participation or activity, and the lesson seemed very contrived.

Summary of Analysis of videos

This chapter has been a description of my analysis of the 42 videos in my study. I went through each PCK category in turn, showing how my coding of the categories facilitated the analysis. In summary, it is clear that the presence of PCK in the observed classrooms was rather limited both qualitatively and quantitatively. The opportunity to develop proficiency, the use of examples and some engagement with learners' prior knowledge though mostly in the form of checking homework were the areas most prevalent. The focus was mostly on procedural aspects. Only a minority of the teachers used representations, showed more than one method, displayed longitudinal coherence or engaged in more substantial ways with learner thinking (misconceptions and errors).

It remains to be seen to what extent it was the same teachers displaying the latter characteristics or if the PCK profiles of the teachers were more varied. I will engage this in the next chapter. It also remains to be seen to what extent the presence of PCK in the teaching correlated with teacher background variables and learner performance. This will be engaged in my final chapter.

Chapter 5: TEACHER PROFILES

Chapter 4 described my analysis of 42 video-recorded grade 6 mathematics lessons from schools in KwaZulu-Natal, which I intend to use to get a picture of the teachers' mathematical pedagogical content knowledge (PCK). With the results derived from my analysis, I hope to be able to formulate some sort of measure, if at all possible, of the teachers' demonstrated levels of PCK and determine if there exists a relationship between teachers' PCK levels and their learners' mathematical achievement.

It would not be a true reflection of the teachers' PCK if I considered only their actual teaching in the classroom, since PCK is considered to be what a teacher *knows, does* and the *reasons* for his actions (Rohaan, 2009). In this chapter, I will examine the teachers' background information and their test results to draw up a PCK profile for each teacher. Using these profiles, I will try to link their PCK to the learners' test results to try to determine if teachers' PCK affects learner achievement.

Teacher Biographies

The teachers' biographical information was collected via the teacher questionnaires during the data collection phase (see Chapter 3). This information revealed details of their education and training and I will include only the most pertinent aspects here. More than two thirds (69%) of the group had been teaching for 11 years or more. Two of the teachers had 1 year of teaching experience, three had 2-5 years experience and four had 6 – 10 years of teaching experience. Two teachers did not answer the question about their pre-service professional teacher training. Eighteen of the teachers had passed Grade 12 without exemption/endorsement and fourteen had passed with exemption. Two of the teachers had no teacher training, four had one year of teacher training, 5 had two years and 8 (25%) had three years of teacher training. Forty percent or thirteen teachers had more than three years of teacher training. More than two thirds of the group (72%) said that they felt adequately prepared to teach the current mathematics curriculum. However, 33% had not been on any in-service training courses that were specific to mathematics. In terms of support from the provincial DoE (Department of Education), 73% of the teachers said that the mathematics curriculum developer or subject advisor had not visited their classroom during 2008. Four teachers (12%) reported that they had received one visit in 2008, two had been visited twice and one teacher reported more than two visits.

This information paints a quite bleak picture of the state of preparedness of the mathematics teachers in terms of education, training and support. If 11 (28%) of the teachers in this study had less than three years of teacher training, which is the minimum requirement, and 13 (33%) had not had specific mathematics training, what then can we expect the learners' mathematical gains to be? What can we expect of our educators if they, being under-qualified and under-prepared, do not receive adequate help and support from curriculum developers or subject advisors? The obvious answer is, not much.

Teacher Test results

There were 24 questions/items in the teacher's test. Each item was a common error made by children in primary mathematics. The teachers were asked to diagnose these errors by answering multiple choice questions.

Figure 5.1 shows the frequency of scores from the respondents. 3 teachers got less than 10% of the questions correct. 8 out of the 34 respondents got more than half of the questions correct. The highest scoring respondent got just over 2/3 of the questions right. One can of course question to what extent this is representative. But as the teachers were chosen using stratified random sampling within one district which we suspect is amongst the better performing in the province, it is fair to assume that these results are at best representative but more likely slightly above how the grade 6 teachers in the province would perform overall.

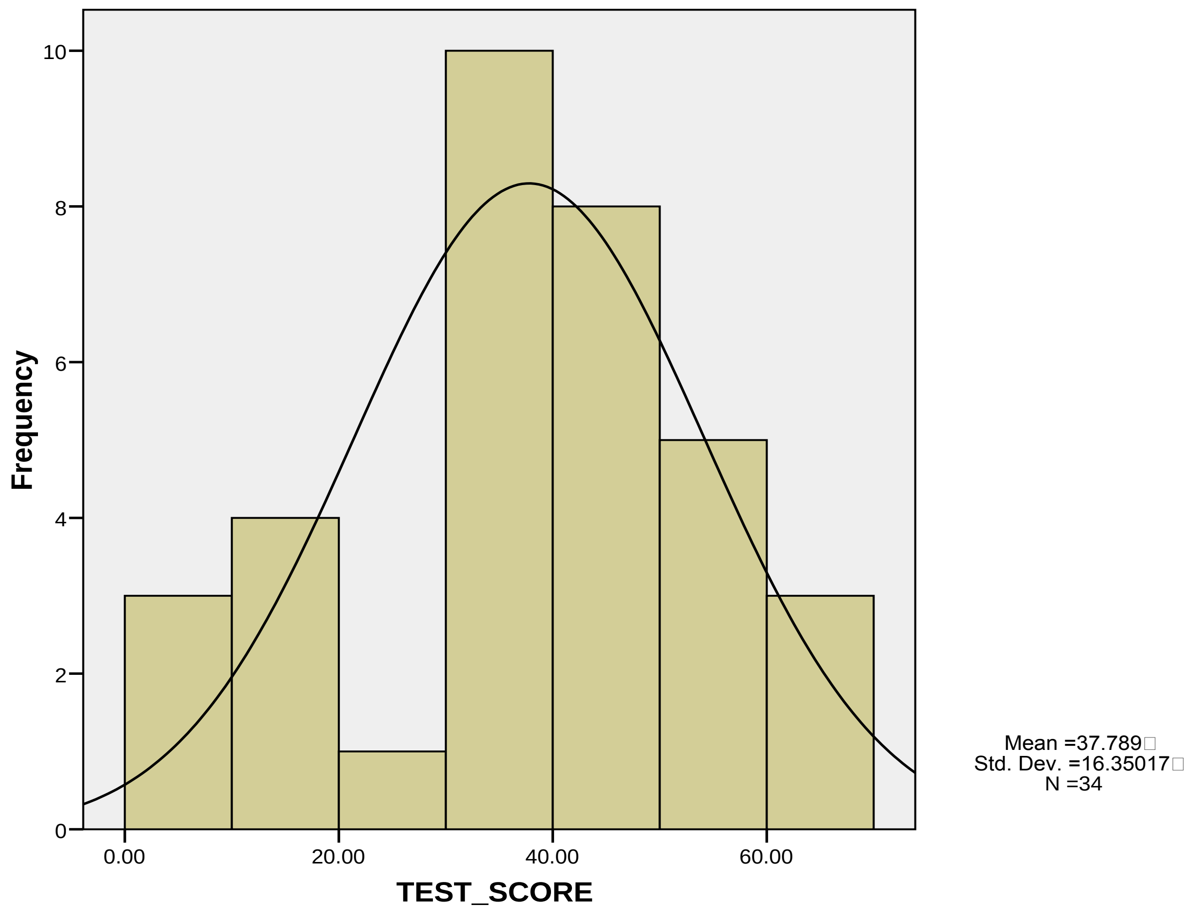


Figure 5.1: Distribution of teachers' test score

We still need to interrogate these data further, looking at the content areas, the mathematical versus the pedagogical content knowledge, and the procedural versus the conceptual.

Summary of Teacher test results for PCK questions

At the outset, I want to stress that my analysis of how the teachers responded to the PCK questions on the teacher tests was only added here to supplement my study. It is not something I engaged in any depth, but I hope to do so in a further study.

Of the 24 test items, six were identified as dealing with teachers' PCK. Table 5.1 (see Appendix) is a summary of the teachers' responses to the PCK items in the teacher test.

The last column - percentage correct - refers to the percentage of teachers who actually chose the correct answers to the test items. This percentage is calculated of the total number of teachers who took the test. The PCK items focused on teachers' knowledge of learners' conceptions of perimeter and of place value, the use of representations and learners' conceptions of fractions and addition of fractions. These types of learner errors go to the heart of trying to assess teachers' deep understanding of the mathematical content, as well as the way learners understand mathematical concepts. This is believed to be central to PCK (Jordan *et al*, 2008; Ma, 1999; Shulman, 1986).

Of the test's PCK items, there is a wide range in the percentage of correct responses, with the highest being 71% and the lowest being 12%, at an average of 45%. This to me is alarming: the fact that, in this study, less that half of the teachers demonstrated acceptable levels of PCK in mathematics, as measured by the test. However, these figures are subject to a small increase when one considers that only one question in the entire teacher test had a 100% response rate.

These figures do suggest that, while PCK does exist as a form of observable teacher knowledge, the teachers in this study exhibited rather low levels of this specialised form of knowledge. However, a problem with multiple choice questions is that they do not provide an opportunity for the educators to *explain the reasons* for their choices. Some of the educators could have used an elimination process for the answers that they chose. Yes, this would have required the teacher to actually work out the learners' answers to figure out what they did right or wrong, but PCK also requires the teacher to articulate their reasoning. Without this verbalization, we have an incomplete understanding of the teachers' PCK.

Teacher PCK Profiles

In chapter 3, I endeavoured to provide a certain degree of validity to my PCK instrument, and to the coding process I used in my analysis of the 42 videos. I am quite confident that I managed to do that. Using this instrument and applying the coding process as consistently as I could, I decided to create a PCK profile of each teacher, to get a pictorial view, as it were, of the kinds of teachers in my study. The rationale behind this was that this would enable me to understand what behaviours are common among the educators. This was extremely difficult because it required making judgment calls about which categories of PCK are strong and which are weak. For example, almost all the educators attained high 'scores' for proficiency but I have since debated the importance of this category in the PCK concept, and have decided that proficiency should not be considered very highly with regard to teachers' PCK rating.

The type of representation I settled on was the radar, a kind of 'spider-web' diagram which displays changes in value relative to a central point. The filled radar shows the area covered by a data series. Below are examples of filled radars:

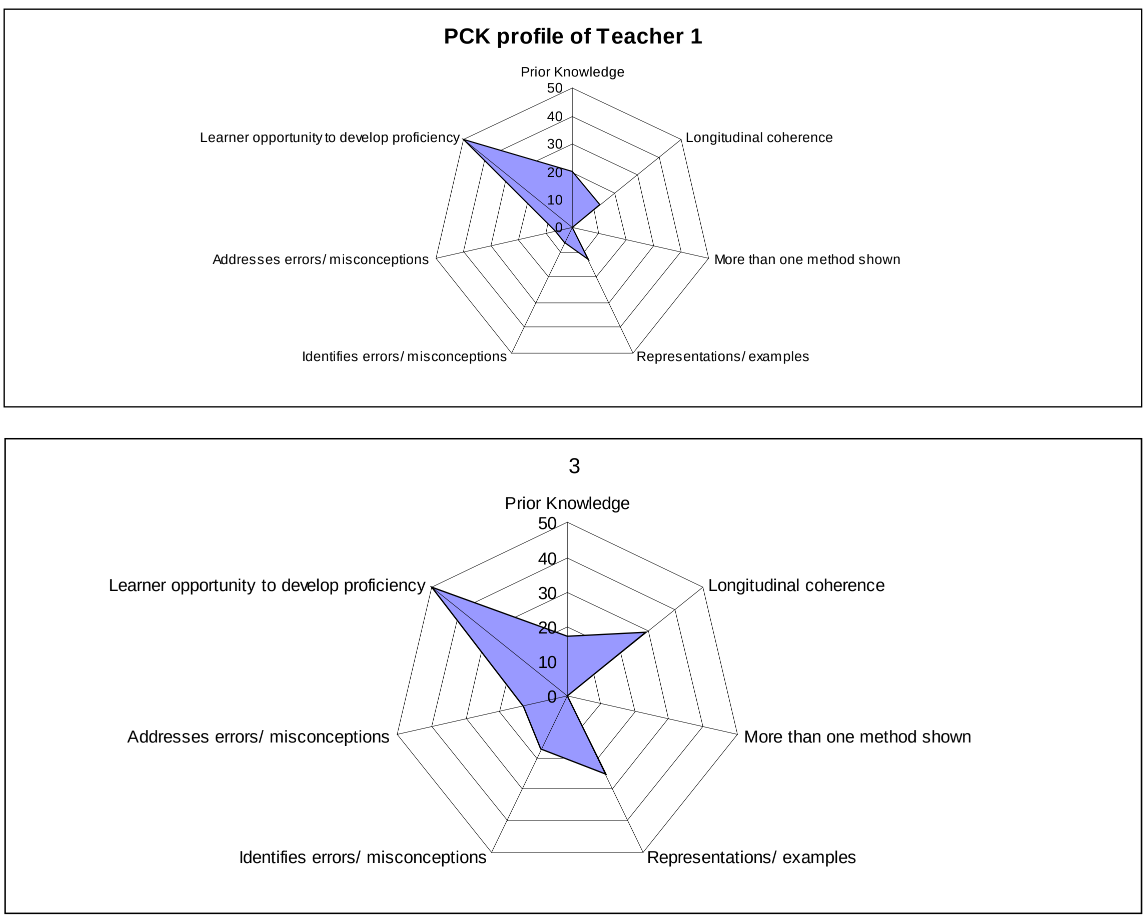
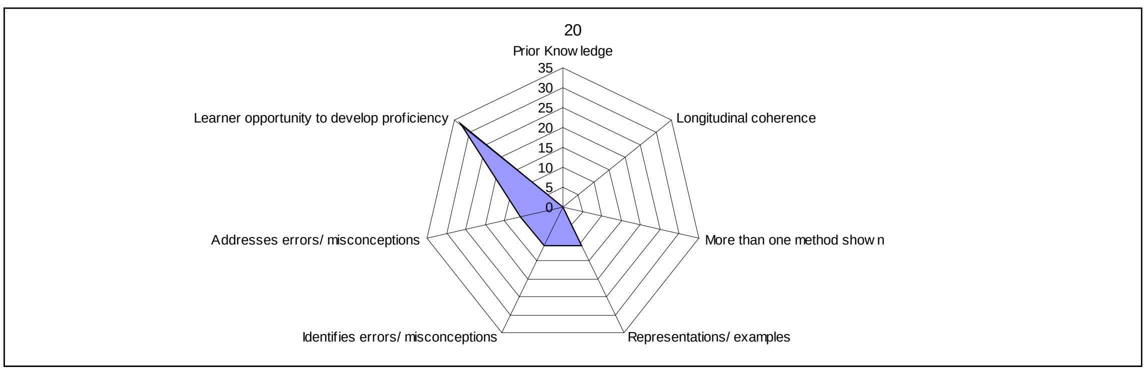


Figure 5.2- Examples of PCK profiles of teachers

These representations give the reader a quick visual appreciation of the categories most frequently favoured by the teachers in relation to each other, and their frequency of use during a lesson. The shaded area forms a shape based on the frequency of each PCK category as indicated in the table used in my analysis. The larger the area formed by the shape, the higher the frequencies of the categories, and vice versa. This allowed me to place the teachers in groups based on their profiles.

After creating a profile for each of the 39 educators in my study, I decided to place these teachers into 2 'groups' based on these profiles. Using the arbitrary codes 1 and 2, with 1 being teachers with 'low PCK' and 2 being those teachers with 'high PCK' levels, I coded each of the teachers according to their profiles of PCK. The following are the 2 types of profiles, their codes and an explanation of why the teachers fall into each group.

PCK Profile- Code 1 (low PCK)



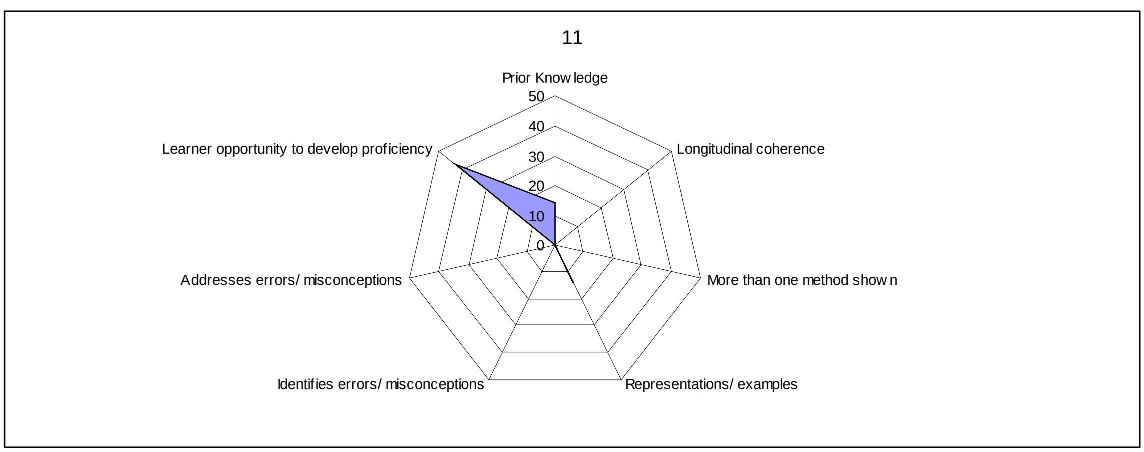


Figure 5.3- Examples of profiles of teachers coded PCK 1

Figures 5.2 shows two examples of the PCK profiles of teachers who fall in group 1. After a lengthy and rather difficult judgment call, I have decided that the lessons of 26 educators of the 39 in my study reflected low PCK levels. There were many variables that I had to consider before deciding on these groupings. First, I had a look at the relative frequencies of the other categories present in each teacher profile. If these frequencies were not high, relative to the frequency of the other categories, then those educators would also be regarded as exhibiting low levels of PCK. That is to say, the educators did not show or use these aspects of PCK for a significant part of the lesson that I observed. The second consideration was the total number of categories present in the teachers' profiles. If a teacher has a very high percentage for a category, but the teacher had scores for only two categories, then that teacher too would be regarded as having low PCK.

PCK Profile – Code 2 (high PCK)

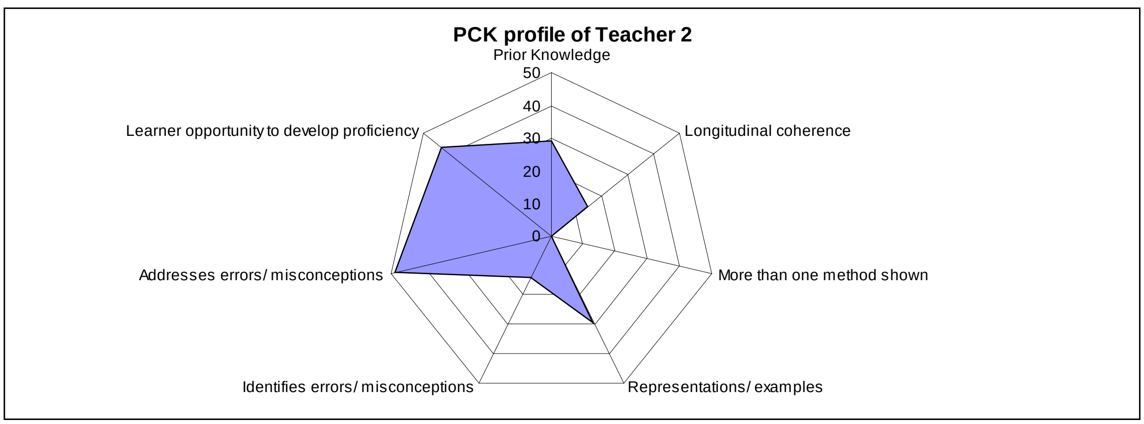


Figure 5.4- Example of profile of teacher coded PCK 2

Figure 5.3 is an example of a PCK profile of a teacher with a code 2. In my study, 13 of the 39 educators whom I believe have demonstrated high levels of PCK, fall under this group. Teachers with Code 2 PCK had either 5 or 6 of the seven PCK categories filled in (no teacher had all 7 categories filled in), and also spent a greater amount of time on the various categories, hence the larger shaded area when compared to those educators who fall under group 1. These teachers in group 2, even though they spend time on developing proficiency, also pay attention to the other categories which I regarded as being more important in determining a teacher's PCK status. Categories such as prior knowledge, misconceptions/errors, representations and longitudinal coherence, deal with student understanding and thinking, and provide greater evidence of a teacher's repertoire and ability to enhance student understanding.

Linking teachers' PCK to other variables

Using my PCK instrument, I analysed the 42 videos as meticulously as possible and finally settled on a tentative PCK 'score' for each of the 39 teachers. 26 teachers (67%) got 'low PCK' score (Code 1), while 13 (33%) received 'high PCK' scores (Code 2).

This however was just the first level of analysis of the teachers' PCK based purely on what I had observed and believed to be reliable indicators of PCK. Next I decided to try to link my PCK groups to the other variables in the larger study, to see if any correlations exist between them. I had a few questions and theories in mind: 1) What is the relationship between teachers' PCK and their test scores (and hence their content knowledge)? 2) What is the relationship between the teachers' qualifications and their PCK? 3) What is the relationship between teachers' PCK and learner mathematical gains? I would also have liked to interrogate the link between the teachers' theoretical and their practical PCK, but due to time constraints I could not do so here. This is an area for further study in this field.

Teacher PCK and teacher test

Although I earlier described the teachers' results of the PCK questions of the teacher test (Chapter 5), I believe that overall the teacher test focused mainly on the teachers' content knowledge. I used the PCK results to group the teachers into 'high' and 'low' PCK groups. The next step was to try to determine if the teachers' content knowledge correlates with their PCK, and this required some statistical analysis. Using my codes, this was completed by the statistician in the project, Yougan Aungamuthu.

When we entered the teachers' test scores next to their PCK scores (either 1 or 2), we discovered that only 26 of the 39 teachers in my study had written the teacher tests. This rang some alarm bells with regard to validity, because the sample size did seem small and results might have become skewed. We continued with the statistical analysis, but the results which follow must be read with this in mind.

In order to find any relationships between the different variables in the study, we used ANOVA. ANOVA is an acronym for ANalysis Of VAriance. The purpose of ANOVA is to test for significant differences between means. In general, in order to test for statistical significance between means, we are actually analysing variances. The variables that are measured (in this case the teachers' test scores, learners' test scores and teacher education) are called *dependent variables,* while the variables that are controlled (teachers' PCK scores) are called *factors* or *independent variables*.

A quick look at the mean for each PCK group suggests that teachers in the PCK group 2 (high PCK) scored better on the test than those in PCK group 1 (low PCK).

Group Statistics

	PCK group	N	Mean	Std. Deviation	Std. Error Mean
Mark percent	1.00	16	41.9643	20.21110	5.05278
	2.00	10	60.6349	11.44130	3.61806

A one way ANOVA was used to test the null hypothesis, that the means of the PCK groups are equal, against the alternate hypothesis that the PCK group means are not equal.

ANOVA

Mark_percent

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2145.185	1	2145.185	7.047	.014
Within Groups	7305.461	24	304.394		
Total	9450.646	25			

From the ANOVA table above, the null hypothesis is rejected. That is to say, the teachers in PCK group 2 scored significantly higher on the teacher test than teachers in PCK group 1. This suggests that good content knowledge is a necessary condition for good PCK.

Teachers' PCK and learner test scores

From an early report of the larger study, we know, statistically, that students scored better on the second test than on the first.

We first looked at whether there was a difference in learner scores of the two PCK groups on the Learner Test 2 (LT2).

ANOVA

SCORE_LT2

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	195.643	1	195.643	.891	.346
Within Groups	279671.337	1273	219.695		
Total	279866.980	1274			

The table above says that there is no significant difference in the learner scores of the two PCK groups on LT2.

We then tested whether the gains, from learner test 1 to learner test 2, was different for learners from the two PCK groups.

Test Statistics (a)

	Test_gain
Mann-Whitney U	41821.500
Wilcoxon W	56356.500
Z	-1.595
Asymp. Sig. (2-tailed)	.111

a Grouping Variable: PCK

The previous table says that, once again, there is no significant difference between learner gains, from test 1 to test 2, between the low and high PCK groups. In other words, the suggestion is that teachers' PCK does not significantly affect learner mathematical gains.

This is contrary to what previous research would lead us to expect and suggests that other factors must be more significant determinants of learner improvement. I will discuss this further in the next chapter.

Teacher qualifications and PCK

The teacher questionnaire created a problem in this section, because in terms of qualifications, the questions required details of secondary school education, pre-service professional teacher training and professional teaching certificate, diploma or degree. The responses threw up a real mixture of qualifications and deciding which the most appropriate qualification was, to test for teachers' PCK, proved rather difficult. In short, this is what Mr. Aungamuthu could extract:

In Group 1 (low PCK, n=16): 11 of the teachers stated that they have a professional teaching qualification, 9 teachers possess academic qualifications and 16 educators have attended mathematics-specific in-service training courses.

In Group 2 (high PCK, n=10): 9 educators are in possession of a professional teaching qualification, 8 teachers have an academic qualification and 9 have attended mathematics-specific in-service training courses.

It appears that the teachers in Group 2 are more likely to have a professional teaching qualification or an academic qualification, but the results were not significant.

I will discuss these and the findings from chapter 6 in my final chapter.

Chapter 6: DISCUSSION

In this chapter I will discuss the findings of each of the PCK categories, which are intended to provide a clearer picture of the levels of PCK demonstrated in the lesson recordings of the 39 teachers in my study.

Teachers' practical PCK

All teachers in this study possess degrees of a specialised type of knowledge known as pedagogical content knowledge (PCK), whether they are aware of it or not. The exhibited levels of PCK vary from one teacher to the next, and it is believed that many factors contribute to this. These factors may include formal and informal teacher education, which is responsible for the subject matter (content) and curriculum knowledge of teachers, training, which is important for the general pedagogical knowledge of teachers, and experience. However, the analysis did not reveal any correlations between level of PCK as per my analysis and educational background of the teachers. Further analysis is needed to interrogate this.

Identifying learners' prior knowledge and longitudinal coherence

The vast majority of teachers in the study spent time trying to identify the prior knowledge of the learners before moving on to the day's work. 90% of the educators spent at least 6 minutes at the beginning of the lesson on this activity. This is somewhat in keeping with the departmental lesson plan guidelines which suggest that at least 10 minutes at the beginning of a lesson should be spent in this way.

Teacher questions were the most popular method of identifying the learners' prior knowledge, with just one educator beginning her lesson with a mental test. The prior knowledge of many learners was seriously lacking in some cases, but the educators seemed not overly concerned with this, and continued. The educators seemed satisfied as long as there were some learners who remembered the work done in previous lessons.

11 educators showed evidence of longitudinal coherence, while the rest (28) showed no evidence of this category. This suggests that the majority of educators in my study lacked either a deep understanding of the underlying concepts vital to make connections between mathematical topics, or an understanding of the relevance of this to their teaching. If this is in fact a true enough reflection of mathematical knowledge of the educators – and the test could indicate that it is, as discussed in chapter 7- then it is a matter of grave concern. Both categories, prior knowledge and longitudinal coherence, deal with the connections that are made in mathematics classrooms, connections which facilitate understanding. An educator must be able to have a deep and profound understanding of mathematics and mathematical concepts to be able to make these connections that lead students having a meaningful appreciation of mathematics (Ma, 1999; Fennema & Romberg, 1999; Jordan, 2008). My preliminary analysis of teachers' knowledge suggests that they are not encouraging their learners to make these connections and construct these relationships. Learning in these classrooms is therefore achieved at a surface level where the teachers are satisfied with the learners knowing or remembering facts or skills. This is indicative of teachers demonstrating low levels of PCK, in these categories at least (An, 2004).

Those 11 educators, whom I identified as displaying evidence of longitudinal coherence, could be described as having deep and broad PCK in these categories. They tend to recognise that learning with understanding is more important than simply knowing a skill or facts at a surface level, and their instructional methods reveal their understanding of their own students' thinking (Fennema & Romberg, 1999).

Multiple methods to a solution and the use of varied representations and examples

The fact that I identified 5 out of 39 educators who provided more that one solution to a problem again suggests, tentatively, that the majority of teachers in this study exhibited low levels of this type of PCK in the recorded lessons. Effective mathematics educators are those who are able to show their learners multiple methods to arriving at solutions as well the advantages and disadvantages of each method (Ma, 1999).

The use of examples was widespread, with many educators using everyday household examples to help their learners understand concepts, terms or ideas that the learners found too difficult or too abstract. Representations were not as widely used; this could be attributed to some of the lessons not necessarily favouring an extensive use of representations. In the overall summary however, I expected to see a greater use of representations than I did. In hindsight, I concede that I wrongly expected the educators to prepare ‘excellent’ lessons, in which they hoped to impress the researchers, especially after discovering that they would be videotaped. This lack of the use of representations is believed to hinder learners’ chances of developing conceptual understanding (Shulman, 1987; Grossman, 1990) – since a concept can in some ways be considered what is common across representations.

Identifying and addressing errors and misconceptions

Half of the educators in my study identified learner errors and misconceptions, which I felt was a low return; a somewhat different half made some attempt to address errors or misconceptions that they identified. This was a category which caused the greatest concern to me. After studying the videos as closely and as accurately as I could, I came to the conclusion that far too many educators simply took the easy way out when it came to learner errors.

In terms of teachers not identifying learner errors, the most obvious question is “why?” It is disconcerting to think that the educator did not identify the error because he did not even realise it *was* a mistake. Or perhaps he ignored it because he lacked the expertise to address it. These are very real possibilities that cannot be overlooked. I would probably guess that it is a view on learning which sees an error as a result of learners not paying attention or not working hard enough; it is an external locus of control view on teaching: “I presented it; the learners didn’t get it, so it’s their fault.” Only when one realises that errors can be a result of misconceptions, which again result from teaching or other experiences that the learner has only made sense of in a limited way, can one begin to recognise the importance of addressing misconceptions.

Table 6.1 The three stages of teaching as identified by Goldsmith and Schifter (1997).

A1. The initial stage	This stage is characterized by traditional instruction where the teacher strongly believes that students learn best by receiving clear information transmitted by a knowledgeable teacher.
A2. Subsequent stages	The teacher is more focused on helping students build on what they understand rather than helping them in the sole acquisition of facts. The instruction is founded on the teacher's belief that students should take greater responsibility in their own learning.
A.3 The advanced stage.	Instruction is in line with the reform movement recommendations. The teacher arranges experiences for students, in which they actively explore mathematical topics, learning both the hows and whys of mathematical concepts and processes. The teacher is motivated by the belief that, given appropriate settings, students are capable of constructing deep and connected mathematical understanding.

In level 1, the teacher sees teaching-learning as explained above. In level 2, the teacher sees teaching as a matter of what the teacher does, so if the learner does not understand, it is the teacher's fault. Only in level 3 do we have an understanding that it is in the meeting between learner and teacher that learning can happen.

There was precious little engagement with learners and too often the educators would either ignore the learners' incorrect answers to the teachers' questions, or they would simply give the correct answers to repeated incorrect ones. This to me was a travesty. Initially, I was of the opinion that the educators *knowingly* ignored learners because they (the educators) felt it was a waste to spend time and attention on *obvious* (but not serious) errors. However, when I began to notice a pattern of teachers ignoring learners who gave incorrect answers, then the alarm bells began to ring. This to me was an indication of low levels of PCK, because if an educator did not address a learner error because he believed it to be a 'superficial' mistake, then it was naïve indeed to think the learner would realise it and then correct it on his own. This is evidence of a lack of understanding of students' thinking, a skill that develops as educators gain teaching experience and which helps these educators to anticipate potential misunderstandings in the minds of their learners (Graeber, 1999; Van der Valk & Broekman, 1999; O' Connor & Michaels, 1996).

Learner opportunity to develop proficiency

All but three of the educators in my study engaged their learners in some form of activity which I regarded as an opportunity afforded by the educators for the learners to develop proficiency in mathematics. As I explained in chapter 3, I used Kilpatrick's framework to guide me here. Their five strands of mathematical proficiency are interwoven, which implies that the learning process is incomplete if all the strands are not present. However, it is very possible that conditions may not always be conducive for this to occur, and what I was most interested in was the overall frequency of the strands. As far as I could tell, most of the teachers concentrated on developing procedural fluency in their learners, although there were two notable examples of productive disposition, and some aspect of conceptual understanding, but very little evidence of the other strands. While the value of procedural fluency must not be underestimated - without procedural fluency, students experience difficulty deepening their understanding of mathematics or solving problems - attention must also be paid to developing conceptual understanding. According to Kilpartick *et al* (2001), procedural fluency and conceptual understanding are complementary. Understanding enables learners to learn skills easier, it reduces the likelihood of learners making simple errors and helps learners to forget less easily. This is due to the connections that teachers make between mathematical ideas which enhance this understanding.

By educators focusing on one strand of mathematical proficiency, seemingly at the expense of others, suggests that the educators themselves do not possess the necessary knowledge and skills to introduce and develop these strands in the learners that they teach. This then points to possible lower-than-acceptable levels of PCK in terms of developing *all* the strands of mathematical proficiency.

Sequencing and pacing of the lessons

In all of the 42 videos, there was sequencing and pacing of some sort. The educators generally appeared to have an idea of how they wanted their lessons to progress. There was a formulaic order of ‘events’ during the lessons which more-or-less resembled the departmental guidelines (see Chapter 3). All lessons were very strictly controlled by the teachers and I witnessed no unruly or unbecoming behaviour by the learners at all, which is a great credit to the educators (but also could be influenced by the presence of observers with a video camera).

However, I felt that the pacing of the activities during the lessons could have been better. Very little time was spent by the educators on introducing the topic for the day’s lesson and on developing the conceptual understanding of the learners. Instead, the educators chose to give the learners more time to develop proficiency in the form of classwork exercises which encouraged procedural fluency rather than conceptual understanding. In fact, an average of 43% of lesson time was spent in this way. This is substantially above the 25% (15 minutes of a 60-minute lesson) suggested by the national education department’s guidelines. This again suggested to me that the majority of educators possess low PCK levels or that they have a perception of mathematics as mostly procedural in nature.

Overall, based on my analysis, the first level of tentative results shows that all the teachers in my study do possess some form and level of the inclusive form of PCK I have attempted to measure here. This is the specialised form of mathematical knowledge for teaching that only teachers possess (Ball *et al*, 2005). The most obvious indication that these educators do have this knowledge is that no educator earned a zero score in all categories. However, it is my impression that generally, the educators' levels of PCK observed in the videos are low, in terms of what they do in the classroom in the actual act of teaching. This is evident from the areas in which most of the teachers demonstrate PCK, as discussed above.

To what extent can my results be generalised? It may be argued that because the sample size in this study is too small, and the fact that I observed just one lesson per teacher, I should not make sweeping statements. However, the fact that the schools and the teachers in this study were randomly selected lends the results greater credibility. Taken together with a global picture of this study, I will show in the next chapter that perhaps these results are too important not to consider seriously.

Chapter 7: CONCLUSIONS

My research questions were:

1. What are the levels of pedagogical content knowledge (PCK) of grade 6 mathematics educators in KwaZulu-Natal (KZN)?
2. What is the relationship between teachers' PCK and learners' mathematical achievement?

The 39 teachers in my study filled in a questionnaire, wrote a teacher's test and had their lessons video-recorded. The questionnaires revealed details about their education and training; the test was an assessment of their content knowledge of mathematics and of their pedagogical content knowledge (PCK); and the video-recorded lessons provided details of their mathematics content knowledge, general pedagogical knowledge and their observable PCK. In addition, their grade 6 learners wrote a pre-test and post-test with the aim of identifying any mathematical gains over the course of a year.

Several conclusions were reached.

The state of preparedness for the task of teaching mathematics of the majority of teachers is low. At least 32% of the teachers are unqualified, under-qualified and untrained in the general field of teaching and in the specific area of mathematics teaching. Possibly owing to this, their mathematics content knowledge and their pedagogic knowledge levels are low. These are likely predictors of the low PCK levels observed.

Due to their lack of proper education and training in teaching, they are unable to adequately understand their students' ideas and conceptions towards mathematics and are therefore unlikely to be able to enhance their students' understanding of mathematics. Many of these teachers possibly lack a deep understanding of fundamental mathematics (van Wyk, 2007), and so their students will probably not develop a deep appreciation for the subject matter either.
At least 28% of the teachers stated that they do not feel adequately prepared to teach mathematics, and there is a suggestion of a serious lack of support from the education

department, subject advisors and curriculum developers. This does not instill feelings of confidence in teachers and does not augur well for the future mathematics results on which, right or wrong, our country's educational standing is based.

Other factors and PCK- a conclusion

In summary, the statistical analysis provided answers to my questions, even though these answers may not all have been what I expected.

Crucially, the statistics suggested that teachers' content knowledge is necessary for high levels of PCK. This was an expected result especially after I considered my literature review. This finding is mirrored in Sorto *et al*'s (2008) comparative study in Latin America, as well as by Ma (1999) in her comparison between Chinese and American mathematics educators. These authors advocate a strong content knowledge as a prerequisite for PCK, adding that only when teachers are able to understand the subject matter deeply and thoroughly, are they able to help learners make sense of it as well. Teachers' orientations to the content of their subjects significantly influenced the way they taught that content (Grossman, 1990).

I was more than a little surprised that the statistics showed no significant relationship between teachers' PCK and learner mathematical achievement *in this study.* This suggests that teachers with high PCK scores, and therefore considered to be 'good' teachers, do not necessarily guarantee high learner achievement in mathematics, or vice *versa*. Again, the relatively small sample size of teachers in this study lends itself to validity problems. The subjective nature of PCK assessments of video recordings also makes it tricky, to say the least, to assign reliable 'scores' to the teachers. And it is possible that there was not a long-enough period between learner tests 1 and 2 for the teachers' PCK to make a difference in the students' learning. I believe it (teacher PCK) does matter (to student achievement), but these statistics have got me wondering what might have thrown up this result.

At the beginning of this thesis, I listed a few factors which are believed to influence student learning, of which teacher effectiveness was only a small part. Do the statistical results now point to one or more of the other factors? One can surmise that teaching is a small factor when one considers that so many of our learners come from poor, broken, abusive and often child-headed homes. As good as the teacher may be, he cannot compete with the hunger pangs of children who do not eat before (or indeed after) they come to school; children who are frequently absent due to abuse and illness brought on by abject poverty; and children whose parents are uneducated or illiterate so that they cannot support their children's' progress at home. If this is in fact the reality of the situation, then the social background of the learners has more that a little influence on their learning and achievement.

Indeed, a series of single factor ANOVA tests on the learner test scores from the first test suggested that:

(a) Gender has no significant impact on learner scores,
(b) The amount of reading material in the home (often a factor which reflects educational level of parents as well as income levels, in other words, social class) has a significant impact on learner scores,
(c) Level of education of caregiver had a significant impact on learner scores,
(d) Reading at home had a significant impact on learner scores,
(e) The type of caretaker had a significant impact on learner scores – learners raised by their grandmothers or siblings fared worse, and
(f) The frequency of homework had a significant impact on learner scores.

This seems to confirm the stronger role of other factors than the teaching on learner performance. However, these are tentative results, only based on the scores from the first test, not on learner improvement.

Where to from here for PCK?

Sorto *et al* (2008) asked the same question in their regional comparative study while trying to determine predictors of PCK. The results from their study mirror Hill & Ball's

(2004) study that there is the implication that PCK can be taught. This conclusion was reached after results from these studies suggested that higher level content knowledge and more pedagogy classes are significantly related to PCK. The seminal Coleman Report (1966) showed that a teacher's general cognitive ability - as assessed by teachers' scores on verbal ability tests, basic skills tests and college entrance examinations - is significantly correlated to patterns of student achievement in schools.

Another school of thought regarding teachers' PCK is that it develops over time, implying that experienced teachers have higher levels of PCK than novice teachers. Experienced teachers are able to more accurately predict learners' errors or anticipate the misconceptions that their learners are likely to bring to the class (Cochran, 1997). Novice teachers are more likely to rely deeply on the curriculum and not modify the subject matter knowledge to make it accessible to learners. They also tend to make "broad pedagogical decisions without assessing students' prior knowledge, ability levels, or learning strategies" (Carpenter *et al*., 1988, cited in Cochran, 1997). Furthermore, they struggle with lack of skills which allow them to transform mathematical concepts and ideas to make sense to students (Wilson, Shulman, & Richert, 1987).

In the context of my study, which I believe also mirrors the more widespread South African situation; the results indicate strongly that there are deficiencies in the levels of content knowledge and pedagogic knowledge (and therefore PCK) of many of the teachers. This is largely due to the high rate of under-qualification among the teachers, and if content and pedagogic knowledge are strong predictors of teachers' PCK, then it would be reasonable to infer that this is the reason for the relatively low levels of PCK demonstrated by the teachers in this study. Those teachers who are new to the profession, with relatively fewer years of service than more experienced teachers, could also possess low PCK levels for the very reason that is their inexperience.

Important to consider in a study such as this is that only one lesson per teacher was observed and observation alone would not necessarily provide a complete PCK profile of teachers, neither would tests or interviews on their own. Furthermore, 'teachers may only use a small portion of their PCK in observed situations' (Rohaan, 2009), thus making judgments about teachers' PCK difficult. The timing of the school visits, which included the administering of the teacher questionnaire, teacher test, and learner test, cannot be ignored as a possible factor in the results that emerged from my study. Classroom observations too are always artificial situations, and the behaviour of teachers under these conditions must always be taken with a pinch of salt, as it were.

Having said that however, I believe it is vital that efforts be made to improve teacher education and training. If teachers enter the classroom armed with the content and pedagogic knowledge they require, then they would teach with the confidence and understanding that is needed to improve learner understanding. Peer and departmental support must also be available to those teachers who require their assistance. If one were to look beyond the more urgent and obvious need for social upliftment of the majority of our learners, and decide that PCK is worthy of a greater investment, then perhaps a closer look at the teacher education programmes offered by higher education institutions is necessary. Are these programmes paying enough attention to improving teachers' PCK?

Opinion remains divided over the very existence and importance of PCK, what constitutes PCK, what "good" or "bad" levels or qualities of PCK are, and what the effects are (if any) of teachers possessing high levels of PCK. These debates will go on for some time, but debates are good, especially if the direction they take is to improve the quality of mathematics teachers and in doing so, the quality of mathematically-proficient learners these teachers produce.

My work here is far from over.

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APPENDIX

Table 3.1

Sequencing, longitudinal coherence, level
▪ Does the educator start from the known to the unknown, from the easy to the difficult? (Sequencing – in a sense that reflects the conceptual steps of the topic) ▪ Does educator connect new knowledge to prior knowledge? ▪ Does educator connect new knowledge to future knowledge? ▪ Is the lesson on an appropriate level?
Student misconceptions and errors
▪ Does educator ask questions to determine student misconceptions? If not, then how does educator determine? ▪ Does educator address misconceptions? If yes, how? ▪ Does educator identify student errors? ▪ Does educator address errors? If yes, when? (immediately/later in the lesson)
Student understanding
▪ Does educator explain key ideas/ solve a problem/ arrive at a solution in various different ways? ▪ Does educator use various representations and examples to enhance student understanding? ▪ Is the educator aware when learners do not understand a concept/ explanation? ▪ Does educator endeavour to make sense of maths eg provide rationale for algorithms, rather than simply encourage/ force learners to learn rules?
Formative assessment
▪ Does the teacher 'assess' to determine level of student thinking & adjust teaching accordingly? ▪ What is learners' prior knowledge?
Student actions
▪ Are learners encouraged to interact with educator ie are they active or passive during the maths lesson? ▪ Are classwork and homework activities designed with learners in mind? ▪ Are learners given the opportunity to develop proficiency ie practice problems, oral questions?

Table 3.1- Questions used to formulate PCK instrument

Table 5.1

Question characterisation	**Comment**	**Aspect of PCK assessed [bullet number]**	**Percentage correct**
Question 2: Teacher is asked to ‘unpack’ a learner algorithm for multi-digit whole number multiplication.	To do so, the teacher has to be able to recognise the partial products when they appear in places different from the standard algorithm.	Knowledge about the distributive nature of multi-digit multiplication [2]. Knowledge that the basic idea of multiplication can be given different representations, even several symbolic ones. [5]	21
Question 3: Teacher is asked to identify which of three mistakes on addition with regrouping are the 'same kind'. The first two learners have added correctly within place values, but carried '1' instead of '2'. The third learner has simply added incorrectly.	Besides being able to identify wrong answers, the teacher has to be able to distinguish between types of errors. The question does not ask the teacher to state what is similar about the two wrong answers.	On the border of what we would include under PCK. But it does lead to a distinction between careless errors and misconceptions, so we have reluctantly included it. [3/4]	65
Question 6: it asks the teacher to explain the underlying reason why the learner constructs a false identity for a fraction.	Discussed above.	[4]	12

Question characterisation	**Comment**	**Aspect of PCK assessed [bullet number]**	**Percentage correct**
Question 10: learners have been asked to "develop a rule to predict the number of" blocks at any stage. The question requires the teacher to identify the correct learner responses.	It appears to be mathematical in essence. However, two of the answers are correct, but the one is process oriented (1+2+ … + n) while the other is product oriented: 1/2n x (n-1).	Has elements of recognising representations [5] as well as understanding the dual nature of mathematical concepts [1/6]	10A: 71 10B: 15 10C: 59 10D: 47
Question 14: A learner answer sheet is shown; the learner had to make ticks by the right angles in 2D shapes. The teacher is asked to predict what errors the same learner is likely to make on a range of stated tasks.	The teacher has to be able to characterise the nature of the learner's mistake, the underlying misconception.	This falls within knowledge about learner conceptions [4].	14A: 26 14B: 38 14C: 59 14D: 65
Question 18: The teacher is shown two learners' solutions to a task on determining perimeter. The teacher must then indicate which of four statements about the task and the solutions are correct.	The first statement simply asks the teacher to say if the learner is right or wrong, and the last statement states a numerical answer to the task. The second and third statement implies identifying the reason why the one learner's answer is wrong.	The first and fourth statement is simply about identifying correct and incorrect numerical answers and does not fall under PCK. The second and third statement is similar to question 14, and falls within knowledge about learner conceptions [4].	18A: 50 18B: 53 18C: 24 18D: 71

Table 5.1 - Summary of Teachers' test scores for PCK items

Student report: M.Ed dissertation

Name of student: Virendra Ramdhany (922429642)

Title of dissertation: Tracing the use of Pedagogical Content Knowledge in Grade 6 Mathematics Classrooms in KwaZulu-Natal

After reviewing the reports of both the external and internal moderators, I have made the necessary corrections, revisions or responses which can be seen in the table below.

<u>Overall</u> Internal examiner: I am however concerned with the generalizations he sometimes makes about his findings, which seem to say that the teachers in this study had low levels of PCK. It is important to bear in mind that in this study only one lesson per teacher was observed and analyzed for PCK.	Modifier added wherever I felt I had generalised. Instead of saying ‘teachers had low levels of PCK’, I said ‘lessons observed showed low levels of PCK’.
<u>Chapter 1: Introduction</u> Top of p. 2: say which of the TIMSS years this is from.	Inserted year 1995
You state that other developing countries were also taking part in the study; mention their results.	I included the results of the other developing countries mentioned in the chapter.
p. 3, the external asks about the use of 'levels' in PCK of the teachers.	As I attempted to formulate an instrument which I hoped would be able to assign a value to the teachers’ PCK, I also hoped to be able to place the teachers into groups based on their measured ‘levels’, for want of a better word. That is to say, do the teachers demonstrate high or low PCK levels in the lessons observed?
<u>Chapter 2: Literature Review</u> Provide an ending to the literature review, possibly introducing the framework and mention how you have adapted or modified Shulman’s model of PCK to suit his study -	Although I felt that my conclusion was adequate, I did add in a paragraph which stated briefly that my conceptualisation of PCK, which draws heavily on Shulman, also contains aspects of Ball and Ma.

to be expanded on in your next chapter Page 6: Ball et al reference needs a year.	Inserted year 2008
Pages 7-11: Very nice review of all the definitions of teachers' knowledge. However, candidate needs to argue why to go with "PCK" construct instead than others. In particular why not built on South African researchers "MfT" construct?	My thesis came about due to my involvement in the larger project. The project works with PCK rather than MfT or even MKT. It was therefore easier due to the research I had already done for the project.
Page 14: A period is needed at the end of first paragraph (…achieved.)	Period inserted at end of sentence.
Page 14: In the discussion of Ball et al (2005), the aspect of the nature of the instrumentation is needed since the subsection refers to the measure of PCK. Ball et al spent almost a decade developing the instruments to achieve validity and reliability characteristics.	I added a bit more details about the longitudinal study they were involved in; the questionnaires/tests they used; the fact that they controlled for things such as SES; and their enlightening results which suggested that improving teachers' PCK stalls the widening of the achievement gap among the poorer learners. The nature of their instrumentation in this study could not be found in this reference. This is something I hope to take up in future study.
<u>Chapter 3: Methodology</u> Page 17: Why is the phrase *significant relationships* in quotes? If the candidate does not feel this is an appropriate phrase, an argument/critique should be made.	The sentenced has been re-phrased. The quotes signified author's own words.
Page 18: Phase 1 of data collection talks about a questionnaire and test. A little more needs to be said about these instruments, in particular about their validity and reliability. This is important because the study makes links with the results of these instruments.	Page 19. A little more detail added regarding the instruments in terms of reliability and validity.
p. ? Include copy of the test, says the internal.	I resisted the urge to include a copy of the original teacher test here, as this thesis is part of a larger project and the test will, in all probability, be used in other studies. I therefore did not want it in the public domain. In my study, I focused mainly on

	the analysis of the videos. This point has been added to the thesis. (page 21)
page 21 (on validity issues and data collection) he mentions some of the problems he encountered but does not clearly say how he addressed those in his study, e.g. the mismatch between first and second learner tests. Is this the reason why at the end only he had the results of only 76% of the learner results? This needs to be made clearer.	I believe that it was quite clear in my thesis that I used only the results of those schools that wrote both test, hence 76% of the total participant schools. I also do not believe that these problems could be addressed in my study.
p. 22: The PCK instrument on page 22 has a column on 'level appropriate', but he has not made any reference to it in his analysis.	This was necessary for the larger project. When the videos were coded in a large group, it was noted that all lessons were pitched at the appropriate level, according to the national assessment guidelines. It was not integral to the focus in my study.
Pages 21-35: Candidates' proposed instrument (categories?) should relate to existing ones (see Hill's rubric for measuring MKT in the classroom). If this is not possible at this point, the candidate should discuss how each aspect relates to all the aspects of PCK mentioned before. This way, the new instrument fills the gaps or builds on previous research. Maybe a diagram?	I must have missed this publication. I do not recall seeing a rubric in any of the studies, although I did see various examples. I will however take this up in one of the papers I am currently working on.
Page 33 -35: Did the candidate use an inter-reliability method with at least two independent raters? If this was not possible, the candidate should acknowledge the limitation.	I have added a text about this: There were many occasions when we coded several videos in a group. We did this until we had almost complete inter-coder reliability, but on occasion I did need to consult with my supervisor regarding boundary cases. However, it is likely that the coding can and may have 'shifted' over the course of the process. (Page 35)
Although coding the same teachers at different points in time and obtaining similar measures is one way to validate the instrument, it does not necessarily means that the codes are measuring what they are supposed to measure. Depending on the goal of the lesson, teachers can demonstrate different aspects of PCK. In other words, PCK is a function not only of	I have since added a few lines making a point of allowing for this. Page 36.

teachers' characteristics, but a function of the lessons' goal. So, it is not surprising that Teacher C (page 35) has different codes for different lessons.	
<u>Theoretical framework</u> The external makes reference to the lack of an overarching theoretical framework for the study. The examiner does recognise that this is a short coming of the field.	I experienced some difficulty with this during my research, owing to the shortcoming mentioned by the examiner. However, I feel this is a more general issue and I did not engage it in any depth.
<u>Chapter 5: Teacher profiles</u> Page 54: More explanation about what constitute "low PCK" and "high PCK" is needed. What was difficult about making the judgment call?	Further explanations offered, as well as details of some difficulties I encountered.
<u>Chapter 7: Conclusions</u> Page 67: fix numbering of the research questions	Numbering sorted out.
A few technical aspects that need to be attended to: • Page (i) and cover page – spelling of KwaZulu-Natal – a capital 'z' • Page (vi) – Chapter Four: write PCK in full. • Also, chapter 4 has subtopics but they do not appear in the Table of Contents • Chapter one ends abruptly without any conclusion. • Page 30 – end of first paragraph- how did you know the educator "had no idea what to do". Provide evidence for this. Rather say the educator 'did not do anything". • Pages 34, first line – to clarify rather indicate that "there were three teachers who were **each** recorded in two different classes…" • Page 39; take out the last sentence "I do however stand to correction". • Page 49 – Introduction is missing...make sure all your	Capital 'z' inserted here, as well as anywhere else where necessary. PCK written in full. Subtopics included in Table of Contents. I have added a conclusion to the chapter. Examiner misread- perhaps it was ambiguous on my part, as I refer to the learners and not the educator. Language fixed, ambiguity removed. 'each' inserted to clear confusion. Last sentence deleted. I feel there is enough of an introduction and conclusion to most chapters.

chapters have introductions and conclusions.	
• Page 52, subheading “teacher Profile” – is similar to the title of the chapter…how about “Teacher PCK profiles”? or something else.	Subheading changed to ‘Teacher PCK profiles’.
• Page 55, line 3…”if these frequencies were not significantly high…” clarify what you mean by “significantly high”.	Sentence changed, the word ‘significantly’ removed. Original wording quoted from authors.
• Page 56, question 2: “does the teachers’ education influence their PCK” – I don’t think this study was able to answer that question...you could only establish a relationship between the two variables.	Formulation corrected to “What is the relationship between teacher qualifications and their PCK?”
• Page 59 – subheading “Teacher education and PCK” gives a view that you will discuss teacher education. I suggest you use “Teacher qualifications and PCK’.	Subheading changed to “Teacher qualifications and PCK”.
• Page 63...you are introducing this framework for the first time, and this is the chapter where you are discussing your findings? I suggest you mention it in your literature review if you want to use it.	This framework was simply adding to the discussion, and not informing my study. Therefore it was added here and not earlier.
• Page 68…9th line write “stats” in full.	“Statistics” written in full.

I trust that this meets the requirements of my supervisor and the Head of School.

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Viren Ramdhany