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UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

What do first and fourth year pre-service teachers notice when observing teaching?

Dominique Peixinho

Student number: 1834856

Supervisor: Dr Zaheera Jina Asvat

Research Report submitted to the School of Education,

Faculty of the Humanities,

University of the Witwatersrand, Johannesburg,

In partial fulfilment of the requirements

For the degree of Masters in Education

March, 2025

Declaration of academic integrity

I declare that this Research Report is my own work, guided by my supervisor Dr Zaheera Jina Asvat. It is submitted for the Masters in Education Degree at the University of Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other university.

Dominique



17th day of March 2025

Abstract

The journey to becoming a teacher requires pre-service educators to view teaching as an informed practice, recognizing and integrating the knowledge and pedagogical reasoning that underpin effective instruction. Despite the objectives of teacher preparation programs, research indicates that pre-service teachers often struggle to connect theoretical concepts from coursework with their practical applications. These programs aim to bridge this gap through coursework and work-integrated learning (WIL). However, during the COVID-19 pandemic, pre-service teachers were unable to partake in in-person practicums. The Teacher Choices in Action module TCiA module provided a unique opportunity for remote engagement with WIL, allowing pre-service teachers to observe video-recorded lessons and analyse them through lesson observation reports. This study utilizes secondary data and adheres to the highest ethical standards. It investigates the aspects of mathematics teaching that first and fourth year pre-service teachers notice when observing a lesson on exponential equations. Drawing on the concept of semantic density from Legitimation Code Theory (LCT), the study explores the complexity of mathematical content knowledge and pedagogical content knowledge reflected in these observation reports. Employing a qualitative case study design, the findings suggest that pre-service teachers demonstrate weaker semantic density, focusing primarily on surface-level aspects of both mathematical content knowledge and pedagogical content knowledge. The Mathematics Teaching Framework (MTF) provided a useful lens for analysing their lesson observation reports, revealing that both first- and fourth-year pre-service teachers prioritized explanatory communication but paid less attention to coherence, learner participation, and lesson goals. This suggests that while they recognize the importance of clear explanations, they may not yet fully understand how these explanations should be embedded within a coherent instructional sequence that actively engages learners. To address these challenges, the study recommends incorporating structured reflection, combining video and in-person observations, and providing explicit instruction on pedagogical reasoning. Encouraging peer discussions and tracking professional noticing over time could further enhance teacher preparation. This research underscores the importance of bridging theory and practice in teacher education. Strengthening professional noticing and pedagogical reasoning can better prepare pre-service teachers for effective mathematics instruction.

Key words: legitimation code theory (LCT); semantic density; mathematics teacher framework (MTF); pedagogical content knowledge (PCK)

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Abbreviations used in this study

DHET- Department of Higher Education and Training

LCT – Legitimation Code Theory

MRTEQ – Minimum Requirements for Teacher Education Qualifications

MTF - Mathematics Teacher Framework

PCK – Pedagogical Content Knowledge

TCiA – Teachers Choices in Action

RMRTEQ – Revised Minimum Requirements for Teacher Education Qualifications

SD – Semantic Density

WIL – Work-integrated Learning

Chapter 1 Introduction and Rationale

1.1 Introduction

Prior to their teacher education programmes, pre-service teachers spend many years (during their school career) watching teachers teach. Lortie (1975) highlights that although learners observe teaching during these years, they do not necessarily notice the more intricate aspects of the practice. He further highlights that pre-service teachers may notice the visual aspects of a teacher's actions but may not understand the complex activities of the teaching practice. In this view the pre-service teachers have not shifted their gaze continuing to focus on the observable actions of the teacher rather than the underlying pedagogical reasoning (Lortie, 1975). However, to teach effectively, pre-service teachers need to notice the more specialised aspects of the teacher's work. Therefore, learning to teach requires them to shift their understanding of what the profession entails.

If pre-service teachers were to teach in schools without the more intricate activities of a teacher they might "mimic classroom routines without the deeper thinking needed to design and support learning" (Langsford & Rusznyak, 2024, p. 2). For effective mathematics teaching pre-service teachers need to integrate both the specialized knowledge of mathematics teaching and the pedagogical choices that inform practice. To help pre-service teachers develop this new gaze, teacher preparation programmes engage them in university-based coursework and work-integrated learning (WIL). The South African Policy of Minimum Requirements for Teacher Education Qualifications (MRTEQ), necessitates teacher preparation programmes to bring "the knowledge and practices into the foreground" as well as highlight that teachers require the ability "to draw reflexively from integrated and applied knowledge" (South Africa Department of Higher Education & Training (DHET), 2011, p. 11).

Through WIL, pre-service teachers can come to learn that teaching is influenced by many contributing factors, enabling them to develop professional noticing skills (Rusznyak & Bertram, 2021). Professional noticing can be understood as the way "that teachers attend to pre-service teachers' thinking, interpret their thinking, and make decisions about how to respond based on their own assertions" (Amador, 2016, p. 218). Langsford and Rusznyak (2024, p. 4) describing noticing as "developing a sensitivity to how practice is embedded in context while considering a range of alternative actions that might be appropriate under other

circumstances". For pre-service teachers to succeed, they need to observe aspects of teaching that may have eluded their notice during their school experiences.

Professional noticing allows a pre-service teacher to understand why a teacher makes the choices they do (Amador, 2016). A part of learning to teach, is to learn to see the important decisions and other aspects of teachers' actions that are informed by pedagogic reasoning (Rusznyak & Bertram, 2021). During WIL, pre-service teachers engage with teaching as a practice and learn to professionally notice. WIL engages a pre-service teacher with the practice itself. Through this engagement with practice the pre-service teachers can see that teachers do not act without consideration, whether it be about their learners, context or other aspects. Through this engagement with WIL pre-service teachers can learn how to professionally notice. Amador (2016, p. 218) argues that "the ability to learn from teaching is dependent on the ability to notice". Rusznyak and Bertram (2021) highlight that WIL has value for pre-service teachers to acquire different bodies of knowledge that inform teaching from their coursework. Together these bodies of knowledge may inform pre-service teachers' abilities to professionally notice. Teacher preparation programmes require the connection of practice and theory to support the development of powerful teaching (Darling-Hammond, 2006).

Teacher preparation programmes should therefore develop pre-service teachers' ability to notice the more intricate aspects of mathematics teaching over the duration of the programme as the pre-service teachers engage with WIL. This study seeks to compare what pre-service teachers tend to focus on when observing mathematics teaching, at the start of their teacher preparation programmes (first-year pre-service teachers) to the end of their teacher preparation programmes (fourth-year pre-service teachers). This comparison is based on an analysis of pre-service teachers' lesson observation reports, in which they observed an online lesson on exponential equations. The reports are interpreted using Legitimation Code Theory's[1] (LCT) concept of semantic density, which describes the condensation and interrelation of meanings within socio-cultural practices. In this study, semantic density is used to analyse the complexity of pre-service teachers' reports in terms of their mathematical content knowledge and pedagogical content knowledge.

[1] Legitimation Code Theory (LCT) is a sociological framework developed by Karl Maton to analyse knowledge practices across different fields

1.2 Context of the study

To fulfil the practical requirements of teacher preparation programs, pre-service teachers undergo work-integrated learning (WIL) through school practicums, mandated for a minimum of 20 weeks in the four-year Bachelor of Education degree (DHET, 2011). However, the Covid-19 pandemic disrupted in-person WILs due to public gathering restrictions. The Teachers Choices in Action (TCiA) module was developed to address these challenges and enable remote engagement with WILs. TCiA allows pre-service teachers to observe teaching practices and discern both visible and less visible aspects (Rusznyak, 2020). Aligned with Minimum Requirements for Teacher Education Qualifications Policy guidelines (DHET, 2011), Rusznyak (2022a) argues that the module introduces concepts, helping pre-service teachers understand teacher choices during lessons. Pre-service teachers learn to professionally notice by examining why teachers make certain choices and what influences those decisions. The TCiA module offers South African pre-service teachers a unique opportunity to study classroom teaching through a lesson library showcasing diverse lessons across specializations (Rusznyak, 2020, p. 19). During the TCiA module, participants watched various video-recorded mathematics lessons from the library and wrote observation reports based on these lessons. Report writing guidelines encouraged them to draw on theoretical coursework knowledge to make sense of observed teaching practices (Rusznyak, 2020). This practice-based engagement expects pre-service teachers to foreground different bodies of knowledge when interpreting lessons. The online module offers pre-service teachers the flexibility to pause, rewind, and replay lessons at their discretion providing a unique way to engage with lessons compared to in-person WIL (Rusznyak, 2020).

Despite these advantages, it is argued that pre-service teachers often struggle to connect theory to practice (Mårtensson & Ekdahl, 2021; Jina Asvat, 2025) and tend to focus only on visible pedagogical actions when observing lessons (Rusznyak & Bertram, 2021). This research study aims to compare the extent to which first-year and final-year pre-service teachers integrate theory (coursework content) and practice (teacher's pedagogy) when observing online mathematics lessons. The comparison aims to determine if pre-service teachers establish better connections between theory and practice after engaging in teacher preparation programmes. Furthermore, this study seeks to analyse the complexity of the bodies of knowledge (content and pedagogic) that pre-service teachers bring to the forefront when reporting on mathematics teaching.

1.3 Rationale

The introduction highlights that teaching involves more than visible actions, emphasising the need for pre-service teachers to transition from their 'apprenticeship of observation' (Lortie, 1975). However, the challenge arises as this apprenticeship often inadequately frames their perception of the teacher's role (Lortie, 1975). Learning to teach demands a shift in understanding, departing from personal experiences as a learner (Darling-Hammond, 2006). The practice of teaching is more complex than one might believe when they observe it every day for twelve years. "Teaching's inherent complexity poses a challenge for new teachers" (Darling-Hammond, 2006, p. 38), as they cannot enter a classroom and mimic the actions of the teachers they have observed (Langsford & Rusznyak, 2024).

Teacher preparation programs aim to bridge theory and practice, yet a divide often persists, with pre-service teachers struggling to integrate content and practice (Loughran, 2019). Work-integrated learning (WIL) should foreground both theory and practice, as stipulated by MRTEQ (DHET, 2011). Yet, pre-service teachers tend to focus on visible teaching aspects, neglecting the critical invisible components that shape teaching moments (Rusznyak, 2020). This separation between coursework knowledge and practical knowledge undermines the purpose of WIL (Rusznyak, 2020).

Shulman (1987) advocates for the development of pedagogical content knowledge (PCK) by blending content and pedagogical knowledge, crucial for effective teaching (Appova & Taylor, 2020). MRTEQ expects South African pre-service teachers to cultivate PCK (DHET, 2011). Yet, a gap exists between knowledge gained and its application in practice. The study aims to investigate the extent to which pre-service teachers integrate mathematical content knowledge and pedagogy, addressing the observed theory-practice divide. It explores how pre-service teachers report on mathematics teaching during WIL, aiming to uncover aspects of potential PCK development in their observation reports.

1.4 Research questions

The study aims to investigate the extent to which pre-service teachers integrate mathematical content knowledge and pedagogy when observing mathematics teaching.

1. What differences are there between how first and fourth year pre-service teachers describe mathematical content of a lesson?

2. How do the way pre-service teachers observe and interpret mathematics classroom practices change over their teacher preparation programme?

3. What differences are there in how first and fourth year pre-service teachers account for the choices teachers make?

1.5 Significance of the study

This study seeks to be of benefit to teacher preparation programs as a means to see how pre-service teachers bridge the separation between practice and theory. This research study seeks to investigate the extent to which pre-service teachers integrate mathematical content knowledge and PCK when observing mathematics teaching. Through this investigation, the study will display how pre-service teachers use these bodies of knowledge to inform teaching, evidently showing how they merge theory and practice. This study explores how pre-service teachers report on mathematics teaching during WIL, aiming to uncover aspects of knowledge and pedagogy that the pre-service teachers notice in their lesson observation reports. I have chosen to examine the PCK which pre-service teachers notice in order to see how they blend together content and pedagogy. This study has analysed reports from 5 different South African Universities that made use of the TCiA module. This comparison will afford insight commonalities and differences between the aspects of mathematics teaching which pre-service teachers notice.

1.6 Standpoint of the researcher

After completing a four-year teacher preparation program, as well as an Honours program, I secured a position at a private secondary school, teaching mathematics, natural science, technology, and life science to various grade levels. I initially felt confident in my grasp of content knowledge for teaching Mathematics, Life Science and Natural Sciences, having immersed myself in these subjects during my teacher preparation programs. However, I soon realised that mastery with the content was not sufficient; conveying that knowledge to learners required a nuanced approach that was meaningful, engaging, and accessible.

My responsibilities extended to designing tasks tailored to individual learners, ensuring that my questions aligned not only with content knowledge but also with the unique needs of each student. Additionally, I faced the challenge of delving into the unfamiliar realm of

'Technology,' necessitating both an understanding of the content and the development of effective teaching methods. While attempting to engage with mathematics, life sciences, and technology, I encountered difficulties in making the content comprehensible to my learners. This led me to the realisation that the content knowledge gap I faced went beyond a simple understanding of the subject matter; it encompassed the dimension of pedagogical content knowledge (PCK), as articulated by Shulman (1986, p. 9). During my experiences, I came to a profound realisation: teaching encompasses far more than I initially understood. Despite spending thirteen years in classrooms before my pre-service teacher education, I realized that my observations merely constituted an "apprenticeship of observation" (Lortie, 1975), a perspective unique to the teaching profession. While I could visually discern aspects of teaching, I lacked comprehension of its intricate practices (Lortie, 1975). In my own teaching journey, I soon discovered that mastering mathematical concepts or scientific processes alone wasn't enough to effectively engage pre-service teachers. Despite being introduced to learning theorists like Vygotsky, Piaget, and Skinner during my pre-service education, I struggled to bridge theory and practice. I recognized a gap between theoretical knowledge and its application in the classroom, compounded by the siloed nature of my learning experiences.

During my pre-service education, I engaged in work-integrated learning (WIL), spending six weeks each year in schools. This experience afforded me insights into the multi-layered nature of teaching, influenced by visible and invisible factors (Rusznyak & Bertram, 2021). Through WIL, I began to develop the knowledge required for effective mathematics instruction. While I designed and taught lessons during WIL, my reflections often remained within the pedagogical realm, neglecting to focus on the work of making the knowledge understandable for the learners in my care. Real-time teaching experiences left little opportunity for reflection or revision, leading to lost moments of insight and growth. During WIL, I discovered that I failed to integrate the complexity of both pedagogical and content knowledge, which I now understand pre-service teachers are expected to emphasize when reporting on mathematics teaching.

1.7 Outline of the Report

This report is divided into five chapters. In the current chapter (chapter 1), the background to the study, rationale for the study as well as the research questions were given. In the following chapter (chapter 2) the conceptual and theoretical framework which foreground this study is provided. Chapter 3 provides a discussion of the methodology used in this study. In chapter 4

the data analysis is provided, along with the discussion of the results. In the final chapter (chapter 5), the conclusion for the study is provided.

Chapter 2 Conceptual and Theoretical Framework

2.1 Introduction

In the previous chapter, I provided a background to the study, presented the rationale, the research questions and the significance of the study. This chapter introduces a conceptual framework that integrates professional noticing, pedagogical reasoning, pedagogical content knowledge (PCK), content knowledge, and the elements of the Mathematics Teaching Framework (MTF) to explore the complexity of pre-service teachers' observations of a lesson. Elements of the Mathematical Teaching Framework (MTF)[2], such as the lesson goal, explanation, exemplification, learner participation and coherence portray expertise and complexity in mathematics teaching and are vital for understanding PCK. Professional noticing plays a crucial role in helping pre-service teachers navigate the intricacies of teaching, particularly by observing how mathematical content knowledge and PCK are enacted through teacher explanations and student interactions. As Darling-Hammond (2006) argues, the alignment of theory and practice through noticing is an essential pre-condition for the cultivation of effective teaching. The MTF and Legitimation Code Theory used in this study, provide a structure for investigating how pre-service teachers interpret classroom practices and what they prioritize in lesson observation reports, which offers insights into their understanding of teaching. By examining what they notice and consider significant, we can assess their depth of knowledge regarding the teacher's pedagogical reasoning and their ability to link mathematical content knowledge and PCK to instructional practice.

2.2 Conceptual Framework

2.2.1 Professional Noticing and Pedagogical Reasoning

The argument for using professional noticing to investigate the mathematical content knowledge and pedagogical content knowledge (PCK) which pre-service teachers notice, can be built on the foundation of research around learning to teach through observation and analysis

[2] The Mathematics Teaching Framework (MTF), developed by Jill Adler and colleagues, is an analytical tool designed to examine and enhance mathematics teaching practices. Originally termed Mathematics Discourse in Instruction (MDI), the framework focuses on key teaching components, including lesson goals, exemplification, representations, tasks, explanatory communication, and learner participation. It aims to make mathematics teaching more transparent and improve learning outcomes.

of classroom practice. In this chapter I will discuss how professional noticing has been widely used by pre-service teachers to identify, interpret, and make sense of key classroom events. Early pioneers like Lampert and Ball (1998) introduced the use of video in teacher preparation, which allowed pre-service teachers to examine teaching practices in detail, thereby potentially fostering a deeper understanding of teaching and learning. Through their multimedia systems, teachers could reflect on pedagogical challenges, helping them develop more nuanced insights into the instructional process (Putnam & Borko, 2000). Video-based tools enabled pre-service teachers to notice not just surface-level details, but also deeper pedagogical elements (Sherin & van Es, 2002). As van Es and Sherin (2002) point out, "noticing" involves recognizing what is important, connecting these events to broader principles of teaching, and applying contextual knowledge to interpret classroom dynamics. As pre-service teachers' knowledge of practice and experience increases, they become more adept at noticing important instructional moments, especially when given the opportunity to observe video footage multiple times, examining lessons from different angles. Similarly, Santagata et al (2021) emphasize that video-based programs can potentially enhance the ability of pre-service teachers to notice key aspects of teaching, which contributes to their professional growth. Through engagement with teacher preparation programmes, pre-service teachers should be equipped with the conceptual tools to notice what matters in the practice. By the end of their teacher preparation programmes their interpretations of teaching should be more sophisticated than those who have just started the programmes (or first year pre-service teachers)

By paying attention to how teachers manage these aspects of instruction, pre-service teachers can better interpret the rationale behind instructional choices and see how they align with broader pedagogical goals (Amador, 2016). Moreover, the ability to notice allows them to see beyond surface-level teaching, delving into the pedagogic reasoning that informs a teacher's decisions (Rusznyak & Bertram, 2021). Professional noticing in this context becomes a tool for pre-service teachers to connect their theoretical coursework with real-world teaching. There is a possibility that pre-service teachers relate theory and practice together, although it is highlighted that they have a difficult time articulating their pedagogical reasoning (Barends, 2022). "Through pedagogical reasoning, the 'why' of teachers' practice is made available and in doing so, begins to illustrate the nature of teachers' professional knowledge" (Loughran, 2019, p. 527).

As pre-service teachers engage with classroom practice during Work Integrated Learning (WIL), ideally, they would learn to apply their knowledge by observing important instructional decisions that shape the learning experience. It would be expected then, that pre-service teachers nearing the end of their qualifications (final years) would be better equipped for observing and interpreting teaching in comparison to first years (who have just started their teacher preparation programmes). Noticing helps the pre-service teachers understand the complexities of teaching, particularly how mathematical content knowledge and PCK is enacted through teacher explanations and interactions with learners. This alignment of theory and practice through noticing is critical for the development of effective teaching (Darling-Hammond, 2006). Thus, using professional noticing to investigate what pre-service teachers identify as important in lesson reports allows us to analyse the depth of their understanding of the teacher's pedagogical reasoning as well as both mathematical content knowledge and PCK. By highlighting what they observe and interpret, we can gain insight into how they are learning to teach, and how they perceive the essential components of effective instruction.

2.2.2 The Four Fundamental categories of competence

In Chapter 5, Morrow (2007) describes what teacher education is and what it should entail. He describes teacher education as "a kind of education which enables someone to become more competent in the professional practice of organising systematic learning and nurtures their commitment to do so" (Morrow, 2007, p. 69). Learning to teach encompasses one to become a professional. A pre-service teacher enrolled in their teacher preparation programme does so to not just mimic the actions of teachers they have encountered during their apprenticeship of observation (Lortie, 1975). Instead, they become members of the professional practice (or practices)." A "professional practice is shaped and guided by the theory that informs it, and by the concepts, beliefs and principles of those who participate in it" (Morrow, 2007, p. 77). However, Morrow (2007) warns that the idea that teacher education will produce a fully competent professional teacher. He argues that at best teacher education can provide a good or bad start of the professional development to become a teacher.

Morrow (2007) adopts the notion about thinking of teacher education in terms of competences. He highlights that this approach is advantageous in thinking in terms of practical knowledge. Morrow (2007) then provides the "four fundamental categories of competence that need to be taken into account in [t]eacher [e]ducation programmes" (p. 84).

1. The first competency involves a strong conception of teaching and its ideals or organising systematic learning. This includes but is not limited to an understanding of the ethical ideals, the history and traditions of the practice. Furthermore, this competence distinguishes between accidental features of the practice with definitive features (Morrow, 2007).
2. The second competency includes the content knowledge that makes it possible for the teacher to teach it. The competency of making content accessible to learners.
3. The knowledge and understanding of the ways "structural factors both enable and place limits on the possible implementations of the practice of teaching" (p. 85).
4. The last competence, which Morrow (2007) argues is the principal competence is competence in organising systematic learning. This competence draws on and presupposes the first three.

As highlighted above, it is not reasonable to believe that at the end of the teacher preparation programmes a pre-service teacher is going to be fully competent. Since the principal competence is organising systematic learning, I present the argument that pre-service teachers should first be able to notice how professional teachers organise systematic learning before they can do it themselves.

2.2.3 Pedagogical Content Knowledge (PCK)

Shulman (1986) introduced the concept of pedagogical content knowledge (PCK) as a means to answer, what he believed to be, the 'missing paradigm' in research on teaching as well as teacher education. He believed that too much consideration was placed on general teaching pedagogy and insufficient attention to of content knowledge used for teaching (Shulman, 1986). Shulman (1986, 1987) conceptualised PCK as the blending of content knowledge and pedagogical knowledge or the formulations or representations of the subject matter (content) in order to make it comprehensible for others. "The foundation of PCK is thought to be the amalgam of a teacher's pedagogy and understanding of content such that it influences their teaching in ways that will best engender pre-service teachers' learning for understanding" (Berry et al., 2008, p. 1272). To Shulman (1987) pedagogical content knowledge (PCK) "represents the blending of knowledge and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (p. 8).

Shulman (1986) argues that pedagogical content knowledge (among others) form the professional knowledge base of teaching. PCK is identified as one of the seven categories of the knowledge base along with content knowledge, general pedagogy, knowledge of learners, curriculum knowledge, knowledge of contexts, knowledge of educational purpose and values, as well as their historical and philosophical grounds (Shulman, 1987). Of the listed knowledge categories, PCK is argued to be the most influential (Ball et al., 2008).

Despite its widespread application, researchers including: Appova & Taylor teaching (2019), Ball et al., (2008) Depaepe et al., (2013), Park & Oliver, (2008) point to some issues surrounding the concept of PCK. Rollnick et al. (2008) define PCK as how teachers navigate subject matter, pre-service teachers and curriculum. In contrast Park and Oliver (2008) describe it as "[the] teachers' understanding and enactment of how to help a group of pre-service teachers understand specific subject matter using multiple instructional strategies, representations, and assessments while working within the contextual, cultural, and social limitations in the learning environment" (p. 264). However, Mazibe et al (2020) find PCK elusive, emphasising its private nature. Mazibe et al (2020) highlight that PCK is a private construct that develops differently in individuals, making it difficult to interpret. Critically, Ball et al. (2008) argue that the ambiguity surrounding PCK's definition stems from its under specification. They state: "Many seem to assume its nature and content are obvious. Yet what is meant by pedagogical content knowledge is underspecified" (Ball et al., 2008, p. 389). It is for this reason that Ball and colleagues (2008) have come up with some refinements to PCK, specifically for the teaching of mathematics. Their work lays the foundation for mathematical knowledge for teaching (MKT), which they describe as the "mathematical knowledge needed to carry out the work of teaching mathematics" (Ball et al., 2008, p. 395).

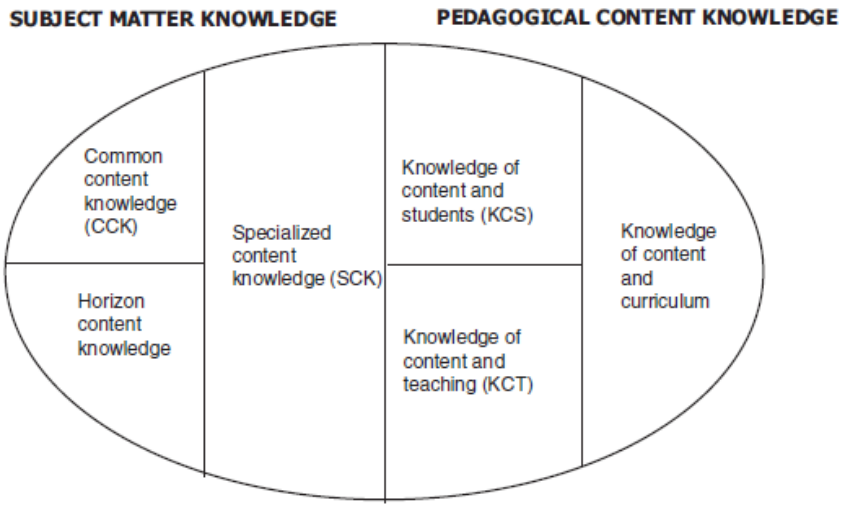
2.2.4 Mathematical Knowledge for Teaching

The mathematical knowledge for teaching (MKT) is argued to include not "only the mathematical knowledge common to individuals working in diverse professions, but also the subject matter knowledge that supports that teaching" (Hill et al., 2008, p. 431). It can then be used to describe the complexity in mathematical knowledge. Ball et al (2008) highlight the complexity of trying to understand the bodies of knowledge that make up mathematics teaching and decided that the best way of trying to create such an understanding of these types of knowledge is by starting at the practice. In their study they looked at the knowledge that teachers use in the 'teaching' of mathematics, which they argue includes everything that must

be done by a teacher to support pre-service teachers' learning of mathematics (Ball et al., 2008). They contend that the concept of pedagogical content knowledge holds value but is underspecified and unclear (Ball et al., 2008). Ball et al (2008) build "on the promise of pedagogical content knowledge, reporting new progress on the nature of content knowledge for teaching" (Ball et al., 2008, p. 389).

The subject matter knowledge for the teaching of mathematics includes common mathematical knowledge such as computational knowledge; the teacher must have the ability to do the work that she is teaching. This type of knowledge was classified as *common content knowledge* (Ball et al., 2008). Additionally, they highlight that mathematical knowledge for teaching also includes content knowledge specific to teaching such as the knowledge required to engage with learners' errors. This type of knowledge was highlighted to be *specialised content knowledge* (Ball et al., 2008). In addition to the subject matter knowledge, Ball et al. (2008) highlight the pedagogical content knowledge which they believe to make up the mathematical knowledge for teaching. It is understood that the pedagogical content knowledge needed for mathematics teaching is made up of: knowledge of content and pre-service teachers, knowledge of content and teaching as well as knowledge of content and curriculum (Hill et al., 2008). Figure 1 displays the bodies of knowledge that Ball et al. (2008) believe to make up the mathematical knowledge for teaching.

***Figure 1**: Mathematical knowledge for teaching*



The mathematical knowledge for teaching "illuminate[s] some of the specialised mathematical work of teaching that marks it out as distinct from mathematicians" (Adler, 2015, p. 44). Hill et al (2008) illustrate a strong correlation with mathematics teachers' content knowledge and

their teaching. It was found that "not only do high-knowledge teachers avoid mathematical errors and missteps, they appear able to deploy their mathematical knowledge to support more rigorous explanations and reasoning, better analysis and use of student mathematical ideas, and simply more mathematics overall" (Hill et al., 2008, p. 457). Therefore, highlighting the importance for teachers to represent an appropriate level of mathematical knowledge for teaching (MKT).

Despite on-going debates, scholars like Depaepe et al. (2013) recognize the enduring impact of pedagogical content knowledge (PCK) in teaching and teacher education research, as emphasized in the South African Minimum Requirements for Teacher Education Qualifications (MRTEQ) (DHET, 2011). PCK, seen as the pedagogical translation of specific subject matter, is crucial for effective mathematics teaching and contributes to pre-service teachers' professional identity (Appova & Taylor, 2019). However, studies reveal variations in how PCK is developed among individuals, influenced by values, beliefs, and contextual factors (Lannin et al., 2013; Mazibe et al., 2020). Preparing future mathematics teachers requires a nuanced understanding of these factors. The literature highlights PCK's vital, context-specific role in mathematics education. While it enhances teaching, reflection, and technology use, challenges include weak subject knowledge, knowledge gaps, and technological PCK readiness (Jina Asvat, 2024). In this study I explore how pre-service teachers, guided by their teacher preparation programs, notice mathematical knowledge for teaching and pedagogical knowledge when observing a lesson on exponential equations. The analysis of their observations aims to unveil insights into their noticing of mathematics teachers' pedagogy, content knowledge. The reader is advised that in I selected Pedagogical Content Knowledge (PCK) because it allows for an examination of the blending of content and pedagogy. I opted not to use Mathematical Knowledge for Teaching (MKT), as its distinct components extend beyond the scope of this research.

2.2.5 Pre-service teachers learning to become teachers

Darling-Hammond (2006, p. 21) argues that "among pre-service teachers who become teachers, those enrolled in formal pre-service preparation programs are more likely to be effective than those who do not have such training". In the programmes of preparing to become a teacher attempts are made to inform pre-service teachers that the role of a teacher is unlike to what they have experienced during their apprenticeship of observation (Darling-Hammond, 2006; Lortie, 1975). These programs make use of modules to inform the knowledge base of

the prospective teacher. Cochran-Smith and Lytle (1999) argue that a central construct within the knowledge base of teachers is PCK, requiring them to blend content and pedagogy. Pre-service teachers must come to understand that teaching is an embodied practice which is informed by different bodies of knowledge that they should acquire during their engagement with programmes in preparation of becoming a teacher (Rusznyak & Bertram, 2021). Mathematics teaching specifically, is an informed practice which "demands… knowledge at the intersection of content and teaching" (Ball et al., 2008, p. 403). The complex activity of teaching mathematics requires the teacher to not only be proficient in mathematics but also have the knowledge on how to best allow their learners access to mathematical knowledge. The mathematical knowledge for teaching in particular draws attention to the specialised mathematical work of teaching (Adler, 2015). A part of learning to teach, is to learn to see the important decisions and other aspects of teachers' actions that are informed by pedagogic reasoning (Rusznyak & Bertram, 2021). However, Jina Asvat (2025, p. 58) shows that pre-service teachers "often internalise the misconception that mathematics lacks creativity or reasoning, reducing it to rote memorisation. When [pre-service teachers] adopt such classroom routines, they risk perpetuating this limited view of mathematics, conflating the roles of mathematics teachers".

Teacher preparation programmes require the connection of theory with practice to support the advancement of powerful teaching (Darling-Hammond, 2006). However, a problem that novice teachers face, is the incompatibly between their experience in the classrooms and the theoretical knowledge they acquire in academic settings (Lin, 2005). Due to the influence of their initial understanding of the practice, pre-service teachers often focus on visual aspects of teaching and do not tend to the more intricate aspects (Lortie, 1975). The embodiment of the practice requires pre-service teachers to engage with both the knowledge base that informs it as well as the practice itself. Teacher preparation programs engage in the practical aspect through the use of work-integrated learning (WIL), as necessitated by the MRTEQ (DHET, 2011). Rusznyak and Bertram (2021) highlight that WIL has value for pre-service teachers to integrate and apply different bodies of knowledge that inform teaching form their coursework.

The engagement with WIL can be done by the pre-service teachers through either, engaging in the practice themselves or through observing experienced practice (DHET, 2015). Spangeberg (2017) argues that engaging with WIL through the latter, allows pre-service teachers to engage with "learning-from-practice, such as observing best practice, participating in micro-teaching

exercises and taking subject methodology courses" (p. 94). In the context of this study, pre-service teachers engage with WIL by observing online teaching of mathematics lessons. The online TCiA module that participants of this study engage with, allows pre-service teachers the opportunity to pause, rewind and replay the lesson as they wish (Rusznyak, 2020b). Engaging with WIL in this manner "allows for a depth of reflection and analysis [which is] not possible during live observations" (Santagata et al., 2007, p. 125).

However, Spangenberg (2017) notes that some pre-service teachers "have informally complained that theory offered in the mathematics methodology modules is not relevant to what is expected in practice" (p. 93). In their study Rusznyak and Bertram (2021) determine how the quality of learning during the engagement of WIL would be strengthened if pre-service teachers recognise how teachers' choices in lessons are informed by principled knowledge, contextual priorities, material conditions and ethical orientation of the practice. Langsford and Rusznyak (2024) highlight pre-service teachers' capacity to recognize and interpret educators' intentions and decisions is essential for their pedagogical development and grasp of effective teaching practices. This study focuses on the extent to which pre-service teachers employ pedagogical knowledge and mathematical content knowledge, to understand the choices behind the mathematics lessons they observe. This is done through the analysis of pre-service teachers' lesson observation reports.

2.2.6 Exponential Equations

A thorough understanding of exponential equations requires knowledge of various interconnected mathematical concepts that form the foundation of this topic. Exponents represent repeated multiplication (Pournara et al., 2021). For example, in the expression $2 \times 2 \times 2$, the number 2 is multiplied by itself three times. Exponential notation consists of a base and an exponent. The base is the number being multiplied, while the exponent indicates how many times it is multiplied. The example can be written as a power: 2^3, where 2 is the base and 3 is the exponent. In this example, $2 \times 2 \times 2$ is expressed in exponential form as 2^3.

Exponential equations is a subtopic of exponents which is covered towards the end of the topic in most Grade 10 Mathematics textbooks (see Platinum; Mind Action Series; Classroom Mathematics). The systematic learning of this topic requires an understanding of the algebraic expressions and equations; exponential laws as well as order of operations. An exponential equation is an equation with variables in the exponent position. Finding the solution of an exponential equation requires one to find the value of the unknown which satisfies the result.

The teaching of exponential equations requires the teacher to have an in-depth conceptual understanding of the topic based on its high relationality to other topics in mathematics (such as algebra, functions and relationship as well as logarithms). The Wits Maths Connect Secondary Project highlights that "exponents and powers involve repeated multiplication" (Pournara et al, 2021, p. 2). An "equation consists of two expressions that produce the same result" (Pournara et al, 2021, p. 1). An exponential equation involves exponential expressions, where the results are the same and the variables or unknowns are the exponents.

According to CAPS, the topic of exponential equations is covered in Grade 10 after simplifying exponential expressions (DoE, 2015). Solving exponential equations requires the one to find the value of exponent that satisfies the results of the expressions. For example:

$2^x = 2^3$

$\therefore x = 3$

This topic develops from exponents but requires a substantial understanding of Algebra and is later crucial to the understanding of logarithms (which are covered in Grade 12). In grade 7 they are introduced to exponential form, in addition to doing basic calculations in exponential form. For example:

1. $a^n = a \times a \times a \times a$ for n number of factors and,

2. $5^3 + 6^2 = 5 \times 5 \times 5 + 6 \times 6 = 125 + 36 = 161.$

In grade 8 they are introduced to the laws and definitions of exponents (limiting to natural number exponents) (DoE, 2011, p. 15). These laws include and definitions:

Exponential Laws

- $a^n \times a^m = a^{n+m}$
- $a^n \div a^m = a^{n-m}$
- $(a^m)^n = a^{mn}$
- $(a \times t)^n = a^n \times t^n$

Exponential Definitions

- $a^n = a \times a \times a \times a \ldots n$ times
- $a^0 = 1$

- $a^{-n} = \frac{1}{a^n}$ (Taken from Wits Maths Connect Project (see Pounara, 2021)

Teaching exponential equations may elicit some difficulties. Birenbaum and Tatsuoka *(*1993*)* found in their study that learners tend to have issues with applying the definition of $a^0 = 1$ and the law of $(a^m) = a^{m \times n}$. Lay (2006) highlights that learners often misunderstand $a^0 = 1$ due to the understanding of exponents as repeated multiplication. He highlights that the initial state should start at one since its multiplicative properties do not change its outcomes. This highlights to the learners that any number raised to the power of 0 is one. At a grade 10 level, learners may not be adept with the conceptual connections to relate the concept of exponential equations to exponential functions or the quotient law of exponents. This isolated understanding of the topic results in a difficulty understanding the definition $a^0 = 1$, as they try to understand it solely on their own conception of repeated multiplication. In a more recent study Hewson (2013) discovered that learners displayed difficulties with solving exponential equations, by making the bases the same (see figure 2). In the first question, the student presents a misconception of factorising the base and the product of the exponent. Similarly, example two demonstrates a misconception of halving the original base and writing it as an exponent.

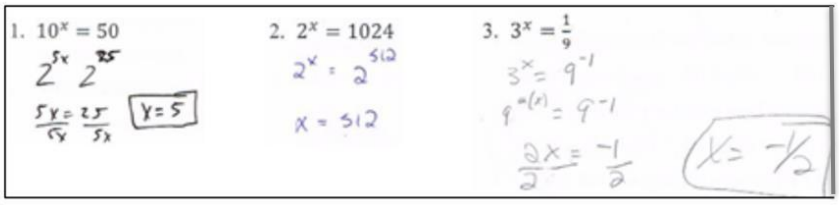


Figure 2: Grade 10's errors in solving exponential equations (see Hewson, 2013)

Tbakeni and Mutambara (2023) argue that "[e]xponential equations are a vital part of high school mathematics" because there are "an important branch of mathematics which [cut] across all spheres" (p. 150). In their study, they found that many mathematics leaners memorized algorithms and did not conceptualise the material they learnt but instead used their rote memorisation. These learners "have the tendency to apply rules even if they do not understand them". Jupri et al (2021) and Tseng (2012) assert that pre-service teachers typically rely on algorithmic techniques when working with exponential equations, often failing to demonstrate a strong conceptual understanding. In their study Jupri et al (2021) found that pre-service teachers tend to not make links to their prior knowledge or make use of sense strategies but instead follow structure strategies that provide the procedures for them to follow. Their

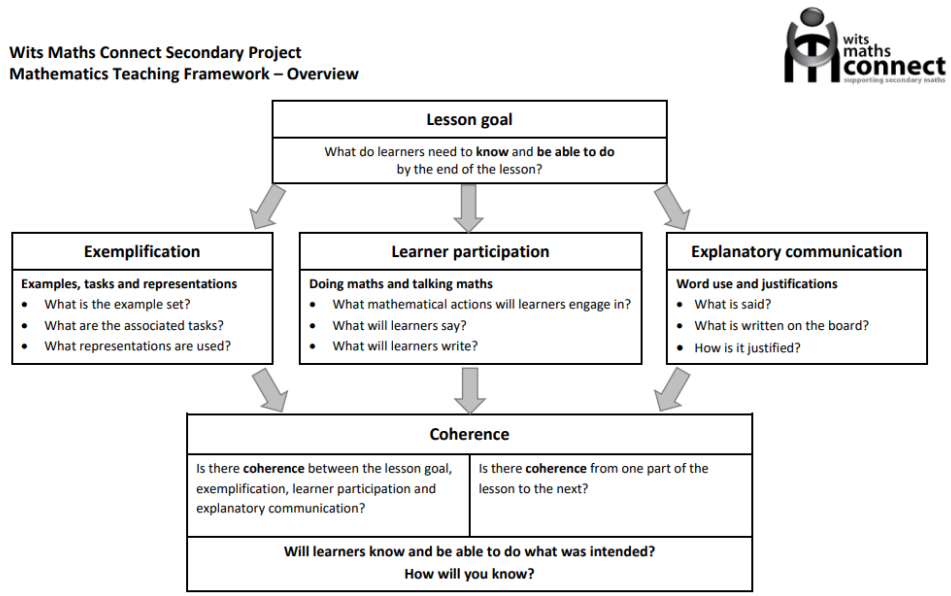
strategies made use of in the study demonstrated difficulties in recognizing familiar structures (Jupri et al., 2021).

Jupri and Sipiyati (2020) argue that to help pre-service teachers better understand what they've learned, it's important to find out where their weaknesses lie. Tseng (2012) highlights the importance of starting with concrete examples before providing the general theorem to pre-service teachers. Hewson (2013) highlights the difficulty placed on educators in helping pre-service teachers deal with their mistakes on exponential equations, such as preparing themselves to spend more time on the topic.

2.2.7 Mathematics Teacher Framework

PCK is argued to be contextual, unique, difficult to identify or underspecified (Park & Oliver, 2008; Mazibe et al., 2020; Ball et al., 2008). However, evidence of this knowledge may display itself through manifestations of the PCK (Rollnick et al., 2008). For interpretation of these manifestations a use of a mediator is required. This study employs the use of the mathematics teaching framework (MTF) as a mediator for the visible manifestations of PCK. Figure 3 gives a brief description of the framework to the reader. A more detailed description is then given below.

Figure 3 Mathematics Teaching Framework



The use of a framework assists a researcher to make sense of a certain context, and in the sense of mathematics teaching does not exclude the culture of the mathematics classroom (Trouche

et al., 2023). The Mathematics Teaching Framework "[MTF is] an ideational resource to foreground it as a reified set of ideas about mathematics and mathematics teaching in general, and ideas in a mathematics lesson in particular" (Adler, 2021, p. 1212). This study uses the Mathematical Teaching Framework to interpret pre-service teachers' understandings of teaching, through what they have written in their lesson observation report. "Mathematics is viewed as an interconnected network of scientific concepts and mathematics teaching therefore as goal directed, with mediation of learning toward sophisticated ways of thinking in a discipline" (Adler, et al 2023, p. 42).

The Mathematics Teaching Framework structures mathematics instruction around a clear lesson goal, ensuring alignment between exemplification, learner participation, and explanatory communication. Exemplification involves selecting examples, tasks, and representations to illustrate concepts. Learner participation focuses on pre-service teachers' engagement in mathematical actions, while explanatory communication addresses how mathematical ideas are conveyed and justified. Coherence across these components ensures that instructional choices support the intended learning outcomes.

This framework aligns with pedagogical content knowledge (PCK) (Shulman, 1987), which integrates subject matter and pedagogy for effective teaching. However, pre-service teachers often struggle to move beyond their 'apprenticeship of observation' (Lortie, 1975), relying on their experiences as learners rather than understanding the complexities of teaching (Darling-Hammond, 2006; Langsford & Rusznyak, 2024). While Work-Integrated Learning (WIL) aims to bridge theory and practice (Loughran, 2019), pre-service teachers often focus on visible teaching aspects, neglecting the invisible pedagogical choices that shape instruction (Rusznyak, 2020). This theory-practice divide hinders their ability to integrate content and pedagogy effectively.

By analysing how pre-service teachers report on mathematics teaching during WIL, this study explores their PCK development, particularly in selecting examples, engaging learners, and structuring explanations. The Mathematics Teaching Framework provides a lens to examine these aspects, identifying areas where teacher education programs can better support pre-service teachers in bridging theory and practice.

The MTF framework helps mathematics teachers with the transparency of mathematical teaching (Adler, 2021). As part of teacher preparation programs pre-service teachers are

required to observe mathematics teaching in practice. The complex activity of observing someone else's PCK can be particularly challenging as it is uniquely constructed (Mazibe et al., 2020). During their engagement of WIL through the TCiA module, participants of the study report on the teaching of mathematics. The use of this framework allows me, as the researcher, insight into the visible actions of the teacher that the pre-service teacher focuses on. In this study, I make use of the MTF framework to offer insight into the PCK that pre-service teachers may bring to forefront when writing lesson reports on observed lessons. It is a useful tool in that it represents "a shared language on teaching practices" allowing me to analyse, pre-service teachers' reports on the teaching of Exponential Equations lesson, where they should use their bodies of knowledge to interpret the actions of the teacher they are observing (Adler, et al 2023, p. 42).

The conceptual framework for this study can be illustrated as

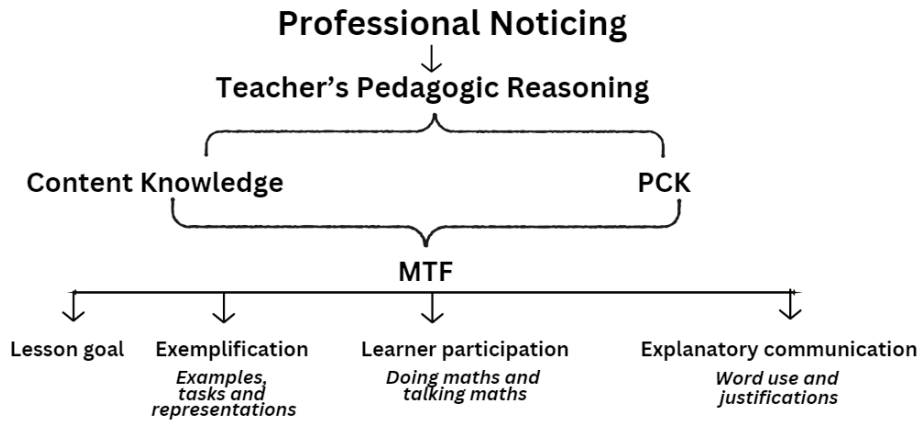


Figure 4: Conceptual Framework

Figure 4 illustrates the conceptual framework this study makes use of. Starting from the bottom, making use of the MTF one can determine which aspect of mathematics teaching pre-service teachers use knowledge and PCK to interpret and understand the teacher's pedagogical reasoning. These elements that the pre-service teachers choose to focus on give insight into what they are professionally noticing about the teacher's pedagogic reasoning.

2.3 Theoretical Framework

2.3.1 Legitimation Code Theory (LCT)

Maton (2013) describes Legitimation Code Theory (LCT) as a 'toolkit' which can be used for the study of practice. LCT is a framework that can be used by researchers to engage deeper with their study by extending their access to conceptual tools through the codes that it provides.

Maton (2013) argues that "LCT cumulatively works within the problematic approach of code theory to offer concepts that extend existing conceptual tools" (p. 10-11). LCT is multi-dimensional and widely applicable, as the concepts offered in this theory may be applied to many different scenarios as well as across disciplines. Hence, there are many different studies that make use of LCT as a lens across disciplines such as mathematics, science, languages (Blackie, 2014; Clark, 2019; Doran, 2021) among many others.

LCT has several different dimensions, each dimension focused on conceptualizing a specific legitimation code (Maton, 2014). In this study, I concentrate on Semantics. "Semantics" refers to the meaning that we give ideas, actions, symbols, words or images. The emphasis on the Semantic dimension is useful for analysing to address context-dependence and meaning condensation (Maton, 2013). Two semantics concepts address these issues: semantic gravity and semantic density. This study focuses on the latter, describing how meaning condenses within socio-cultural practices (Maton, 2011, 2013).

2.3.2 Semantic Density:

As highlighted above semantic density describes condensation and relation of meanings within socio-cultural practices. In other words semantic density is how complex or simple meaning is. The meanings tied to a concept can determine its level of complexity, the more meanings associated with a concept, the more condensed the concept or a greater complexity. "This process of adding meanings to a symbol or practice is termed condensation" (Maton & Doran, 2017a, p. 50). Condensation is one type of complexity. The other type of complexity derives from a network of knowledge externally from the concept. "Put another way, semantic density explores the relationality of meanings: the more meanings are related, the stronger the semantic density" (Maton & Doran, 2017b, p. 49). This is the relational type of complexity.

Due to the contextual nature of this concept there have been a multitude of studies conducted across the fields that draw on the concept of semantic density. Numerous studies have been conducted in educational research. Education specific research in this area include: the complexity of pre-service teachers reflections on their practice (Rusznyak, 2022b), the promoting of pre-service teachers competencies in informatics education (Ritter & Standl, 2023), inclusive education in teacher education in South Africa (Walton, 2017), how complex or abstract science learning outcomes are (Lee & Wan, 2022), for the aid of teaching organic

chemistry (Blackie, 2014), the development of pre-service teachers' contextual and conceptual understandings of inclusive teaching (Walton & Rusznyak, 2020) as well as developing an emergent response to the practical requirements of teacher preparation programs (Rusznyak, 2022a) among others. However, there are limited studies in mathematical education that make use of the concept of semantic density.

Legitimation Code Theory allows for the translation between theory and data creating a relationship between the two (Maton & Chen, 2015). For development of these relationships, it is argued that researchers require external languages that can be used to determine their use in a specific study, such as the boundaries that classify the data (Maton & Chen, 2015). These boundaries allow the researcher to determine what classification the data may be given, 'weaker' or 'stronger' and are typically comprised of concepts. Such devices can indicate how the concept may be understood empirically through the criteria which relates with the data (Maton & Chen, 2015). Semantic density manifests on a continuum, from less complex to more complex meanings. Maton and Doran (2017b, p. 49) argue that, "the stronger the semantic density (SD+), the more meanings are condensed within practices; the weaker the semantic density (SD–), the fewer meanings are condensed". Based on the concept of semantic density the translation device Table 1 was designed as a tool to analyse the potential PCK manifestation in the descriptions provided by first- and fourth-year pre-service teachers regarding a lesson focused on teaching exponential equations. PCK manifestation will be seen when complex content is brought into relation of complex pedagogical reasoning. This translation device is used to determine the semantic density of two different concepts: the mathematical content and the pedagogical reasoning. It displays how this study works with two different forms of semantic density of each concept. We can distinguish between the different strengths of how the pre-service teachers' written Lesson Observation Reports see complexity associated with teachers' work.

Table 1 Translation device of the study

Focus: Mathematical Content Knowledge			
Concept	**Categories**	**Indicators**	**Examples**

stronger	SD++	Pre-service teachers describe the detail of the content to be learnt and make links between the lesson and the overarching purpose of the subject and its competencies. OR Pre-service teachers describe a network of ideas in the lesson and explain how they are connected to one another	Solving exponential equations is an important step developing learners' conceptual understanding of logarithms, which is covered in Grade 12.
	SD+	Pre-service teachers give a detailed account of a concept or skill that learners need to understand during the lesson.	In the lesson the teacher describes what a power is (a number with a base and an exponent).
Weaker	SD–	Pre-service teachers refer to the content of the lesson mentioning concepts or skills without articulating detail.	The lesson is on exponential equations
	SD– –	Pre-service teachers refer to aspects of the lesson without reference to the content.	The teacher kept the children busy and motivated.

Focus: Pedagogical Knowledge			
Concept	**Categories**	**Indicators**	**Examples**
stronger	SD++	Pre-service teachers describe patterns in the teacher's actions and suggest overarching reasons for those patterns. Typically, Pre-service teachers explicitly mention technical terms from educational theories and approaches.	The teacher makes use of semantic waves. Starting on a high flat-line, unpacking the concepts to make them more comprehendible. Then repacking them to create generalizations.
	SD+	Pre-service teachers describe the teacher's actions and/or suggest a specific reason for each individual action. Typically, Pre-service teachers do not explicitly mention technical terms from	The teacher asks the learners to copy from the board and complete the activity.

		educational theories and approaches	
Weaker	SD–	Pre-service teachers describe the teacher's actions without suggesting a reason for those actions.	The teacher explains what the learners must do.
	SD– –	Pre-service teachers describe aspects of the teacher's classroom practice without mentioning what the teacher is doing or why.	The lesson is on exponential equations.

2.4 Conclusion

This chapter has outlined a conceptual framework that positions professional noticing as key to understanding the relationship between mathematical content knowledge, pedagogical content knowledge (PCK), and effective teaching. By analysing what pre-service teachers observe and prioritize, we can understand their grasp of pedagogical reasoning and their ability to connect content knowledge with instructional practice. The integration of the Mathematics Teaching Framework (MTF) enhances this analysis, offering a structured way to link teaching practices to broader pedagogical concepts. This framework underscores the importance of noticing in bridging theory and practice, enabling pre-service teachers to engage with critical aspects of classroom instruction. By focusing on their observations and interpretations, we gain insight into their learning process and their perceptions of effective teaching. This chapter thus lays the groundwork for exploring how professional noticing can foster the development of teaching expertise, particularly in mathematics education.

Chapter 3 Research Methodology and Research Design

3.1 Introduction

This study aims to investigate the ways in which pre-service teachers describe, notice and interpret mathematical teaching as a practice. It seeks to analyse how participants view teaching as a practice informed by pedagogical content knowledge (PCK). Shulman (1987) describes PCK as the "blending of content and pedagogy into an understanding of how particular topics, problems or issues are organised and presented for instruction" (p. 8). This study hopes to

identify the complexity at which pre-service teachers notice the mathematical content knowledge and pedagogical content knowledge of the teacher, and how these are blended (if at all) when observing a mathematics teacher in practice. It therefore makes use of the qualitative research approach, through analyses of pre-service teachers' individual lesson observation reports, which are influenced by their context and social relations. This study specifically looks at the reports that mathematics pre-service teachers have written based on an online mathematics lesson on the topic of exponential equations. It seeks to compare the reports of first year pre-service teachers to that of final/fourth year pre-service teachers; to see what they notice in practice of mathematical teaching.

3.2 Context of the study

The Covid-19 pandemic posed a problem for pre-service teachers to attend in-person teaching practicums. The Teacher Choices in Action (TCiA) module was developed in response to fulfil the teaching practicum requirements of the teacher preparation programmes through remote access. It was used as an online replacement of work-integrated-learning when pre-service teachers were unable to complete their practicum requirements in schools (Rusznyak, 2020a). The module helped pre-service teachers (in different specialisations) to interpret and observe the pedagogical choices of a teacher within their specialist subject/phase.

The TCiA module provided pre-service teachers with an alternative to school-placed teaching experience by providing a learning-from-practice approach (Rusznyak & Bertram, 2021). "The module draws the attention of pre-service teachers to the ways teachers work with subject knowledge, education theory and student diversities in their school contexts" (Rusznyak, 2020, p. 4). During engagement with the module pre-service teachers choose video recorded lessons (based on their specialisation) and analyse the choices that the teacher makes in these lessons, looking at how the teachers "work with concepts, and engage pre-service teachers in discussion, learning activities and assessment tasks" (Rusznyak, 2020a). The accessibility of this online module allows pre-service teachers to observe the practice in ways unlike real-time, in that they can pause/rewind to reflect and understand the choices made by the teacher.

The module was composed of six different units: 1) choosing to be a teacher, 2) teacher choices in different contexts, 3) teacher choices that work with knowledge, 4) teacher choices that promote cumulative learning, 5) teachers choices for inclusive teaching and 6) teacher choices to manage learning environments (Rusznyak, 2020a). After completing each unit, the pre-service teachers had to choose a lesson from the online lesson library, watch it, analyse the

lesson and then submit a lesson observation report (Rusznyak, 2020a). I acknowledge that pre-service teachers may have noticed more than they documented. However, since there is a pending restraint on a written report, this study takes their written responses to reflect what they deemed most significant.

3.3 Research Methodology

3.3.1 Qualitative Research

This study looks at the individual lesson observation reports of pre-service teachers', focusing on what they notice in the mathematics lesson they observe, which includes the teacher's pedagogical reasoning. Hollstein (2011, p. 405) argues that qualitative approaches "emphasize that making sense of action and meaning" and this "always involves understanding the other". This study analyses the meaning pre-service teachers attribute to the practice of teaching. Additionally, Cresswell and Poth (2016) highlight that qualitative research "begins with assumptions, a worldview, the possible use of a theoretical lens, and the study of research problems inquiring into the meaning individuals or groups ascribe to a social or human problem" (p. 37). This study makes use of a Legitimation Code Theory as a theoretical lens to better understand the meaning pre-service teachers attribute to mathematical teaching in practice.

Creswell and Poth (2016) further argue that "the collection of data in a natural setting sensitive to the people and places under study and data analysis that is inductive and establishes patterns or themes" (p. 37). Participants of this study were in a natural setting of completing the online TCiA module to meet the work-integrated-learning requirements of their teacher preparation programmes. This module gives pre-service teachers the opportunity to slow down the teaching process (Santagata et al, 2007) and thoughtfully engage in their observation of the practice in ways not possible during live observations.

Qualitative research requires certain tools to collect and analyse data (Creswell & Poth, 2016). During the data analysis of the mathematical lesson observations, there was an attempt to establish trends in how participants bring mathematical content knowledge and pedagogical knowledge together during their observations. "To level all individuals to a statistical mean overlooks the uniqueness of individuals in our studies" (Creswell & Poth, 2016, p. 40). This research approach allowed me to gain insight in what each individual participant valued in mathematics teaching for their reports. This insight allows me to compare the value of practice placed on at the initial and final stages of teacher preparation programmes.

3.3.2 Case study

This research uses data in the form of lesson observation reports specifically taken from the TCiA module. A case study research approach has been taken, which can be described as a research study which "involves the study of an issue explored through one or more cases within a bounded system" (Creswell & Poth, 2016, p. 73). Although multiple institutions, with slightly different teacher preparation programmes have been included in the study they have all used the TCiA module for the purpose of work-integrated learning. Similar studies have been conducted which look at different domains such as in subject specialisation or qualification type, which assist in creating a more rounded analysis of what pre-service teachers notice when observing lessons. Creswell and Poth (2016) argue that the "data can be a holistic analysis of the entire case or an embedded analysis of a specific aspect of the case" (p. 75). To give a more holistic view on the aspect of what pre-service teachers notice about the practice of teaching mathematic, this study compares first, and fourth year lesson observation reports written by pre-service teachers enrolled in different South African universities. This study provides insight into the extent to which mathematics pre-service teachers describe, analyse and interpret mathematical teaching as a practice.

3.4 Research Design

3.4.1 The participants

The participants were first- and fourth-year pre-service teachers enrolled in a Bachelor of Education degree in one of five South African Higher Education Institution (Universities A, B, C, D or E). Each of these universities made use of the Teachers Choices in Action (TCiA) module. These universities are situated across four different provinces in South Africa, namely Gauteng, Western Cape, Limpopo, North West and Kwazulu-Natal. To ensure anonymity of the participating universities, the listing of these provinces are not in correspondence to the listing of the pseudomonas of the universities. These universities offer Bachelor of Education (BEd) programs that prepare pre-service teachers for teaching in different phases. These universities offer four-year Bachelor of Education (BEd) programs that prepare pre-service teachers for teaching in different phases. All of which provide specializations in Foundation, Intermediate, Senior, and FET phases, combining academic coursework with practical teaching experience. All graduates qualify for registration with the South African Council for Educators (SACE). Differences include specialization options (University B offers Mathematics, Science, and Economics specializations), delivery modes (University E provides both contact and distance learning), and admission criteria.

The participants all have a specialisation in Mathematics. All the universities in this study offer comprehensive courses in both content and methodology that participants must successfully complete to advance in their teacher education programmes. The RMRTEQ specifies that during their teacher preparation programmes, pre-service teachers must engage with "disciplinary learning" which includes "specific specialised content knowledge", in addition to "specialised pedagogical content knowledge" which includes "knowing how to present the concepts, methods and rules of a specific discipline in order to create appropriate learning opportunities" (DHET, 2015, p. 10). These participants were pre-service mathematics teachers, who were required to engage with mathematics content courses as well as mathematical pedagogical courses. The participants of this study are either starting their journey in becoming a mathematics teacher (first- years) or are nearing the completion of their teacher preparation programmes (fourth- years).

During their teacher preparation programs, pre-service teachers typically engage with a range of courses, which together provide them with access to various bodies of knowledge essential for teaching (DHET, 2011). A crucial part of this knowledge comes from engaging in practice. However, due to circumstances such as the Covid-19 pandemic, participants were required to transition to remote learning, including their work-integrated learning (WIL) (Rusznyak, 2022a). As a result of the pandemic's restrictions, pre-service teachers had to shift from learning through practice to learning from practice by observing online mathematics lessons (DHET, 2011).

3.4.2 Method of Data Collection

This study makes use of already collected data from pre-service teachers engaging in the Teachers Choices in Action (TCiA) module. This module was utilized by universities across South Africa as an alternative for in-person teaching practicums due to the constraints imposed by COVID-19. Pre-service teachers engaged with the TCiA module to meet the WIL requirement of their qualification (DHET, 2011). Due to the restraints caused by the pandemic pre-service teachers were unable to attend face-to-face practicums, as a result the TCiA module afforded them the opportunity to observe experienced teachers' practice through recorded lessons. Research suggests that video recorded lessons can be beneficial in relating theory and practice. "Teachers can study video as a way to learn from their own teaching and the teaching of others" (Santagata et al., 2021, p. 120). To understand teaching mathematics as a practice, pre-service teachers are required to engage with WIL (DHET, 2015). Pre-service teachers'

lesson observation reports of a recorded mathematics lesson on exponential equations (during the TCiA module) were collected as the data for this study. Participants of this study were enrolled in a Bachelor of Education in one of five South African universities (University, A, B, C, D and E). Participants were either in their first or fourth year of their teacher preparation programme.

3.4.3 The Lesson Observation Reports

Throughout the TCiA module participants observed recorded mathematics lessons. During engagement with this module, pre-service teachers were required to complete several tasks, two of which were lesson observation reports. Pre-service teachers had to choose a lesson from the lesson library and write a lesson observation report based on this lesson. My research focuses on pre-service teachers' reports on the lesson on exponential equations.

3.4.4 The Exponential Equations Lesson

The lesson which pre-service teachers observed was chosen from the lesson library within the Teacher's Choices in Action (TCiA) module. During engagement with the module, pre-service teachers were required to observe a lesson based on their specialisation and write a lesson observation report, based on this lesson. The data for this study consists of lesson observation reports based on a Grade 10 lesson on exponential equations. Other mathematics lessons which the pre-service teachers had the option to choose include (but are not limited to): AP mathematics lesson on implicit differentiation (Grade 11); AP mathematics lesson on derivatives of trigonometric functions (Grade 12); theorem of Pythagoras (Grade 8); introduction to trigonometry (Grade 10); investigating real patterns (Grade 10); Future value annuities in financial maths (grade 12).

The Grade 10 exponential equation lesson is a short 10-minute, online lesson focused on solving exponential equations. This lesson does not take place in a typical classroom setting instead it takes place in a studio setup, with a mix of digital and physical teaching tools. There is a teacher who explain the math concepts, focusing on exponential equations and a presenter who introduces what is to be expected during the lesson. The teacher uses a screen to show equations and break them down step by step. The learner is engaged, listening to the teachers and solving problems on paper. They write down calculations and follow along with the lesson. The teacher guides them by explaining the steps and making sure they understand. The setup includes bookshelves, a desk, and a digital screen for visuals. The teacher is energetic and makes use of clear explanations. The lesson combines traditional teaching (writing on paper)

with modern tools, making it interactive and easy to follow. There were 6 examples presented in this lesson with varying levels of complexity. These are listed below in the order in which they were presented:

- $3^x = 81$.
- $128 = 2^x$
- $243 = 3^{x+2}$
- $4 \times 5^a = 100$
- $5 \times 5^{x-1} = 625$
- $3^n \times 3^{n-2} = 81$

3.5 Analytical Frameworks

This chapter outlines the analytical frameworks used to compare the lesson observation reports written by first-year and fourth-year pre-service teachers, with a focus on what they notice and consider significant regarding the teacher's pedagogical reasoning. The aim is to analyse the extent to which pre-service teachers engage with both the mathematical content knowledge of the lesson and the pedagogical strategies employed by the teacher they are observing. To achieve this, I draw on the Mathematics Teacher Framework (MTF) and Maton's (2013) Legitimation Code Theory (LCT).

The Mathematics Teaching Framework (MTF) provides a structure for analysing mathematics teaching by focusing on different domains that influence effective instruction. Typically, the MTF consists of: Mathematical Content Knowledge – the teacher's understanding of mathematics concepts, procedures, and structures. Pedagogical Content Knowledge (PCK) – the teacher's ability to teach the mathematics effectively, including knowledge of the elements of the MTF which include – lesson goal, exemplification, explanatory communication, learner participation and coherence. The MTF was used to interpret the aspects of mathematical content knowledge and pedagogical content knowledge that the pre-service teachers noticed in their reports. This framework was used to identify the themes of PCK which emerged from the data. These themes were identified based on the focus of the pre-service teachers writing. Such as; "The teacher engaged the learner by giving exciting problems, during the beginning of the lesson" was coded as an exemplification theme since the focus was on the examples (problems) provided in the lesson (student 19739).

LCT, specifically its semantics dimension, is used as a tool to explore the complexity of these focal points; the complexity with which they describe content knowledge, pedagogic reasoning, and the extent to which they bring these together or keep them separate.

3.6 Example of Lesson Observation Report

To illustrate what first and fourth year pre-service teachers notice about observed lesson of Exponential Equations, I present the examples below of how their lesson observation reports were coded. Two short excerpts were taken from a first- and fourth-year's lesson observation report.

3.6.1 First Year Lesson Observation Report on the lesson on Exponential Equations

This short excerpt was taken from student 19739: This is a grade 10 mathematics lesson on the concept of solving exponential equations

"Exponential Equations is a chapter that deals with equations which include exponents, equations are two equal mathematical expressions, whereas exponents consist of a base and a power. Exponential equations focus on the two equations which contains a variable and the value of the variable needs to be found. The topic contains logical arguments and solutions to the problems, these problems are meant to develop learner's prior knowledge of power numbers and solving for x or variables. This topic will develop learner`s ability to combine prior knowledge and problem-solving skills in mathematics, this lesson requires learners to have had knowledge of solving for variables and power number including laws of exponents from Grade 9 so that they can fully understand how to solve Exponential Equations".

The excerpt's coding is demonstrated by table 2 which is followed by a description of the pathway taken to conduct the analysis of the example. Semantic Density (SD) from Legitimation Code Theory (LCT) was used to code the mathematical content knowledge and the pedagogy apparent in the lesson observation report as highlighted by the different colours below. The colour yellow was used to code the SD of the mathematical content knowledge within the lesson observation report, while the colour purple was used to code the pedagogy.

Table 2 Coding of Excerpt

Student ID: 19739		**Grade: 10**	**Theme**	**Knowledge SD** ++/+/-/--	**Pedagogy SD** ++/+/-/--
Subject: Mathematics	**Year: 1**	**University:** A			
Exponential Equations is a chapter that deals with equations which include exponents, equations are two equal mathematical expressions, whereas exponents consist of a base and a power.			**Mathematical Analysis**	+	--
Exponential equations focus on the two equations which contains a variable and the value of the variable needs to be found.			**Lesson goal**	+	--
The topic contains logical arguments and solutions to the problems, these problems are meant to develop learner's prior knowledge of power numbers and solving for x or variables.			**Exemplification**	-	-
This topic will develop learner`s ability to combine prior knowledge and problem solving skills in mathematics, these lesson requires learners to have had knowledge of solving for variables and power number including laws of exponents from Grade 9 so that they can fully understand how to solve Exponential Equations.			**Mathematical Goals**	-	-

In line one of the excerpts, the pre-service teacher is describing the focal concepts of the lesson (equations and exponents). The theme was coded as mathematical analysis. In the MTF, mathematical analysis falls under the lesson goal which determines what learners need to know and be able to do by the end of the lesson and more specifically, the mathematical ideas of the concept. The description of the content shows a higher semantic density and was thus coded as SD+. While the description displays more complexity than mere mention of the content, it does not display more complex links and therefore was not given a code of SD++. This line of the excerpt shows no mention of the teacher's pedagogy at all and was therefore given a coding of SD-- for the teacher's pedagogy. A similar trend is found in line two of the excerpt. Line three however, highlights the problems that learners will engage with in this topic. The theme was coded as exemplification. The MTF highlights that the example set, tasks and representations all fall under the larger category of exemplification. Line three speaks about the mathematical

problems and how they will develop on learners' prior knowledge but are not specifically stating the aspect about these examples that do so. Hence, the coding of exemplification as a major category instead of the refine ones mentioned above. Line three also alludes to the teacher's work of linking to learner's prior knowledge. Due to this line not specifically describing the pedagogy of the teacher, this line was coded as a SD- for the pedagogy. Line 4 displays evidence of mathematical content knowledge but only mentions the content of this lesson and was therefore given a coding of SD-. Similarly, this line the pre-service teacher did not specifically describe the work or thinking of the teacher but instead alluded to it as was therefore given a code of SD- for pedagogy.

This coding was conducted for the first- and fourth-year lesson observation reports as described above. The following sections focus on comparing the lesson observation reports between first- and fourth-year pre-service teachers.

3.7 Rigour

Objectivity in qualitative research methodology is not entirely possible as it requires a degree of subjectivity to make inferences and give meaning to the data (Creswell & Poth, 2016). Since, I analysed pre-service teachers' lesson observation reports, there is a high level of descriptive validity in these written reports. As for the analyses of these reports there is a degree of validity as they are based on subjective interpretations. I ensured to the best of my ability to not make judgements on what I value in the lesson topics as this would make my research less valid. I checked my interpretations of the data with my supervisor to ensure maximum validity of my results. Since my study forms part of a larger study reliability can be achieved if other researchers who conduct the same research would obtain the same results as I have. When establishing trends in the data, to ensure credibility in my study, I tried to find trends that falsify my patterns.

This study makes use of qualitative research methodological approach. A difficult part of using this research approach is the establishment and maintenance of rigour. It is important for researchers to be confident in the validity of the conduction of their study as well as in the results (Merriam & Grenier, 2019). Where validity displays "whether the means of measurement are accurate and whether they are actually measuring what they are intended to measure" (Golafshani, 2003, p. 599). Since, this study makes use of pre-service teachers' lesson observation reports; there is a high level of descriptive validity in these written reports. In addition, there is a degree of validity for the analyses of these reports, as they are based on

subjective interpretations. It is argued that a qualitative approach cannot entirely ensure objectivity, since it requires an amount of subjectivity to make inferences and interpretations as well as to give meaning to the data (Creswell & Poth, 2016). Whilst conducting this study, I ensured that to the best of my ability, I did not make judgements on what I value in the observed lesson observation topic, as this would make my research less valid. Additionally, interpretations for coding my data have been checked by my supervisor to ensure the maximum validity of my results.

3.8 Ethical considerations

The larger study, which my project is part of, has gained ethical clearance and, to ensure that my study posed no threats. I was granted ethical clearance and given protocol number 2024ECE0014M. In addition, the study has been given ethical clearance to use the Teachers Choices in Action data. The participants of the study have given consent for the use of their observation reports, during their participation in the Teachers Choices in Action module. This data was anonymised, and all the identifying details were removed, before commencement of the study. An ethics waiver was applied for and obtained from the university to ensure that an understanding surrounding the ethical undertakings of this project is taken.

3.9 Conclusion

In this chapter I have discussed the research design and methodology of this study. My research required a qualitative and case study approach for data analysis. The participants of this study were first- and fourth-year pre-service teachers enrolled in a Bachelor of Education, in one of five selected South African universities. These participants engaged with the TCiA module as partial fulfilment of their WIL for their teacher preparation programmes. The data of this study was made up of pre-service teachers' lesson observation reports on an observed exponential equations lesson. I tried to ensure the greatest degree of validity and credibility of my research while taking into consideration issues relating to ethics during the writing of my research. The analysis and findings of this study are presented in Chapter 4.

Chapter 4 Analysis and Findings

4.1 Introduction

This chapter presents an analysis of the data collected from pre-service teachers who engaged with the online Teacher Choices in Action (TCiA) module. The dataset consists of lesson observation reports from first- and fourth-year pre-service teachers, a requirement for

participation in the module. Several universities across South Africa utilized this online module, but this study focuses on lesson observation reports from five institutions, labelled as University A, University B, University C, University D, and University E. The reader is reminded that a description of these universities is provided in section 3.4.1.

The data analysed includes only reports from pre-service teachers who specifically chose to observe the lesson on exponential equations from the TCiA lesson library. The reader is reminded that in the lesson the teacher goes through different examples of solving for the unknown (x) in exponential equations by making the bases the same. This selection criterion influenced the number of reports coded from each university, resulting in varying sample sizes: University A (35 reports), University B (10 reports), University C (14 reports), University D (6 reports), and University E (4 reports). Given the scope and length constraints of this study, only University A is examined in depth using a case study approach. The chapter begins with an overview of all five universities before delving into a detailed analysis of first- and fourth-year lesson observation reports from University A.

4.2 Analytical tools used in the study

This study made use of the Mathematics Teacher Framework (MTF) to code pre-service teachers' lesson observation reports into themes. Each element of the MTF was used to code the pre-service teachers' lesson observation reports into themes. Figure 5 provides an illustration of the MTF and its elements that were used to code the themes of the lesson observation reports.

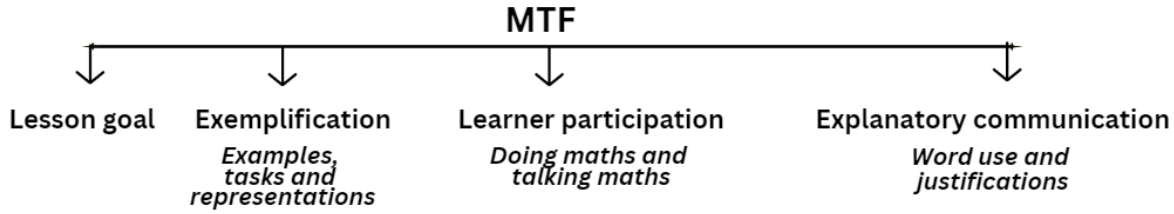


Figure 5: Illustration of MTF's Elements

In addition to the MTF, this study makes use of semantic density from Legitimation Code Theory to analyse pre-service teachers' lesson observation reports. The reader is reminded that semantic density refers to the complexity of pre-service teachers' written lesson observation reports. Maton and Doran (2017) explain that semantic density reveals both the relationality and condensation of meanings. The more meanings are interconnected or condensed within a

report, the higher its semantic density. Semantic density exists on a continuum, ranging from less complex to more complex meanings. To capture this variation, the data was coded into four categories using the translation device outlined in the methodology chapter (see section 2.3.2). Below is a reminder of the translation device for reference:

	Concept	**Categories**	**Indicators**
Knowledge	stronger	SD++	Pre-service teachers describe the detail of the content to be learnt and make links between the lesson and the overarching purpose of the subject and its competencies. OR Pre-service teachers describe a network of ideas in the lesson and explain how they are connected to one another
		SD+	Pre-service teachers give a detailed account of a concept or skill that learners need to understand during the lesson.
	weaker	SD–	Pre-service teachers refer to the content of the lesson mentioning concepts or skills without articulating detail.
		SD– –	Pre-service teachers refer to aspects of the lesson without reference to the content.

	Concept	**Categories**	**Indicators**
Pedagogy	stronger	SD++	Pre-service teachers describe patterns in the teacher's actions and suggest overarching reasons for those patterns. Typically, Pre-service teachers explicitly mention technical terms from educational theories and approaches.
		SD+	Pre-service teachers describe the teacher's actions and/or suggest a specific reason for each individual action. Typically, pre-service teachers do not explicitly mention technical terms from educational theories and approaches
	weaker	SD–	Pre-service teachers describe the teacher's actions without suggesting a reason for those

			actions.
		SD– –	Pre-service teachers describe aspects of the teacher's classroom practice without mentioning what the teacher is doing or why.

4.3 Comparison of semantic density of fourth-year codes across South African universities

This section presents an analysis of the fourth-year lesson observation reports from five universities (A to E), focusing on the mathematical content and pedagogy of the observed lesson. This is followed by a case study examining both first year and fourth-year (final-year) pre-service teachers from University A. An overview of the complexity of each university's lesson observation reports is provided, specifically in terms of mathematical content knowledge and pedagogical knowledge. The dataset consists of written lesson observations from recorded lessons on Exponential Equations, retrieved from the Teacher Choices in Action (TCiA) module. While pre-service teachers may have noticed more than they documented, their written responses reflect what they deemed most significant. As outlined in Chapter 3.5, participants engaged with the TCiA module, selected the Exponential Equations lesson, and based their lesson observation reports on this lesson. The study investigates the extent to which pre-service teachers integrate content knowledge and pedagogical reasoning when analysing the exponential equation lesson.

This section of the analysis explores how fourth-year pre-service teachers from five South African universities reason pedagogically about a Grade 10 exponential equations lesson. Using semantic density (SD) as a framework, lesson observation reports were analysed based on the frequency with which pre-service teachers identified and articulated different levels of content knowledge and pedagogical reasoning in their reports. The findings reveal significant variations across universities, highlighting both strengths and gaps in how future educators conceptualize and describe teaching practices. The analysis starts with the knowledge of the lesson and then moves to the pedagogy.

4.3.1 Analysis of Knowledge Coding across Universities

The analysis of mathematical content knowledge (SD) reveals disparities in how deeply pre-service teachers engaged with mathematical concepts in their lesson observations. Table 3

gives the results from the semantic density analysis for each of the five universities. I use a count in Table 3 to give an actual number of occurrences for each practice per university. In addition, I make use of percentages to help draw comparisons across the universities.

Table 3 Results from semantic density coding of fourth-year Mathematical Content Knowledge

University	SD--	SD-	SD+	SD++	Total
A	112 (68%)	35 (22%)	17 (10%)	0 (0%)	162
B	46 (53%)	20 (23%)	19 (22%)	2 (2%)	87
C	54 (39%)	50 (37%)	28 (20%)	5 (4%)	137
D	37 (39%)	41 (44%)	16 (17%)	0 (0%)	94
E	39 (61%)	23 (36%)	2 (3%)	0 (0%	64

The data presents how fourth-year pre-service teachers, across five South African universities analysed and described the knowledge dimension of a Grade 10 lesson on exponents in their lesson observation reports. The coding categories range from SD-- (content not mentioned) to SD++ (elaborated concepts). The percentages provided indicate how frequently each descriptor was recognized in the reports.

University A

In University A's participants' reports, SD-- (content not mentioned) was the most frequently occurring category, identified 68% of the time. This suggests that pre-service teachers often failed to acknowledge or recognize conceptual elements in their lesson reports. SD- (content mentioned) was identified in 22% of codes, indicating some level of recognition but without elaboration. A smaller proportion (10%) identified SD+ (concepts defined and/or listed). There were no instances (0%) of SD++ (concepts explained and elaborated) recorded, meaning pre-service teachers did not elaborate on concepts and explain aspects of the lesson in depth. This pattern suggests a tendency towards lower semantic density in how pre-service teachers analysed knowledge, with minimal evidence of deeper conceptual engagement.

University B

Lesson observation reports from University B's participants displayed 53% of codes at SD--, which is slightly lower than University A's participants but still a dominant category. SD- (content mentioned) appeared in 23% of responses, showing that about one-fifth of the codes contained at least some reference to the knowledge being taught. The proportion of SD+ (22%) was relatively higher than University A's participants, suggesting a stronger recognition of defined concepts. Notably, SD++ was recorded in 2% of codes, indicating that only a small fraction of the codes elaborated on conceptual aspects in the lesson observation reports.

University C

University C's participants' reports had a slightly more balanced distribution across categories. SD-- was recorded in 39% of instances, which is lower than at participants from both Universities A and B. SD- (37%) was more prominent in comparison to participants from Universities A and B, suggesting that a greater number of codes at this institution at least acknowledged the presence of content. A considerable 20% of codes recognized SD+, indicating the identification of key concepts, while SD++ (4%) was also noted, reflecting the highest proportion of elaboration among the three universities examined so far.

University D

In reports from University D's participants, SD– was identified 39% of the time, matching the participants at University C. However, SD- (44%) was the dominant category, suggesting that the number of codes indicating content was more frequently mentioned in the reports. SD+ was observed in 17% of codes, and SD++ was absent (0%), meaning no codes elaborated on the concepts. This trend indicates a stronger inclination towards recognizing content without extensive elaboration.

University E

University E's participants exhibited a high percentage of SD-- (60%) corresponding with University A's participants, suggesting that most pre-service teachers failed to mention key concepts in their observations. SD- was recorded in 36% of codes, showing that few codes at least acknowledged content presence. The SD+ category was minimal (3%), and SD++ was entirely absent (0%), indicating the lowest engagement with conceptual elaboration across all five universities.

4.3.2 Comparison of Knowledge Coding across Universities

University A and University E's participants displayed the highest proportions of SD--, suggesting that most pre-service teachers struggled to recognize the conceptual knowledge within the observed lessons. University C's participants demonstrated a more balanced distribution, with SD- and SD+ appearing more frequently compared to the other institutions. They also had the highest percentage of SD++ (4%), showing better engagement in elaborating concepts. University D's participants had the highest SD- percentage (44%), meaning more pre- service teachers mentioned content, but the absence of SD++ indicates limited conceptual depth. University B's participants had a relatively higher occurrence of SD+ and a small amount of SD++, implying that some pre-service teachers engaged in defining concepts but with limited deep explanation. Overall, most pre-service teachers across universities struggled to locate the content knowledge within the subject aims and purposes (SD++), with many responses categorized as SD-- or SD-.

The next section of the analysis focuses on how pre-service teachers notice pedagogy in the lesson observation reports they submitted. The coding of pedagogy provides insight into how pre-service teachers from five South African universities reason about the teacher's pedagogy in a Grade 10 lesson on exponents.

4.3.3 Analysis of Pedagogy across Universities

The coding categories range from SD-- (pedagogical aspects not mentioned) to SD++ (justification and critique of teacher actions). The percentages indicate the frequency with which pre-service teachers identified each descriptor in their lesson observation reports.

Table 4: Results from semantic density coding of fourth-year pedagogical knowledge

University	SD--	SD-	SD+	SD++	Total
A	65 (40%)	52 (31%)	42 (26%)	3 (2%)	162
B	40 (46%)	30 (35%)	15 (17%)	2 (2%)	87
C	60 (44%)	45 (32%)	32 (23%)	2 (1%)	137

D	31 (33%)	38 (40%)	24 (26%)	1 (1%)	94
E	25 (39%)	28 (44%)	11 (17%)	0 (0%)	64

University A

Participants from University A, displayed SD-- (pedagogy not mentioned) in 40% of codes, indicating that a significant portion of lesson observation reports did not comment on the teacher's instructional strategies. SD- (teacher action labelled or mentioned in passing) appeared in 31% of codes, showing that some reports acknowledged the teacher's actions without deeper engagement. SD+ (full description of teacher actions) was present in 26% of codes, suggesting that a reasonable number of codes provided a more detailed account of what occurred in the lesson. However, SD++ (explanation, justification, or critique of pedagogy) was found in only 2% of codes, showing very limited engagement in critically analysing teaching strategies.

University B

University B's participants had a higher SD-- percentage (46%) than University A's participants, meaning that an even greater proportion of codes in the lesson observation reports failed to mention the teacher's pedagogy. SD- (35%) was slightly more prominent than in University A' participants, indicating a moderate level of pedagogical recognition but without significant elaboration. SD+ was identified in 17% of codes, showing a lower proportion of detailed descriptions compared to University A's participants. SD++ was present in only 2% of codes, reflecting a similar level of engagement with deeper pedagogical reasoning as in University A's participants.

University C

Participants at University C, SD-- was recorded in 44% of responses, indicating that a large proportion of codes overlooked pedagogy in their analyses. SD- appeared in 32% of codes, like University A's participants. SD+ was noted in 23% of codes, suggesting that a fair number of codes provided descriptive accounts of the teacher's instructional methods. SD++ was recognized in only 1% of codes, showing limited engagement in critiquing or justifying pedagogical choices.

University D

University D's participants showed a lower SD-- percentage (33%) than the previous universities, suggesting that more reports at this institution at least acknowledged pedagogy. SD- was the most frequent category (40%), indicating that pedagogy was mentioned but without full descriptions. SD+ was observed in 26% of codes, showing that a fair number of reports described the teacher's actions in detail. However, SD++ was recorded in only 1% of codes, highlighting a very limited number of critical analyses of instructional strategies.

University E

University E's participants exhibited SD-- in 39% of codes, showing that a considerable proportion of reports did not acknowledge pedagogical aspects. SD- was the most frequent category (44%), meaning that most reports briefly mentioned what the teacher did but without deeper analysis. SD+ (17%) was the second lowest among all universities

4.3.4 Comparison of Pedagogy Coding Across Universities

Universities B and C's participants had the highest SD-- percentages (46% and 44%), indicating that many reports did not analyse pedagogical aspects of the lesson. University D's participants had the lowest SD-- percentage (33%) and the highest SD- (40%), suggesting that more reports acknowledged pedagogy but in a superficial manner. University A's participants had the highest proportion of SD+ (26%), meaning that more reports provided detailed descriptions of teacher actions compared to the other universities. Universities A and B's participants had slightly higher SD++ percentages (2%) compared to the other universities' participants, though the overall percentage remained very low. University E's participants had the weakest engagement with pedagogical reasoning, showing the lowest SD+ (17%) and no SD++ codes at all (0%). Reports from participants across all universities, SD++ occurrences were extremely low, ranging from 0% to 2%, indicating that reports rarely engaged in explaining, justifying, or critiquing the teacher's instructional choices. Most responses fell into SD-- or SD-, showing that pedagogy was either not acknowledged at all or only mentioned briefly without meaningful analysis. Few reports provided full descriptions (SD+), and even fewer demonstrated a deeper understanding by critically engaging with teaching strategies (SD++).

4.3.5 Comparative Analysis of Knowledge and Pedagogy Coding Across Universities

This section provides a comparative analysis of how lesson observation reports from five South African universities analysed a recorded Grade 10 exponential equations lesson. The analysis considers variations in how frequently pedagogy was recognized and described in the lesson, highlighting patterns, strengths, and areas for improvement in pedagogical reasoning.

4.3.6 General trends in Knowledge vs. Pedagogy analysis in fourth-year reports

Across all five universities, the fourth-year pre-service teachers viewed the lesson atomistically without locating the content in the subject structures, nor the teaching strategies among broader pedagogic patterns or approaches. Higher SD-- and SD- proportions suggest that most pre-service teachers either failed to recognize key elements of the lesson or only mentioned them in passing. SD+ was recorded at moderate levels in both knowledge and pedagogy, showing that some pre-service teachers provided descriptions but often without critical engagement. SD++ percentages were consistently low, indicating a significant lack of elaboration, justification, and critique in their analyses of the teacher's instructional approach.

Table 5 Percentage of Codes for Knowledge and Pedagogy for SD-- and SD++ in fourth-year reports across South African universities

University	SD-- (Knowledge)	SD-- (Pedagogy)	SD++ (Knowledge)	SD++ (Pedagogy)
A	68%	40%	0%	2%
B	53%	46%	2%	2%
C	39%	44%	4%	1%
D	39%	33%	0%	1%
E	61%	39%	0%	0%

Knowledge was overlooked more than pedagogy, as SD-- percentages were generally higher for knowledge than for pedagogy (except for participants from University C). University A's participants had the highest SD-- for knowledge (68%), meaning many pre-service teachers did not recognize or mention key mathematical concepts from the lesson. University C's participants demonstrated relatively better engagement with knowledge, showing the lowest SD-- for knowledge (39%) and the highest SD++ (4%), though still low. University E's

participants had the weakest engagement overall, with high SD-- in both knowledge (61%) and pedagogy (39%), and no SD++ in either category. University B's participants performed relatively better in knowledge than pedagogy, with a slightly higher SD++ (2%) for both knowledge and pedagogy compared to participants from other institutions.

4.3.7 Comparison of Knowledge and Pedagogy per University

University A' participants struggled more with knowledge (68% SD--) than pedagogy (40% SD--), suggesting that pre-service teachers were more focused on analysing the teacher's instructional strategies than the mathematical content of the lesson. SD++ in pedagogy (2%) was slightly better than knowledge (0%), but still extremely low, indicating minimal engagement with justification or critique. 26% SD+ in pedagogy versus 10% SD+ in knowledge suggests that pre-service teachers described teaching actions more frequently than they described mathematical concepts. This suggests that pre-service teachers from University A paid more attention to pedagogy than knowledge, but their engagement remained largely descriptive rather than analytical.

University B's participants portrayed similar SD-- percentages in knowledge (53%) and pedagogy (46%), showing that pre-service teachers struggled to engage with both kinds of knowledge when analysing the recorded lesson. Better SD++ engagement (2% for both knowledge and pedagogy) compared to other universities, but still very limited. SD+ was slightly higher in knowledge (22%) than pedagogy (17%), indicating more focus on listing mathematical concepts than describing teaching methods. University B's participants showed a slightly more balanced approach between knowledge and pedagogy, but the lack of depth in SD++ suggests a need for critical engagement in both areas.

University C's participants portrayed the lowest SD-- in knowledge (39%), indicating better engagement with mathematical content than the other institutions. SD++ in knowledge (4%) was the highest across universities, suggesting that more codes in the reports attempted to elaborate on mathematical concepts in the lesson. Pedagogy SD-- (44%) was still high, with SD++ (1%) being lower than in knowledge, meaning that codes in the reports presented the lesson's mathematical content more than they addressed teaching methods. SD+ in knowledge (20%) and pedagogy (23%) shows a somewhat balanced distribution in describing both what was taught and how it was taught. University C's participants showed the best engagement with knowledge among all universities, but pedagogy was still largely overlooked. The slightly

higher SD++ in knowledge suggests a greater tendency to engage with conceptual explanations than instructional analysis.

For University D's participants, SD-- was almost identical in knowledge (39%) and pedagogy (33%), meaning that codes in the reports paid a similar amount of attention to both. The highest SD- (44% in knowledge, 40% in pedagogy) indicated that mathematical content and teacher actions were often mentioned without full descriptions or critical engagement. SD++ was extremely low (0% in knowledge, 1% in pedagogy), indicating that elaboration and justification were nearly absent in the analyses. This suggests that codes in reports from University D's participants acknowledged mathematical content and teaching strategies more than those from other universities but struggled to provide deeper analysis. The high SD- suggests that pedagogy and knowledge were recognized but not expanded upon.

University E's participants displayed the weakest performance across all universities. It had the highest SD-- in knowledge (61%) and pedagogy (39%), indicating that most codes in the reports failed to recognize key mathematical concepts and instructional elements in the lesson. There were zero instances of SD++ in both categories, meaning no evidence of conceptual elaboration or critical pedagogical analysis was found. SD+ was extremely low (3% in knowledge, 17% in pedagogy), showing that only a handful of codes provided descriptions. University E's participants' lesson observation reports demonstrated the weakest engagement with both knowledge and pedagogy, showing minimal recognition of mathematical content and teaching methods.

In the next section, I provide a detailed comparative analysis of one university, University A. I compare the coding of lesson observation reports from first-year learners with fourth-year data. Additionally, I elaborate on the elements from the mathematics teaching framework coding.

4.4 Case study of University A

In this section a case study is conducted to compare the lesson observation reports of first-year pre-service teachers, to that of fourth-year pre-service teachers from University A. This comparison will be done through analysing the semantic density of both types of knowledge (mathematical content knowledge and pedagogy) in their lesson observation reports, as well as

by analysing the different elements of the Mathematics Teacher Framework (MTF) that present themselves in the pre-service teachers' reports.

4.4.1 University A's First Year Reports

Figure 6 illustrates the codes that presented themselves for University A's first year lesson observation reports on the Grade 10 lesson on the topic of exponential equations.

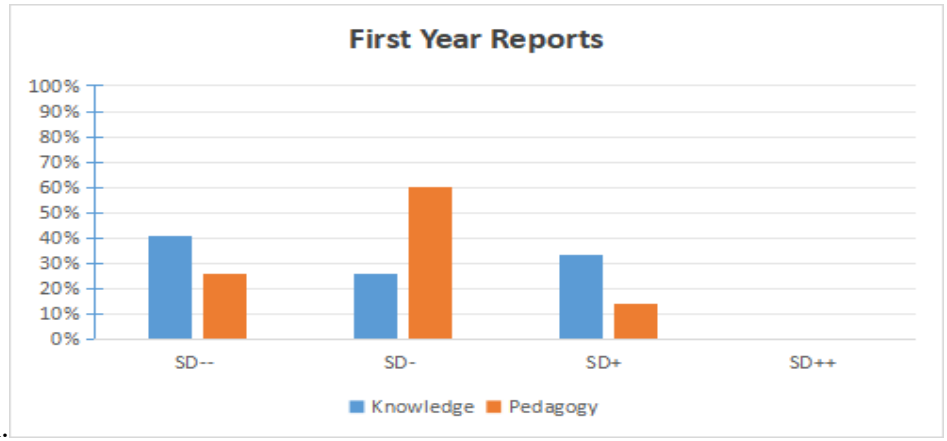
A. 

Figure 6: Semantic Density of Knowledge and Pedagogy Codes in First-Year Reports.

4.4.1.1 Analysis of Knowledge Codes in First-Year Lesson Observation Reports

The first-year pre-service teachers' codes show a predominant classification at the lower levels of knowledge recognition. A significant proportion (41%) of codes did not mention content at all (SD--). This suggests that many first-year pre-service teachers struggled to identify how knowledge was presented or structured by the teacher.

Examples from data:

"The lesson end when the teacher put in together all the presented information highlighting the important points".

In this example, the pre-service teacher refers to the lesson conclusion but makes no mention of the mathematical content of the exponential equations lesson. Instead, the pre-service teacher states that the teacher presented information. This suggests that the pre-service teacher struggled to report on how the teacher presented the content knowledge.

"The interaction between a teacher and the learner shows that there was nothing disturbing the lesson such as noise pollution and violence on the background."

The second example focuses on the dialogue between the teacher and learner as well as the classroom environment. The pre-service teacher made no mention of the content of the lesson.

A further 26% of codes were categorized as SD-, indicating some level of recognition but without elaboration This suggests that pre-service teachers may have listed topics covered in the lesson but did not articulate how concepts were defined or organized.

Example from data:

"As the lesson continues the more complex equations are introduced and way to solve them are shown."

In this example the pre-service teacher mentions the term 'equations' in passing. This shows that pre-service teachers have noticed the mathematical content knowledge but does not further describe or elaborate on the content. Instead, the mathematical content of the lesson was only mentioned in passing.

33% of codes reached SD+, meaning that these pre-service teachers were able to recognize that concepts were defined and/or listed within the lesson. However, they did not go as far as elaborating on how the teacher explained different aspects of these concepts.

Examples from data:

"In this lesson learners learn about solving exponential equation to get the value of a variable that is called X. The variable is always an exponent in the equations."

This example displays that the pre-service not only mentions the content but attempts to describe what the content entails. This pre-service teacher specifically makes mention that exponential equations are used to 'solve for x' as well as that 'x' is the exponent.

None of the first-year pre-service teachers' codes (0%) demonstrated the ability to identify SD++ levels of knowledge, meaning that no reports contained observations where knowledge was both elaborated and aspects explained in depth.

Overall, in the first-year pre-service teachers' codes a significant proportion (41%), do not make any mention of the content of the lesson. This is followed by a reasonable fraction (26%) that briefly mention the content. This suggests that most first-year pre-service teachers struggled to recognize the conceptual knowledge within the observed lessons. However, about a third of the data (33%) was categorized as SD+, implying that some pre-service teachers engaged in describing the concepts of the lesson but with limited deep explanation.

4.4.1.2 Analysis of Pedagogy in First-Year Lesson Observation Reports

The first-year pre-service teachers demonstrated a similarly limited ability to recognize and describe pedagogical work.

26% of codes were categorised as SD-- (pedagogy was not mentioned), meaning that a large proportion of lesson observation reports made no mention of the teacher's actions in the lesson.

Examples from data:
"Most of the learners develop a skill that will be beneficial not just for that particular lesson but for the future."

In this example, the pre-service teacher makes no mention of the teacher's actions. In discussing the particular skill, the pre-service teacher does not mention or describe how the teacher helps learners gain this skill.

"This video is more impactful when she displays her face than if it were just a narrated slideshow, also by doing this, the learners at home will have the idea that the teacher is there but not there".

Although the pre-service teacher mentions the teacher in this example, they do not mention the teacher's actions. The focus is placed on the visual delivery of the lesson but not how the teacher attains systematic learning (Mason, 2002).

A large portion (60%) of codes were categorized as SD-, showing that a large proportion of lesson observation reports mentioned or labelled teacher actions in passing but did not describe them in full. For example, they may have noted that the teacher "asked a question" or "explained a concept" without further detail.

Examples from data:
"When the teacher explain how to solve the equation, the learner also gives her view or idea to solve the equation"

This excerpt mentions that the teacher explained the content of the lesson. However, no further description or elaboration of the explanation is provided.

A small proportion (14%) reached SD+, suggesting that first-year pre-service teachers were able to fully describe what the teacher did. However, they did not engage in deeper analysis,

such as justifying or critiquing the teacher's decisions.

Examples from data:

"The teacher present different equations for learners; these equations start from being basic and as the lesson proceed, they become advanced."

In this excerpt the pre-service teacher describes the pattern of complexity the teacher's explanation takes. However, the pre-service teacher does not further elaborate, justify or explain the teacher's actions.

None of the first-year pre-service teachers' codes (0%) reached SD++, indicating that no codes explained, justified, or critiqued the teacher's actions in a sophisticated manner.

Overall, only 26% of codes made no mention of the teacher's action at all (SD--). While a substantial proportion (60%) mentioned or labelled the teacher's actions. This implies that first-year's reports acknowledge pedagogy but in a superficial manner. A very small percentage of codes reached SD+, and none reached SD++, suggesting that most first-years either failed to recognize key elements of the lesson or only mentioned them in passing.

4.4.1.3. Comparison of Knowledge and Pedagogy for First-Year Pre-service Teachers

University A's first-year codes predominantly operate at the lower complexity levels (SD-- and SD-). First-year pre-teachers were slightly more able to recognize knowledge structure (33% at SD+) than pedagogical complexity (14% at SD+). However, their ability to move beyond basic descriptions remained weak in both categories, with no codes in the lesson observation reports (0%) reaching SD++ levels.

The next section of the analysis focuses on the theme that emerged in the data. These themes were categorised using the MTF.

4.4.1.4 Thematic Analysis of First-Year Lesson observation reports

The reader is reminded that the lesson the reports were based on was a Grade 10 exponential equations lesson. This lesson focused on solving for exponential equations using the same base method. Table 6 illustrates that most of the codes for University A's first-year lesson observation reports were for explanatory communication, making up 34% of the data. The second most prominent theme was Exemplification with 27%. This suggests that the aspects of

the mathematics lesson that the pre-service teachers deemed noteworthy were the examples and explanations used by the teacher.

Table 6 Results of MTF Element in First-Year Reports

MTF Element	Proportion of Element in First-Year reports (Total 215)
Lesson Goal	37 (17%)
Exemplification	59 (28%)
Explanatory Communication	74 (34%)
Learner Participation	30 (14%)
Coherence	15 (7%)

Table 6 illustrates the percentage that each MTF element holds in University A's first-year lesson observation reports. The most prominent theme in the first-year lesson observation reports is explanatory communication, followed by exemplification. Tables 7 and 8 below present the percentage distribution of semantic density codes for each theme, relating to Knowledge and Pedagogy, respectively.

Table 7: MTF elements with stronger semantic density for knowledge in First-Year reports

MTF Element	Percentage of stronger Semantic Density Code
	SD+ (Total 32)
Lesson Goal	10 (67%)
Exemplification	3 (20%)
Explanatory Communication	2 (13%)
Learner Participation	0 (0%)

Coherence	0 (0%)

The table presents the Mathematics Teaching Framework (MTF) elements with stronger semantic density for knowledge (SD+), highlighting aspects of a teacher's practice that first-year pre-service teachers noticed with greater conceptual depth. The elements include Coherence, Lesson Goal, Exemplification, Explanatory Communication, and Learner Participation. Key observations from the table reveal that the Lesson Goal (67%) was the most frequently noticed and described with stronger semantic density. This suggests that first-year pre-service teachers were more attuned to whether the teacher's lesson had a clear purpose and how well it was conveyed, likely focusing on whether the teacher explicitly stated learning objectives or structured the lesson around a central theme. For example, one pre-service teacher noted the lesson goal in terms of a mathematical analysis: "This lesson was to prove that in exponential equations, if the bases are the same on both sides of the equation, then it goes without saying that the exponents of those bases are the same." Exemplification (20%) was noticed to some extent, indicating that some pre-service teachers identified and commented on the examples used in teaching—whether they were varied, relevant, or helped pre-service teachers grasp concepts. However, the lower percentage suggests that many pre-service teachers may not have deeply analysed how examples were selected or sequenced. Explanatory Communication (13%) had even fewer occurrences of strong semantic density, suggesting that while pre-service teachers noticed how the teacher explained concepts, they may not have engaged deeply with how well explanations connected ideas or addressed student understanding. Coherence (0%) and Learner Participation (0%) were not identified with strong semantic density, indicating that first-year pre-service teachers struggled to notice or articulate how well the lesson was structured as a whole (Coherence) and how pre-service teachers were engaged in mathematical discussions or problem-solving (Learner Participation). Their focus remained primarily on teacher-directed aspects rather than interactive elements of the lesson. For instance, one pre-service teacher noted the learner's participation as: "Her learner is active and focused; he also asks questions where he did not understand."

Table 8: MTF elements with stronger semantic density for pedagogy, First-Year reports

MTF Element	Percentage of stronger Semantic Density Code

	SD+ (Total 54)
Lesson Goal	4 (7%)
Exemplification	16 (30%)
Explanatory Communication	28 (52%)
Learner Participation	6 (11%)
Coherence	0 (0%)

The data indicates that explanatory communication (52%) and exemplification (30%) were the most prominent MTF elements contributing to increased semantic density, whereas coherence (0%) and lesson goals (7%) were less emphasized. The high percentage of explanatory communication suggests that pre-service teachers recognized the importance of maintaining engagement through interactive questioning. One example from the reports illustrates this: “In addition the teacher makes sure that her lesson is not a long boring lesson, and she put in the question-and-answer program during the lesson to make learner to recall the information and still keep track with the lesson.” This highlights how the teacher structured explanations to reinforce connections between ideas while keeping learners actively engaged. Similarly, exemplification played a key role in increasing semantic density. Reports often described the teacher’s use of worked examples to make abstract concepts more concrete. One report noted: “She did some examples on how to solve an unknown value from the exponential equation and gave the learner a chance to solve some problems on his own, by doing that she was working with both learner and knowledge at the same time.” This suggests that teachers not only demonstrated mathematical procedures but also encouraged pre-service teachers to engage with examples, strengthening their understanding. However, the absence of coherence (0%) and the minimal emphasis on lesson goals (7%) suggest that pre-service teachers may not have identified these as central to increasing semantic density.

4.4.1.5 Comparison of MTF elements for Knowledge and Pedagogy for First-Year Pre-service Teachers

Table 9: Comparison of MTF elements for Knowledge and Pedagogy for First-Year Pre-service Teachers

MTF Element	Knowledge SD+ (Total 32)	Pedagogy SD+ (Total 54)
Lesson Goal	67%	7%
Exemplification	20%	30%
Explanatory Communication	13%	52%
Learner Participation	0%	11%
Coherence	0%	0%

The analysis of MTF elements in first-year reports shows clear differences between how pre-service teachers approach knowledge and pedagogy. The biggest difference is seen with Lesson Goal. When focusing on knowledge, pre-service teachers put a lot of emphasis on clearly defining lesson objectives (67%). However, when it comes to pedagogy, this drops significantly to just 7%. This suggests that pre-service teachers see goal-setting as more important when thinking about content rather than teaching methods. Exemplification shows the opposite pattern. It's more commonly emphasized in pedagogy (30%) compared to knowledge (20%), suggesting that pre-service teachers value giving examples more when discussing teaching approaches. A major difference also appears in Explanatory Communication. It's much more important in pedagogy (52%) than in knowledge (13%), showing that pre-service teachers focus more on clear explanations when thinking about how to teach. Learner Participation also appears only in pedagogy (11%) and not at all in knowledge, possibly showing that pre-service teachers are more aware of involving learners when discussing teaching practices.

4.4.1.5 Semantic density of MTF Elements where First-Years Simultaneously Reported on Content and Pedagogy

Section 4.4.1.4 displayed the elements of the MTF where first-years displayed more complexity (stronger semantic density) when reporting on the observed lesson. Table 10 provides the number of codes in the lesson observation reports, where first-years reported on both the

content knowledge as well as the pedagogy for each element of the MTF. The codes K- - (no mention of the content lesson) and P- - (no mention of the pedagogy) were excluded, as in this analysis both the content of the lesson and the pedagogy had to be included in the report.

Table 10: Proportion of elements of the MTF, in first-year reports where both Knowledge and Pedagogy are reported on

MTF Element	Semantic Density Codes for Knowledge and Pedagogy			
	K- P-	K- P+	K+ P-	K+ P+
Lesson Goal (37)	8 (22%)	2 (5%)	1 (3%)	0
Exemplification (59)	14 (24%)	12 (20%)	0	2 (3%)
Explanatory Communication (74)	6 (8%)	17 (23%)	2 (3%)	1 (1%)
Learner Participation (30)	10 (33%)	5 (17%)	0	0
Coherence (15)	2 (13%)	0	0	1 (7%)

Table 10 shows the number of codes where first-years reported on the mathematical content and pedagogy simultaneously in their lesson observation reports, for each element of the MTF. The codes that emerged can be listed as: K-P-, K-P+, K+P- and K+P+. These codes show the semantic density for mathematical content knowledge (K) and pedagogy (P) of the observed lesson. A significant proportion of each element's codes (excluding explanatory communication) presented weaker semantic density for both knowledge and pedagogy, with learner participation with the highest proportion of codes (33%) and coherence with the lowest proportion (13%). This suggests a basic recognition of knowledge in the lesson in addition to mentioning or labelling the teacher's actions in passing, although neither of these types of knowledge are being described in full. Across the different MTF elements, there were several codes where the content of the lesson was described, and three of these occurred where pedagogy was only mentioned. Comparatively, thirty-six codes emerged where the pedagogy

was described while the content if the lesson was mentioned without description or further elaboration.

Of the total 37 times the lesson observation reports were classified as ‘lesson goal’ 27% of which presented codes for knowledge and pedagogy together. 25% of these codes presented weaker semantic density for both knowledge and pedagogy. Arbitrarily relating the content knowledge of the teacher and the teacher’s work. To illustrate the patterns of semantic density for knowledge and pedagogy, selected examples are presented for each element of the MTF.

Lesson Goal (K+P-)

“The lesson is about exponential equations and the teacher explains how to solve for x in the equation where we have an x as an exponent”

This example focuses on the theme of the lesson goal, where the content of the lesson is being described but the teacher’s action is briefly mentioned in passing. Majority of the codes for lesson goal, where both knowledge and pedagogy were reported on, displayed low semantic density codes for knowledge (SD-). This suggests that first-years do not recognise conceptual knowledge in making sense of the teacher’s choices regarding the goal of the lesson.

Exemplification (K+P+)

“The teacher firstly started off with the basic foundation of the equation (3 to the power of x equalling to 81), then she broke it down to even easier sums to guide the learners-as of how many times ‘3’ needs time itself to be equal to 81 and that was the answer to the question. Therefore, students would then have the basic idea of the equation”.

In this example, a more descriptive relationship is evident. The first-year describes the teacher’s actions while integration descriptions of the content of the lesson. The theme of exemplification had the highest proportion of codes at the level of semantic density, although this code was only prevalent in 3% of exemplification codes.

Explanatory Communication (K-P-)

“When the teacher teaches, she first explains how the exponential equation should be solved and after that she solves the equation”.

In this example presented for explanatory communication, there is a low semantic density for both the content and the pedagogy. The content and the actions of the teacher are both

mentioned in passing, but neither of which provide further description or elaboration. However, it should be noted that the theme of explanatory communication provides the majority of codes where content and pedagogy are reported on simultaneously.

Learner Participation (K-P+)

"Therefore, the teacher pushes the learner to find solutions to the problem examples on his own and only makes the learner to recognize certain areas and concepts that are virtue for a leaner to consider when it comes to solving exponential equations."

The example presented here shows a stronger semantic density for pedagogy, in reasoning for the teacher's actions. However, the content is not described in relation to these actions. Instead, it is mentioned in passing, suggesting the first-year's reluctancy in viewing the content to make sense of the pedagogy for the theme of learner participation. It should be noted that this theme presents no accounts of stronger semantic density for knowledge.

Coherence (K-P+)

"Also, the teacher took the leaner back to what they studied about in exponents in order for him to understand how the teacher got the answer she got."

The first-year reasons through the teacher's actions in this example and mentions the mathematical content in passing but does not provide further description or elaboration.

The next section of the analysis focuses on the fourth-year pre-service teacher's reports from University A. This is done firstly by analysing the semantic density for knowledge and pedagogy in the reports. Then, a comparison is made between the semantic density codes for these types of knowledge. Thirdly, a thematic analysis is conducted which is followed by a comparison between the different themes that present themselves in the thematic analysis. Lastly, the semantic density of both knowledge and pedagogy codes, that emerged together under each theme, are analysed.

4.4.2 University A Fourth Year Reports

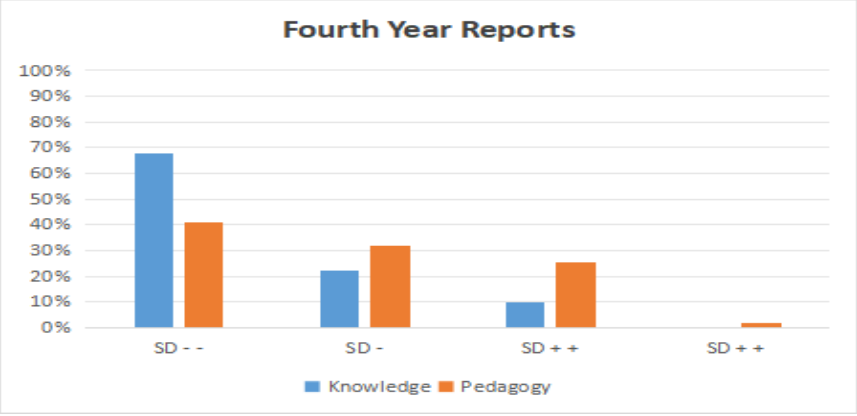


Figure 7 Semantic Density Codes for Knowledge and Pedagogy, Fourth-Years

4.4.2.1 Analysis of Knowledge in Fourth-Year Lesson Observation Reports

A significant proportion (68%) of codes were categorised as SD--, meaning that many codes did not mention the content of the lesson at all.

Examples from data:

"She asks him leading questions that allow the learner to build his knowledge based on what he has previously learned"

In this excerpt, the pre-service teacher makes no mention of the mathematical content of the lesson. The focus is placed on describing the questioning technique used by the teacher, without referring to the content of the lesson.

"Even though there is only one learner involved in the lesson he is able to participate effectively making the teacher's job easier".

In this example provided, the focus is placed on the learner participation but shows no relation to the mathematical content of the lesson.

A further 21% of the data was categorised as SD- in terms of the mathematical content knowledge of University A. This means that the content of the lesson was mentioned but not engaged with, in terms of its meaning, connections, or significance.

Examples from data:

"The teacher allowed a learner to ask questions, and she answered them by showing and reminding the learner of the laws of the exponents"

This example displays that the pre-service teacher mentions the content of the lesson in passing.

The pre-service does not describe or elaborate on the content further.

"The teacher teaches about Exponential Equations, in that lesson the teacher used the following lesson techniques to develop, inform and engage a learner"

In second excerpt provided, the pre-service teacher briefly mentions the name of the lesson. In doing so makes mention of the content. This highlights that within this excerpt, the pre-service teacher did not engage with the meaning of the mathematical content of the lesson; or did not make any connections; or show the content's significance.

Only 10% of the data being categorised as SD+ for mathematical content knowledge of the lesson. This means that only a few codes were able to describe, define or list the content but did not elaborate on the content.

Example from data:

"Exponents are used in exponential equations, as the name implies. The exponent of a number (base) indicates how many times the number (base) has been multiplied."

This excerpt taken from a fourth-year pre-service teacher's lesson observation report, displays an instance content of the lesson is being described. The pre-service teacher briefly describes the concept of exponents.

No codes of fourth-year lesson observation reports (0%) demonstrated the ability to identify SD++ levels of knowledge, meaning that no reports contained observations where knowledge was both elaborated and aspects explained in depth.

The codes from fourth-year pre-service teachers show a predominant classification at the lower levels of knowledge recognition. This suggests that pre-service teachers often failed to acknowledge or recognize conceptual elements or displayed some level of recognition but without elaboration.

4.4.2.2 Analysis of Pedagogy in Fourth-Year Lesson Observation Reports

Similarly, a high proportion (40%) of fourth year pre-service teachers' codes in their lesson observation reports made no mention of what the teacher does and were also categorised as SD--.

Example from data:
“Exponential equations focus on the two equations which contains a variable and the value of the variable needs to be found”

This excerpt provides an example of an instance in the fourth-year lesson observation reports, where the pre-service teacher makes no mention of the teacher’s actions or pedagogical reasoning.

The fourth year pre-service teachers’ codes displayed a higher proportion (31%) of the SD- category for pedagogy in comparison to mathematical content knowledge. This suggests that pre-service teachers were more inclined to notice the pedagogy than the content of the lesson. Although, still indicating a high fraction of the data is only mentioning the teacher’s actions and not reasoning through or describing these.

Examples from data:
“The teacher gave an example and did it and asked questions and the learner was answering”

In this excerpt the pre-service teacher mentions that an example was given to the learner by the teacher. However, they do not describe the example or provide justifications on why this particular example was chosen. Instead, the teacher’s action was just mentioned in passing.

“There is an interaction between presenter and the student as questions are asked and concepts are explained”

In this example, the pre-service teacher mentions the explanations and questioning technique used by the teacher but does not elaborate further.

A fairly large proportion (26%) of the codes reached SD+, meaning that these lesson observation reports fully described what the teacher did. However, did not engage in deeper analysis, such as justifying or critiquing the teacher’s decisions.

Example from data:
“Then by using her resources effectively and visually showing the workings, while speaking what is happening, it caters for both audio and visual learners”.

In this example, the pre-service teacher describes the actions of the teacher. Specifically focussing on the representations used and describing why this is effective.

Only 2% of the fourth-year pre-service teachers' codes reached SD++. This reflects the limited number of times the pre-service teachers were able to explain, justify or critique the action of the teacher.

Example from data:

"Furthermore, by starting the lesson with an example, this shows that in planning of the lesson, the teacher has designed a learning pathway as a semantic wave that starts at a low and moves up to a high".

This excerpt displays pre-service teacher's ability to not only describe the teacher's actions but also justify these using theoretical knowledge gained from their coursework (semantic wave).

The fourth-year pre-service teachers struggled more with knowledge codes (68% SD-- and 10%SD+) than pedagogy codes (40.85% SD-- and 26%), suggesting that pre-service teachers focused on analysing the teacher's instructional strategies in comparison to the mathematical content of the lesson.

4.4.2.3 Comparison of Knowledge and Pedagogy for Fourth-Year Pre-service teachers

The analysis of the fourth-year codes shows that a large proportion of the data were categorised as SD-- and SD- for both the mathematical content knowledge and the pedagogy in the lesson they observed. Although there is some presence of SD+ and SD++, these higher complexity levels constitute a relatively small fraction of the codes. Furthermore, fourth-year pre-service teachers were better able to identify the complexity in the teacher's actions within the lesson they observed in comparison to the mathematical content knowledge. Fourth-year codes showed that they were more likely to describe pedagogy in full (26% of codes at SD+) than knowledge (10% of codes at SD+). However, their ability to explain or justify pedagogy remained limited, with only 1% of codes reaching SD++.

The next section of the analysis focuses on the thematic coding of the fourth-years' reports. This section uses the MTF to categorize the lesson observation reports into themes.

4.4.2.4 Thematic Analysis of Fourth Year Lesson observation reports

Table 11 displays the Mathematical Teaching Framework (MTF) elements that presented themselves in the fourth-year lesson observation reports. The MTF was used to code pre-service teachers' lesson observation reports into themes, which were then coded for their complexity on the content and pedagogy for each theme.

Table 11 Results of MTF Element in Fourth-Year Reports

MTF Element	Proportion of Element in fourth-Year reports (Total 124)
Lesson Goal	17 (14%)
Exemplification	44 (35%)
Explanatory Communication	29 (23%)
Learner Participation	22 (18%)
Coherence	12 (10%)

Table 11 illustrates that most of the codes for University A's Fourth Year lesson observation reports were for exemplification, making up 35% of the data. The second most prominent theme was Explanatory Communication with 23%. This suggests that the aspects of the mathematics lesson that the pre-service teachers deemed noteworthy were the examples and explanations used by the teacher. Table 12 and 13 below, further describes which MTF elements presented stronger semantic gravity focusing on the SD+ and SD++ codes for knowledge and pedagogy respectively. Although, it was found that fourth-year pre-service teachers were more likely to describe pedagogy in full (**with 25% of codes at SD+**) than knowledge (**10% of codes at SD+).**

Table 12: Fourth-year MTF elements with stronger semantic density for knowledge

MTF Element	Percentage of stronger Semantic Density Code
	SD+ (8)
Lesson Goal	5 (63%)
Exemplification	1 (12%)
Explanatory Communication	1 (12%)

Learner Participation	1 (12%)
Coherence	0 (0%)

Table 12 highlights that lesson goal (63%) was the dominant category for stronger semantic density in knowledge, suggesting that pre-service teachers described the content of the lesson primarily in terms of its objectives. For example, one report noted: "The mathematics lesson was about solving exponential equations. It specifically looked at when the bases are the same, what happens and how to find the unknown exponent." Other elements, such as exemplification, explanatory communication, and learner participation (each at 12%), appeared less frequently, and coherence was entirely absent (0%), indicating that fourth-year pre-service teachers struggled to articulate how lesson structure contributed to knowledge complexity. Table 13 displays the percentage of SD+ codes (for pedagogy) that were given for each MTF element

Table 13: Fourth-year MTF elements with stronger semantic density for pedagogy

MTF Element	Percentage of stronger Semantic Density Code	
	SD+ (total 41)	SD++ (Total 3)
Lesson Goal	4 (10%)	1 (33%)
Exemplification	14 (34%)	2 (67%)
Explanatory Communication	16 (39%)	0%
Learner Participation	4 (10%)	0%
Coherence	3 (7%)	0%

It is given that 39% of the data were coded SD+ for Explanatory communication and 34% for exemplification. This finding, along with the attention paid to these two elements overall in the lesson observation reports, suggests that fourth year pre-service teachers describe the teacher's actions for exemplification and explanatory communication.

Examples from the data:

Exemplification: "The lesson begins with an introduction of the topic, and then after the

introduction, the tutors take the learners through examples, starting from the basic exponential equations to more complex ones and they build on the example"

Explanatory communication: "The way this teacher promotes learning in this lesson is that the teacher probes the learner throughout the lesson."

4.4.2.5 Comparison of MTF elements for Knowledge and Pedagogy for Fourth-Year Pre-service Teachers

Table 14: MTF elements for Fourth-Year Knowledge and Pedagogy

MTF Element	Knowledge SD+ (Total 8)	Pedagogy SD+ (Total 41)
Lesson Goal	63%	10%
Exemplification	12%	34%
Explanatory Communication	12%	39%
Learner Participation	12%	10%
Coherence	0%	7%

The fourth-year preservice teachers' lesson observation reports for a Grade 10 exponents lesson reveal differences between MTF elements for knowledge and pedagogy. For Lesson Goal, the knowledge coding shows a higher emphasis (63%) compared to pedagogy (10%). In contrast, Exemplification and Explanatory Communication show stronger semantic density within pedagogy. Exemplification is coded as 34% for pedagogy, compared to only 12% for knowledge. Similarly, Explanatory Communication shows a notable increase from 12% in knowledge to 39% in pedagogy. This indicates that fourth-year pre-service teachers put more emphasis on using examples and explaining concepts when considering teaching approaches rather than just content. Learner Participation remains consistent between knowledge and pedagogy, with both coded at 12% and 10%, respectively. Interestingly, Coherence appears only in pedagogy (7%) and not at all in knowledge.

The next section focuses on the codes where both content knowledge and pedagogical knowledge are reported on for each element of the MTF.

4.4.2.6 Semantic density of MTF elements where fourth-years simultaneously reported on content and pedagogy

Table 15: Elements of MTF in fourth-year reports where both Content Knowledge and Pedagogy are reported on

MTF Element	Semantic Density Pairing		
	K- P-	K- P+	K+ P-
Lesson Goal (17)	1 (6%)	2 (12%)	2 (12%)
Exemplification (44)	3 (7%)	6 (14%)	0
Explanatory Communication (29)	7 (24%)	8 (28%)	0
Learner Participation (22)	0	1 (4%)	0
Coherence (12)	1 (8%)	5 (25%)	0

Table 15 displays the percentage of codes, of each MTF element, where fourth-years simultaneously reported on both knowledge and pedagogy. The reader is reminded that the data was first coded into themes (elements of the MTF) and then by complexity. This analysis presented two codes in the data where fourth-years reported simultaneously on knowledge and pedagogy (K-P- and K-P+) across the MTF elements. This suggests that fourth-years are more likely to briefly mention the content and either arbitrarily the mention the pedagogy as well or describe the pedagogy in relation to the briefly mentioned content. There were no instances of K+P+; K+P++; K++P-; K++P+; K++P++. To illustrate the patterns of semantic density for knowledge and pedagogy, selected examples of the different codes identified within each MTF element are provided.

Examples from Data:

Lesson Goal (K+P-)

“The mathematics Grade 10, Exponential Equation's main idea was to explain to learners how to find the unknown exponent found on a base, this is done by using the same base method.”

In this example, the fourth-year is describing the focus of the lesson and briefly mentions the teacher's action of teacher (explanation). The content is described but is not used to analyse the teacher's actions in-depth. Instead, the teacher's action is mentioned perfunctorily.

Exemplification (K-P+)

"Her lesson then moves back and forth between the complex concept of solving exponential equations and examples of how to do it. This allows for effective teaching and learning to take place"

In this example the fourth-year mentions the content but does not provide more detail about the concepts of the lesson. However, the movement between different examples is described, displaying a stronger semantic density for the teacher's actions in comparison to the content.

Explanatory communication (K-P+)

"The way in which she teaches exponential equations is brilliant, as she gives examples, then asks probing questions to the learner to ensure understanding."

Similarly to the previous example, the content is briefly mentioned here while the teacher's actions are described and a specific reason is provided for these actions. Unlike the previous example, the focus on the excerpt was on what the teacher says to make sense of the mathematical content. There is no complex relationship between the knowledges, the content seems to be arbitrarily mentioned.

Learner Participation (K-P+)

"She also allows her learner to practise the use of mathematical language by explaining how he came about his answers in solving for x"

This example presents the sole code of both knowledge and pedagogy for learner participation in the fourth-year reports. This suggests that fourth-years are unlikely to use knowledge to make sense of the teacher's actions when focusing on learner participation in the lesson.

Coherence (K-P+)

"Additionally, I thought teacher did well with her progression of the topic, as she used quite a few examples to introduce the complex concept of solving exponential equations and then consolidated it, into a general rule".

In this example, the content of the lesson is mentioned briefly while the pedagogy of the teacher is described to show alignment to the lesson goal. This code of stronger semantic density of pedagogy and weaker semantic density for knowledge, is more prominent in the theme of coherence. This suggests that fourth-years value the content knowledge when making sense of the teacher's actions to align aspects of the lesson to the lesson goal. Although, the rudimentary relationship of the content and pedagogy does not define concepts or elaborate further on the content of the lesson.

The above analysis displays that although exemplification was the most prominent theme in the fourth-year reports (35% of codes), explanatory communication had the most codes (52%) where both the content and pedagogy was reported on. This suggest that the fourth-years emphasis on explanations when considering teaching approaches in relation to the content in comparison to the usage of examples in the lesson. The prominent code of stronger semantic density for pedagogy (SD+) and weaker semantic density for knowledge (SD-), displays a arbitrary relationship of the two types of knowledge. This suggests that the fourth-years are unlikely to use mathematical content knowledge to make sense of the teacher's actions.

The next section of the analysis seeks to compare the findings of the first and fourth year lesson observation reports.

4.4.3 Comparison of First and Fourth-Year Pre-service teachers' reports

Table 16: Comparison of MTF Elements for SD+ Pedagogy, First- and Fourth-Year Reports

MTF Element	**First-Year Pedagogy SD+ (Total 54)**	**Fourth-Year Pedagogy SD+ (Total 41)**
Lesson Goal	7%	10%
Exemplification	30%	34%
Explanatory Communication	52%	39%
Learner Participation	11%	10%
Coherence	0%	7%

One of the most noticeable differences is in Exemplification. First-year pre-service teachers noticed exemplification in 30% of cases, while fourth-year pre-service teachers showed a higher emphasis at 34%. This suggests that as pre-service teachers progress through their training, they place greater importance on providing clear examples during teaching. A similar pattern emerges with Explanatory Communication with 52% of instances coded for first year pre-service teachers, compared to 39% for fourth years. Although both groups recognize the importance of clear explanations, first-year pre-service teachers appear to emphasize this aspect more, possibly due to a focus on making concepts understandable rather than engaging pre-service teachers. Lesson Goal is coded with 7% of first-year reports but increases to 10% in fourth-year reports. This suggests that as pre-service teachers advance in their training, they become slightly more conscious of clearly articulating the purpose of the lesson in teaching contexts. Regarding Learner Participation, first-year pre-service teachers this element is coded at 11%, while fourth-year pre-service teachers this element is slightly lower at 10%. Coherence appears exclusively in fourth-year reports (7%), while it is entirely absent in first-year coding. This might indicate that fourth-year pre-service teachers develop a better understanding of maintaining a logical and cohesive flow in teaching as they gain experience.

In the first-year pre-service teachers' reports, explanatory communication exhibited the largest proportion (34%) of codes (see Table 6) followed by exemplification and lesson goal. Explanatory communication also demonstrated the largest proportion of codes for SD+ for pedagogy but not for knowledge (see Table 9). Table 10 illustrated that the theme of explanatory communication held the highest proportion of codes with stronger semantic density for knowledge, where pedagogy was simultaneously being reported on. Similarly, explanatory communication has the largest proportion of codes (35%) in the four-year reports'. It has the highest proportion of SD+ for pedagogy (see Table 13), although it does not have any codes at SD++. This suggests that both first and fourth-years value the explanatory communication that a teacher makes use of when making sense of the teacher's actions.

In the first-year pre-service teachers' reports, majority of codes that reported on both content and pedagogy were at the weaker semantic density for both types of knowledge (K- P-). Learner participation (33%) presented the highest proportion of this code. With the exception of the element of explanatory communication, where the semantic density of the pedagogy was stronger. This suggests that fist-years rudimentarily use content to make sense of the choices the teacher makes, for the goal of the lesson, the examples used, learner participation as well

as how the lesson relates to the lesson goal. A similar trend is found in the fourth-year reports, although the majority of these codes have a stronger semantic density for pedagogy. Explanatory communication in both first and fourth-year reports resembles codes with stronger complexity, specifically in pedagogy.

Both first-year and fourth-year pre-service teachers' codes operate at the lower complexity levels (SD-- and SD-), indicating a reliance on surface-level observation. First-year pre-service teachers were slightly better at recognizing knowledge structure (33% of codes at SD+) than pedagogical complexity (14% of codes at SD+), yet no codes advanced to the highest level (SD++). In contrast, fourth-year reports showed a modest improvement in identifying complex pedagogical actions—with 25% of their responses at SD+ compared to only 10% for content—though their ability to explain or justify these practices remained very limited (only 1% of codes reached SD++). Overall, while there is a slight progression from first to fourth year in the depth of pedagogical observation, both groups continue to struggle with moving beyond basic descriptions toward deeper, analytical engagement.

4.6 Discussion of Findings

Across all universities, pre-service teachers demonstrated limited engagement with mathematical content knowledge in their lesson observations. The overwhelming presence of SD-- and SD- codes indicates that many pre-service teachers either failed to notice or only superficially referenced the mathematical concepts underpinning the Grade 10 lesson on exponential equations. University A exhibited the highest proportion of SD-- (68%), followed closely by University E (61%). Only University C demonstrated any significant level of SD++ (4%), suggesting a slightly stronger ability to elaborate on and explain mathematical concepts in their reports. This analysis highlights a persistent challenge in bridging the gap between theoretical understanding of mathematical content and its application in practice.

Despite exposure to content knowledge and pedagogical content knowledge in their coursework, many pre-service teachers did not exhibit the ability to notice or articulate complex mathematical ideas in their observations. As suggested by Darling-Hammond (2006) and Rusznyak and Bertram (2021), this indicates an underdeveloped capacity for connecting theory to practice through professional noticing.

The analysis also show that pre-service teachers tended to focus more on pedagogy than on content; however, their reasoning about pedagogy was largely descriptive. The majority of

codes fell into SD-- and SD- categories across universities, with very few instances of SD++. Even among fourth-year pre-service teachers, whose training should have enabled more sophisticated pedagogical reasoning (Amador, 2016; Rusznyak & Bertram, 2021), the reports were dominated by descriptions of teacher actions without justification or critique. University D's reports displayed the lowest proportion of SD-- codes in pedagogy (33%) and the highest SD- codes (40%), suggesting a marginally better recognition of pedagogical practices. However, the lack of SD++ (1% or lower in all universities except University A and B at 2%) illustrates a persistent difficulty in articulating the pedagogical reasoning behind instructional decisions. This aligns with the concerns raised about pre-service teachers' reliance on surface-level observations drawn from their apprenticeship of observation (Lortie, 1975) rather than engagement with the principled knowledge that underpins teaching practice. When comparing first- and fourth-year pre-service teachers from University A, a slight improvement was noted in pedagogical reasoning. Fourth-year reports contained more SD+ and the rare SD++ codes, particularly in pedagogical descriptions.

The thematic analysis using the Mathematics Teaching Framework (MTF), Fourth-year preservice teachers show a slight increase in emphasizing lesson goals and coherence compared to first-year pre-service teachers, suggesting a more structured approach to pedagogy. However, first-year pre-service teachers place a higher emphasis on explanatory communication, possibly due to a stronger focus on making content clear.

The thematic analysis showing the simultaneous reporting of knowledge and pedagogy, showed arbitrary and rudimental relationships between the types of knowledge when making sense of the teacher's choices in their lesson observation reports. The codes where both types of knowledge were reported on mostly presented where a focus was placed on one and the other was mentioned in passing, for example K-P+ and P-K+. Additionally, a large majority of the codes presented as K-P- for both the content of the lesson as well as the pedagogy. This suggests that pre-service teachers do not use the content knowledge of the lesson to make in their pedagogical reasoning. Fourth-year pre-service teachers provide more codes with weaker SD for knowledge but slightly stronger SD for pedagogy.

Chapter 5 Discussion of Results and Conclusion

5.1 Introduction

In this study, I set out to investigate the extent to which pre-service teachers integrate mathematical content knowledge and pedagogical content knowledge (PCK) when observing and interpreting mathematics classroom practices. Drawing from the literature, particularly the conceptual framework of professional noticing and pedagogical reasoning, the findings reveal the challenges pre-service teachers face in shifting from their initial 'apprenticeship of observation' (Lortie, 1975) to a more informed, analytical understanding of teaching.

5.2 Summary of Findings

The study highlights that first-year pre-service teachers tend to focus on surface-level features of mathematics teaching, primarily describing observable actions rather than engaging with the deeper pedagogical reasoning behind them. This aligns with Rusznyak and Bertram's (2021) argument that novice teachers often struggle to move beyond visible classroom routines to engage with the underlying principles guiding instructional choices. Fourth-year pre-service teachers demonstrated a modest improvement in their ability to recognize and articulate aspects of pedagogical reasoning, yet their lesson observation reports remained largely descriptive rather than analytical. Additionally, fourth-years presented a slight improvement in using the content of the lesson to make sense of the teacher's actions through their pedagogical reasoning. The data, analysed using Legitimation Code Theory's (LCT) concept of semantic density, supports this conclusion by showing that while there is some progression in the complexity of pedagogical insights, the shift towards high-level professional noticing remains limited.

Professional noticing, as conceptualized by Amador (2016), requires pre-service teachers to attend to significant teaching moments, interpret their meaning, and respond with informed pedagogical decisions. However, the findings suggest that even after four years of teacher preparation, pre-service teachers struggle with the latter two aspects of noticing—interpreting and responding. While they may recognize key instructional moments, their ability to connect these observations to theoretical frameworks or broader pedagogical strategies remains weak. This finding supports Barends (2022), who argues that pre-service teachers often find it difficult to articulate the pedagogical reasoning underlying their observations, despite being exposed to theoretical coursework.

A key component of effective mathematics teaching is the ability to integrate content knowledge with pedagogical strategies, as emphasized by Shulman's (1987) concept of PCK. This study reveals that pre-service teachers, even in their final year, still grapple with this integration. The Mathematics Teaching Framework (MTF) provided a useful lens for analysing their lesson observation reports, revealing that both first- and fourth-year pre-service teachers prioritized explanatory communication but paid less attention to coherence, learner participation, and lesson goals. This suggests that while they recognize the importance of clear explanations, they may not yet fully understand how these explanations should be embedded within a coherent instructional sequence that actively engages learners.

The findings also align with the broader literature on teacher education, which emphasizes the persistent gap between theory and practice (Loughran, 2019). Despite efforts to bridge this divide through work-integrated learning (WIL), the study reinforces concerns that pre-service teachers often struggle to apply theoretical knowledge in practice (Mårtensson & Ekdahl, 2021). The Teachers' Choices in Action (TCiA) module provided an opportunity for pre-service teachers to engage in video-based observations, a pedagogical tool that has been shown to enhance professional noticing (Santagata et al., 2021). However, while the module allowed pre-service teachers to repeatedly observe and reflect on teaching episodes, the data suggests that deeper engagement with pedagogical reasoning requires additional scaffolding and explicit instructional support.

5.3 Limitations of the Study

While this study provides valuable insights into pre-service teachers' development of professional noticing, several limitations must be acknowledged. Firstly, the study relied on lesson observation reports, which capture only what pre-service teachers explicitly articulate and may not fully reflect their cognitive processes. Some pre-service teachers might have had deeper insights but struggled to express them in writing. Secondly, the study was limited to pre-service teachers engaged in online video observations rather than in-person classroom experiences, which could impact the depth of professional noticing. In-person interactions allow for real-time questioning and adaptive engagement, which are missing from video-based analysis. Lastly, the sample was drawn from universities that implemented the TCiA module, limiting the generalizability of findings to pre-service teachers who experienced different WIL structures.

5.4 Recommendations

To improve pre-service teacher education, programs should encourage structured reflection in lesson observations, helping pre-service teachers connect their observations to theoretical concepts. A combination of video-based observations and in-person classroom experiences would provide a more balanced and engaging approach to work-integrated learning (WIL). Teacher preparation courses should also include explicit instruction on pedagogical reasoning, guiding students in understanding the choices teachers make and their impact on learning. Encouraging collaboration through peer discussions and group analysis of lesson reports can further deepen their insights. Lastly, tracking pre-service teachers' development over time would help assess how effectively they are integrating content knowledge and pedagogy, informing improvements in teacher education programs.

5.5 Conclusion

Given the findings, it is clear that teacher preparation programs need to place greater emphasis on developing pre-service teachers' ability to engage in professional noticing and pedagogical reasoning. One approach could be to integrate structured reflection exercises that prompt pre-service teachers to articulate not just what they observe, but why certain instructional choices were made and how these choices align with principles of effective teaching (Darling-Hammond, 2006). Additionally, explicit instruction in making connections between coursework and observed practice could help mitigate the theory-practice divide.

In conclusion, this study contributes to the growing body of research on pre-service teacher education by highlighting the ongoing challenges in fostering professional noticing and pedagogical reasoning. While pre-service teachers show some progression in their ability to notice instructional decisions over the course of their training, the findings suggest that deeper engagement with pedagogical reasoning requires further intervention. By strengthening the integration of theory and practice within teacher education programs, future cohorts of pre-service teachers may develop a more sophisticated understanding of the complexities of mathematics teaching. The study underscores the importance of continued research into effective pedagogical strategies that support the transition from novice observer to reflective practitioner, ultimately enhancing the quality of mathematics education.

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Appendix A TCiA Ethics Clearance Certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG | WSoE Wits School of Education

SCHOOL OF EDUCATION ETHICS COMMITTEE

CONSTITUTED UNDER THE UNIVERSITY HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: 2024ECE0014M**
PROJECT TITLE	Exploring the Pedagogical Content Knowledge (PCK) in mathematics lessons' observation reports by first-year and fourth-year pre-service teachers.
INVESTIGATOR	**Dominique Peixinho**
SCHOOL/DEPARTMENT OF INVESTIGATOR	WSoE
DATE CONSIDERED	08 April 2024
DECISION OF THE COMMITTEE	Approved unconditionally
RISK LEVEL	Minimal Risk
EXPIRY DATE	Date of submission of the Research Report
ISSUE DATE OF CERTIFICATE	22 April 2024
CHAIRPERSON	Dr. Lawan Abdulhamid

cc: Dr Zaheera Jina Asvat

DECLARATION OF INVESTIGATOR

To be completed in duplicate and **ONE COPY** returned to the Chairperson of the School/Department ethics committee.

I fully understand the conditions under which I am are authorized to carry out the abovementioned research and I guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee.

Signature _____ **Date** 29 / 04 / 2024

Appendix B TCiA Ethics Clearance

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Rusznyak

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H19/09/47**
PROJECT TITLE	Teacher Choices in Action: South African pre-service teachers' learning from practice
INVESTIGATOR(S)	Prof L Rusznyak
SCHOOL/DEPARTMENT	Education/
DATE CONSIDERED	13 September 2019
DECISION OF THE COMMITTEE	Approved Risk Level: Minimal
EXPIRY DATE	21 October 2022

DATE 22 October 2019 **CHAIRPERSON** J. Knight
(Professor J Knight)

cc: Supervisor : N/A

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

_____ _____/_____/_____
Signature **Date**

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES