Planning for Numeracy in Higher Education:
A South African University of Technology Case Study

Shoba Rathilal

Submitted in fulfilment of the academic requirements for the

Degree of Philosophy (PhD): Higher Education Studies

School of Education

University of KwaZulu-Natal

November 2020

Declaration

I, Shoba Rathilal declare that

1. The research reported in this thesis, except where otherwise indicated, is my original research;
2. The thesis has not been submitted for any degree or examination at any other university;
3. The thesis does not include other's data, analysis, graphs, pictures, tables or any other information unless it is acknowledged as being sourced from other persons;
4. The thesis does not include the writings of other authors without acknowledgement. Where writings have been reworded, but relates to the thoughts by other authors, this has been referenced in text. Where the exact words have been used, this is signalled with quotation marks and referenced.

____

S. Rathilal

Acknowledgements

The PhD journey is one of the most challenging and sometimes lonely journey of trying to make meaning and explore new possibilities of understanding and acting. It requires constant academic, emotional and material guidance and support.

The culmination of the PhD journey in this thesis is a result of the multiple input of my support structure. I therefore want to acknowledge and thank:

- My supervisor Prof Wayne Hugo for his vision in respect of the possibilities of the study from its conceptualisation. Prof Hugo provided much needed leadership, but also balanced this with the confidence in my ability and therefore encouraged me to go on without constant monitoring.
- The Higher Education cohort facilitators and students who provided regular input on research practices and critique and feedback on this study. Special thanks to Prof Brian Shawa and Prof Michael Samuel who co-ordinated the groups I was part of.
- Prof Tennyson Mgutshini for research guidance and support.
- The departments and other key informants that participated in the study without who the study would not have been possible. All colleagues were extremely willing to participate and share.
- My editors, Barbara Louton and Dr Nereshnee Govender for ensuring that I met all the necessary academic English requirements of a PhD.
- My transcribers Dr Nereshnee Govender and Ms Simone Govender for lightening the demands by providing me with a draft transcription that I could work from.
- My brother, Prof Sudesh Rathilal for assisting with formatting and finalising the presentation of the thesis. My sister, Sunita Rathilal for assisting with responding to edit suggestions.
- The late Prof Ngwenya, director of CELT who supported me with approval of leave where possible, so I could focus on studies and funding to support my research activities.

- Colleagues from CELT at DUT who supported with tasks that freed me to focus on my research.
- My friend, colleague, and fellow student, Nalini Chitanand who provided support, critique, guidance and encouragement. Also, thanks to my friend, colleague and fellow PhD student, Roshnee Sunder.
- My friends and family who continued to encourage me, believe that I could complete this qualification and pray for my success.
- Pradeep Bhanlal, my family, my friend, my confidant for the unwavering confidence and constant encouragement and support.
- The Rathilals, especially my mum for the encouragement, "scolding" and prayer that resulted in the completion of my thesis. Thank you, my family, for standing by me through all the challenges of the PhD, listening to my constant stories of frustration or joy and celebrating every little milestone of the journey.

I believe that this thesis was completed by hard work, unwavering support, and most importantly divine grace without which nothing is possible.

Hinduism presents us with multiple dimensions and manifestations of Divinity. I acknowledge and offer gratitude to all dimensions of divine energies and all manifestations of divinity that blessed this journey from inception to culmination.

"Jai Shri Krishna"

Dedication

For my mum

Abstract

Numeracy is a national issue in South African education and society. The National Benchmark Tests indicate over 80% of students accessing higher education are likely to experience difficulties meeting the numeracy demands of the curriculum; employers have also expressed dissatisfaction with graduate numeracy practices. There is therefore a need for higher education to engage in the development of numeracy.

The university of technology in this case study had recognized the need to develop numeracy in its undergraduate programmes and prioritized this in the Curriculum Renewal Project (CRP). This study sought to understand how numeracy was planned, and explored the organizing principles behind the intended curriculum in the seven selected programmes.

The study adopted social realism as an overarching theory and was influenced by a social practice orientation to numeracy as multiple practices that are socially, politically and culturally influenced. Through inductive and deductive analysis of semi structured interviews of participants in the CRP and curriculum documents, the complexities of planning for numeracy in a formal curriculum was highlighted. Data revealed numeracy as an elusive concept that participants had trouble articulating. The Epistemic Pedagogic Device was used to explore the curriculum process and the dimensions of Legitimation Code Theory (LCT) were used to make explicit the principles underlying how numeracy was planned for.

The study showed that numeracy in higher education has multiple organizing principles that are legitimated in different ways with different numeracy practices expected at different points in the curriculum. The study highlighted multiple external contextual factors that curriculum developers had to negotiate when planning for numeracy and argued that these factors have great impact because of the lack of understanding of the diversity of principles underlying numeracy practices, non-recognition of numeracy as a specialized area and the absence of a ‘academic home’ in higher education. The study suggests that higher education development of numeracy can be enhanced through the recognition and support of numeracy as an emerging field that brings into conversation the scholarship of numeracy and knowledge production, curriculum design and pedagogy of programmes within different disciplines and contextual realities.

Contents Page

List of Figures

List of Tables

Abbreviations

ALM	Adults Learning Mathematics
ANA	Annual National Assessments
CD	Curriculum Document
CHE	Council of Higher Education
CRP	Curriculum Renewal Project
DHET	Department of Higher Education and Training
DUT	Durban University of Technology
ECP	Extended Curriculum Programme
EPD	Epistemic Pedagogic Device
FAI	Faculty of Accounting and Informatics
FAS	Faculty of Applied Science
FEBE	Faculty of Engineering and the Built Environment
FMS	Faculty of Management Science
FHS	Faculty of Health Science
FTE	Full time Equivalent
FYSE	First Year Student Experience
GenEd	General Education
HEQSF	Higher Education Qualification Sub-Framework
HOD	Head of Department
ICT	Information and Communication Technology
LCT	Legitimation Code Theory
LO	Learning Outcome
ML	Mathematical Literacy
NBTPT	National Benchmark Tests Project Team
NBTs	National Benchmark Tests
NLS	New Literacy Studies
NQF	National Qualification Framework
OECD	Programme for the International Assessment of Adult Competencies
PD	Pedagogic Device
PIAAC	Programme for the International Assessment of Adult Competencies
PISA	Programme for International Student Assessment
QL	Quantitative Literacy
QR	Quantitative Reasoning
SA	South Africa
SATAP	Standardised Assessment Tests for Access and Placement
TIMSS	Trends in International Mathematics and Science Study
TIMSSSA	Trends in International Mathematics and Science Study South Africa
UKZN	University of KwaZulu-Natal
UoT	University of Technology

Chapter 1
Introduction, background, context, and overview

1.1 Introduction

Numeracy is considered to be a key factor that will impact the quality of life of individuals and societies increasingly in the future. As our world is affected by the changes that are being brought about by the 4th industrial revolution, numeracy becomes increasingly important to dealing with the challenges to environmental and financial sustainability, health and social well-being.

Numeracy is sometimes considered a form of ‘common sense’ because of its implicit nature. While many definitions of numeracy have been put forward, it is difficult to articulate explicitly what numeracy entails in specific contexts. As a result, it is difficult to specify curriculum requirements for the development of literacy.

Hughes-Hallett (2001), in her article “Achieving Numeracy: The challenge of implementation”, makes an interesting point that there is considerable literature on the *importance* of numeracy, or quantitative literacy, but very little on *how* it can be developed. Although there has been progress in terms of the practices for developing numeracy since Hughes-Hallett’s article, research on developing numeracy in higher education, specifically, is still limited.

Central to the concept of numeracy is its application to the particular context and thus the development of insights around contexts or contextual sense making in which it is used to make meaning. Key to developing numeracy, then, is to first understand *what* numeracy needs to be developed. This is difficult since the numeracy that is needed in different contexts is based on different orientations, underlying principles and assumptions.

In the context of higher education, the kind of numeracy students need will depend on the contextual requirements of their particular discipline, the profession they plan to enter and their civic roles as graduates. In the case of the institution that is the focus of this study, numeracy development was considered important to students' future success in their programmes and in enhancing the graduates' ability to deal with personal, professional and societal responsibilities. While the need to ensure that curricular planning aimed to equip graduates with the numeracy they would require for their future lives was identified by the institution as important, the actual planning for the teaching of numeracy in undergraduate programmes was found to not be a straightforward process due to the many different contextual requirements of the undergraduate programme.

This study seeks to gain an understanding of why such a valued imperative to develop numeracy within undergraduate programmes was not easy to plan for in the curriculum. This study, therefore, aims to provide an understanding of the 'numeracy problem' within the context of a case study at one higher education institution and the approaches different faculties within the institution have taken to addressing this problem.

This introductory chapter begins with a brief overview of the reasons that the development of numeracy is important. This is followed by an initial review of the challenges with developing numeracy in a formal curriculum which result in the need for a study focused on understanding why numeracy is developed in particular ways. An overview of the research process followed in this study, including the research aim, objectives and critical questions, is presented to orientate the reader to the study. Although the theoretical considerations, methodology, contributions of the study and ethical considerations are discussed later in the thesis, a brief discussion of each is included in this introductory chapter.

1.2 Numeracy as a social problem

1.2.1 The importance of numeracy

The aim of improving literacy and numeracy has been a part of national and international developmental agendas for some time. For many years the literacy agenda took ‘centre stage’. In the past few decades, however, society has become increasingly ‘mathematized’ (Vithal, 2012) – functioning increasingly within a “highly quantified framework” (Ernest, 2009, p. 6) – which has placed increasing importance on the need for all individuals to be numerate. It is argued that a numerate society contributes to social justice, economic empowerment, environmental sustainability and critical citizenship.

As stated in the 2016 report of the Organization for Economic Co-operation and Development (OECD, 2016), both literacy and numeracy practices play an important role in forming the foundation for the development of the higher order reasoning required to manage problem solving in technology rich environments. The authors of the report argue that adults who are proficient in numeracy, among other skills, are more likely to be able to take advantage of the changes in modern society. Those who are not, in contrast, face a disadvantage in terms of being able to access opportunities in a society that is strongly influenced by information and communication technology (ICT) (OECD, 2016).

Weist, Higgins & Frost (2007) assert that sound numeracy practices can “enhance individual and collective living in areas such as health, education, finances/economics, politics and social action” (p. 47). They state that these practices are “closely linked to the quality of personal, vocational and civic life” (Weist et al., 2007, p. 50). It may be deduced, then, that in contrast poor or inappropriate numeracy practices can negatively influence an individual’s personal, vocational and civic life as well as that of the collective society – including its professional practices. Schwartz et al (1997 as cited in Wood, Liu, Hanoch & Estevez-Cores, 2015) raise a similar point where they argue that numeracy, or the lack thereof, impacts on a broad range of decisions in all spheres of life.

One of the areas in which extensive research has been undertaken is in the role of numeracy in health – both from the perspective of managing one's personal self-care and treatment and in terms of the clinical practices of health care professionals. It has been argued that poor numeracy, or inappropriate numeracy practices, can lead to irreparable harm in the healthcare context: in fact, it can potentially result in the death of a patient (Warburton, 2010). Eley, Sinnott, Steinle, Trenning & Boyde (2014), investigating improving numeracy skills in emergency medical environments, argue that health care practitioners need adequate numeracy practices in order to protect the health of their patients; they suggest that currently there are poor numeracy practices across the health professions, including doctors and surgeons as found in a study undertaken Australia and New Zealand. They argue that the risks associated with poor numeracy are magnified by fact that many health professionals fail to realise that their numeracy skills are inadequate. Hibbard, Mahoney, Stock & Tusler (2007) found that numeracy also influenced medical insurance decisions and thus impacted on the treatment plan individuals were able to afford.

Another area of concern to individuals and societies is that of economic improvement. Lusardi & Mitchell (2007, 2011) argue that numeracy is key to general financial growth and management. In their studies they highlight the link between numeracy proficiency and the ability to understand and utilise financial information.

The ability to generate wealth is often seen as a key factor in improving standard of living and social status and fostering empowerment. Estrada-Mejia, Vries & Zeelenberg (2016) argue that numeracy is a key contributing factor to the generation and accumulation of wealth over time. In a five-year longitudinal study, they concluded that "participants with low numeracy decumulate wealth, while participants with high numeracy maintain a constant positive level of wealth" (p. 61). According to this study the lack of numeracy, or the use of inappropriate numeracy practices, can actually worsen a person's financial stability. This could be of serious concern in a developing country like South Africa. It could contribute to widening the divide between the very rich and very poor. With South Africa's history of injustice and unequitable provision based on race, this will therefore most likely continue to disadvantage particular groups within society.

Beyond the importance of numeracy to individuals in their different capacities, Vithal (2012) makes reference to the “formatting power” (p. 3) of mathematics within society and argues that “it is imperative to educate those who will come to participate [insiders] in that formatting power and address problems of development as well as those [outsiders] who will need to be able to react to it to ensure that fair, equitable and just solutions are found” (p. 2). It may be argued that a numeracy curriculum has an obligation to develop ‘outsiders’ to the formatting power of mathematics who can be critical of the use of mathematical content and processes in contexts. Skovsmose (2004) suggests that lack of sophisticated numeracy can, in fact, “ensure the social order is maintained in such a smart way that rational citizens by using their own free will can accept an imposed order” (p. 3).

Numeracy development has a useful role to play in terms of developing ‘users’ of mathematical knowledge and as “outsiders” who can critique its use. In the midst of political turmoil, abuse of power and financial fraud, it is crucial that members of a society are in a position to recognise and be critical of such behaviours in a logical and insightful manner. The kind of ‘numerate’ person required to participate in such critical engagement is beyond the ‘basic application to everyday context’ understanding of numeracy but requires deeper engagement with concepts and contexts.

It appears, then, that the level or type of numeracy practices that are used can play a role in privileging certain individuals or communities in a wide range of different spheres of living in the current quantitative and technologically driven era. Lack of particular numeracy practices, on the other hand, can disadvantage people in terms of their individual well-being and development and this can be used by others as a tool to disadvantage communities. The development of numeracy may thus also be important as a social justice initiative to increase equitable access to information and develop particular practices.

In the next section, I explore the insights which large-scale assessments provide into current numeracy practices.

1.2.2 Assessment of numeracy

Interestingly, even though there is strong evidence that numeracy is a contributor to quality of life, both personal and professional, performance on numeracy assessments internationally indicates that poor numeracy is prevalent. While the international assessments, such as the Programme for the International Assessment of Adult Competencies (PIAAC), Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) and the Annual National Assessments (ANA) – have been the subject of some criticism, the large proportion of low scores on these tests draw attention to the fact that numeracy competencies are a challenge nationally and globally.

The 2016 report by the Organization for Economic Co-operation and Development (OECD) on performance in the PIAAC assessments was based on results which were combined over two rounds of assessment generating scores for 35 countries. It reported that "[l]ow-skilled adults are numerous in all countries/economies, with the proportion ranging from one in ten to one in two adults who are proficient at or below Level 1 in the domain of literacy or numeracy" (OECD, 2016, p 44). According to the National Center of Education Statistics website, Level 1 is the most basic level which include activities that require "simple processes such as counting, sorting, performing basic arithmetic operations with whole numbers or money, or recognizing common spatial representations in concrete, familiar contexts where the mathematical content is explicit with little or no text or distractors" (p. numproficiencylevel). More than half the adult population assessed performed below Level 3, where numeracy demands are experienced in embedded contexts which requires respondents to select and use problem solving processes (OECD, 2016). In its simplest form numeracy is likely to be experienced in this way in higher education programmes and in professional practice. These results suggest that there is a large proportion of people globally who will most likely experience difficulty with these numeracy practices.

Participants across the world have also tended to score low on the Programme for International Student Assessment (PISA), another international assessment which is administered to students of fifteen years of age which has a strong connection to school mathematics (OECD, 2018). South Africa has not participated in either of these international assessments, however Grade 6 learners participating in the Trends in International Mathematics and Science Study (TIMSS) have also performed poorly in the test. In fact, the diagnostic report on the 2015 TIMSS suggests that the test scores indicate learners lack the higher-level cognitive skills required to solve problems, lack foundational mathematical skills and that poor language proficiency further impacts on their ability to make meaning when reading test questions (Juan, Slyvia, Zulu, Harvey, Prinsloo et al., 2017). The South African Annual National Assessment (Numeracy), which is administered to learners in various grades, has also reported scores below expected levels in numeracy.

While there are no assessments administered on a national scale to assess numeracy among adults in South Africa, the National Benchmark Tests (NBTs) is available to be used by universities to assess applicants as part of the admissions process. Not all universities use the tests for admissions, some use them as a diagnostic tool to understand students' literacies on entry to university. The NBTs have also reported low Quantitative Literacy (QL) scores (Prince & Frith, 2020). This is discussed in greater detail later in this chapter.

The importance of numeracy for individuals to participate fully in all aspects of life, and the lack of numeracy suggested by the results of the assessments designed to assess numeracy highlight the need for explicit initiatives to develop numeracy. While in the senior phase of Basic Education in South Africa learners are required to study Mathematical Literacy if they are not studying Mathematics as a subject, in higher education there is no common agenda across universities to address the numeracy needs of students, despite concern about widespread issues with numeracy among students.

1.3 The 'numeracy problem' in the context of higher education in South Africa

The higher education sector in South Africa has been reconfigured numerous times. Post-apartheid, and in the context of the new South African Constitution of 1996 and the Act of 1997 and 1997 White Paper, higher education as a sector as well as the individual institutions within it were forced to examine their role in advancing transformation. Badat (2010) described clearly the various social purposes of higher education identified in the White Paper. He claims that these purposes resonate with the core roles of higher education of production, use and application of knowledge through research and development and of producing critical graduates that can contribute to economic and social development and maintain democracy.

As part of the transformation agenda, the higher education sector is expected to "conceptualise (and) plan…higher education in South Africa as a single, coordinated system", "ensure diversity in its organisational form and in the institutional landscape", "diversify the system in terms of the mix of institutional missions and programmes that will be required to meet national and regional needs in social, cultural and economic development", and "offset pressures for homogenisation" (DoE, 1997 as cited in Badat, 2010, 5).

The restructuring of the higher education sector since 2001 has resulted in 23 public higher education institutions, comprising 11 universities, 6 comprehensive universities and 6 Universities of Technology (UoTs) – all of which have had to reconfigure their programmes and seek approval again from the Council of Higher Education for their new offerings. It could be argued that the type of institution that was most affected was the university of technology. These institutions were formerly Technikons with a strong vocational skills orientation. The UoTs continue to grapple with the implications of their new identity. Historically, they attracted many students who did not meet traditional university requirements and thus had a role in developing graduates with the key knowledge and skills to contribute to the social and economic development of the country.

Inadequate numeracy practices have continued to be a problem across the different levels of education in South Africa. The National Benchmark Tests (NBTs) are designed to assess students' quantitative literacy or numeracy practices on entrance to higher education. The results of a sample of students across the higher education sector for the National Benchmark Project Quantitative Literacy (QL) in 2009 indicated that only 25% of the students entering higher education were equipped for the numeracy demands of the undergraduate curricula (Yeld, 2009). Frith and Prince (2018) report that the scores on the National Benchmark Project

Quantitative Reasoning (QR) test in 2016 suggest that over 80% of the more than approximately 80 000 prospective students that wrote the test were likely to experience challenges in their programmes if their institutions did not make provision in the curricula to address the development of quantitative literacy or numeracy. These scores suggest there has been an increase in proportion of students writing the tests that are likely to experience challenges to deal with numeracy demands in higher education. Low numeracy scores are seen to have a greater effect than low literacy scores on academic performance in higher education, thereby impacting negatively on students' success in higher education (Brady, 2014).

Poor quality of basic education is often cited as a reason for the inadequate numeracy competencies of students entering higher education (Frith & Prince, 2016). This often motivates design of curricula that is premised on a discourse of under-preparedness (Boughey, 2010) within a deficit framing (Lillis and Scott, 2007) that is focussed on 'upskilling' students with the numeracy practices they should have mastered at school.

While it cannot be denied that poor schooling experiences have influenced students' competence in numeracy, there are many other social, cultural and political factors that have influenced, and continue to influence, the way numeracy is conceptualized, signified and legitimatized in higher education and how it is experienced by students in their different disciplines and in the context of a highly quantified society. An emphasis on the development of numeracy within higher education is thus crucial.

Galligan and Taylor (2005) found that there were discrepancies between the numeracy practices of new tertiary students and the numeracy demands of their programmes. Galligan (2013) argues that academic numeracy is a university wide issue and should be addressed in a systematic way.

1.4 The ‘numeracy’ problem in the context of one higher education institution: Durban University of Technology (DUT)

The Durban University of Technology (DUT) was formed by the merger of Technikon Natal and ML Sultan Technikon, which had focused largely on vocational skills training. The merging of higher education institutions and elimination of training colleges and technikons gave rise to a new institutional type within the higher education sector: the ‘university of technology’ (UoT). With this new identity came a new role in the changing educational context post-apartheid.

As a UoT, the focus of DUT has shifted from the vocational training which was the business of the technikons, to programmes that are both professionally and socially beneficial. Recently, UoTs have expanded beyond diploma programmes to offer professional degrees and post graduate qualifications. UoTs have both an academic and professional orientation to their programmes.

As has been discussed, gaps often exist between the numeracy practices of students entering higher education, those expected in higher education and those expected of a professional graduate. At DUT there is anecdotal evidence that the numeracy practices of students are lower than what is required and this undermines their ability to succeed in the programmes in which they are enrolled. There is also anecdotal evidence that industries have found some DUT graduates to have inadequate numeracy skills, along with deficits in other non-technical practices, such as communication and writing.

1.4.1 Numeracy at the institution: The past including student performance in entrance tests

The idea of addressing students’ numeracy development is not new to DUT, but none of the previous initiatives have been as explicit as within the Curriculum Renewal Project (CRP) initiated in 2011. The low levels of numeracy among new students enrolling in the institution were the primary motivator for planning initiatives to develop students’ numeracy practices. In 2015, over 90% of the first year registered students that wrote the National Benchmark

Project Quantitative Literacy (QL) test achieved scores in the intermediate, lower and basic categories, suggesting that students needed structured support within the curriculum to achieve appropriate competence in quantitative literacy (National Benchmark Tests Project Team, 2015). Students achieved similar results on the Standardised Assessment for Access and Placement (SATAP) in 2011, 2012 and 2014 (Access Project Team, 2011; 2012; 2014). This suggested that a large proportion of students entering first year at DUT were not appropriately numerate to deal with the implicit and explicit numerical demands of their curricula. This could create a barrier to accessing disciplinary knowledge and thereby reduce students’ chances for success (National Benchmark Tests Project Team, 2015).

The primary approaches used by DUT to develop students’ numeracy are discussed next.

1.4.2 Interventions to address the numeracy challenge: The case of the Curriculum Renewal Project at DUT

At the DUT, a strategic decision was made to engage in a curriculum renewal project across all programmes at the institution. This curriculum renewal project (CRP) was initiated in 2011 by the Vice Chancellor at that time, Professor Ahmed Bawa with specific imperatives that needed to be addressed through the new curriculum to be planned by programmes. Although this process started in 2011, there are still programmes who have not yet completed the process which could be indicative of the challenges of curriculum planning experienced by programmes.

The CRP allowed DUT the opportunity to further develop its identity as a university of technology within the South African higher education landscape informed by national policies, plans and strategies. This included the Higher Education Act (No. 101 of 1997); the National Development Plan; recommendations of the National Planning Commission; the White Paper for Post-School Education and Training in South Africa and the Department of Higher Education and Training (DHET) 2014−2019 Enrolment Plan (DUT, 2014). According to the DUT Strategic Plan, the DUT context within this landscape is one of transformation, reconstruction and development.

DUT chose to focus on curriculum renewal rather than re-curriculation or curriculum revision with the intention of significant change. This was strongly influenced by a transformative agenda and aligned to the social justice agenda of higher education. The Vice Chancellor's intention was for DUT's programmes to focus on the holistic development of students as responsible professionals and citizens equipped to be both producers of knowledge and critical users of knowledge – an agenda in keeping with the transformative purpose of higher education identified in the White Paper and the Act of 1997.

This project led to the renewal of curricula with major changes across most undergraduate programmes. There were certain institutional imperatives that defined the process, such as the compulsory inclusion of general education to constitute 30% of all undergraduate programmes. As part of the process, the attributes that graduates would need in their roles as professionals and critical citizens were identified as outcomes of programmes which programmes were tasked with developing in their students over the course of the programmes. Being numerate was one of the core attributes identified.

To achieve these graduate attributes and to ensure that all students reaped the benefits of mathematics or quantitative reasoning (QR), all programmes were required to have a compulsory mathematics or numeracy/QR component (Gwele, 2012; DUT, 2015). What this meant, and how it was to be achieved, was left to the curriculum designers and the general education task team to determine.

1.5 Personal interest and experience

At a personal level, I have been working with quantitative reasoning (QR) and numeracy intermittently at Durban University of Technology for over 20 years. However, the curriculum renewal project placed an institutional focus on numeracy at DUT for the first time.

My work in this area, like that of many of my colleagues across South Africa, was influenced by the need to improve the numeracy levels of students who were perceived to be entering higher education underprepared, especially in numeracy. Over the years, however, it became evident through experience and research in this area that numeracy is not the 'step child' of mathematics and that a repetition of the mathematics taught in basic education would not ensure that graduates would attain adequate numeracy levels.

During the curriculum renewal process, I served on the General Education Task Team. In this capacity, I worked on the design of a rubric for quantitative reasoning/numeracy. I also developed one of the institutional modules for numeracy which was not included in this study. Personally, I felt that the principles of the curriculum renewal process provided an opportunity to consciously engage with what numeracy practices are important, how they are used and how they could most effectively be developed and assessed within curricula. However, in my capacity as an academic development practitioner working with staff on curriculum design, I was aware that the directive from leadership to incorporate numeracy into the curriculum was understood in various ways by staff. The imperative to design a new curriculum was met with a range of reactions – from excitement to nervousness and fear. There were many factors that needed to be considered in the design of curricula: the institutional imperatives; the criteria set by professional bodies for certification; the students enrolled at the institution; the research in the discipline; the structure of undergraduate programmes within South Africa; the capacity of staff; and the institutional resources available.

DUT considered planning to enable students to develop the numeracy practices they would need for their future careers to be an important aspect of designing undergraduate programmes that contribute to transformation, reconstruction and development. However, it was noted in conversations with curriculum developers that this process was influenced by various social, cultural, historical and political factors and contexts which sometimes came into competition with each other.

I believed that an investigation into how the imperative to incorporate numeracy development was understood and translated into curriculum in one institution could provide useful insights into how numeracy in higher education is understood, what drives its inclusion in higher education undergraduate development and what factors influence its configuration.

1.6 Rationale and purpose of this study

This study was designed with the intention of gaining insight into the challenges involved in planning for numeracy in a curriculum and allowing for a re-envisioning of possibilities for developing numeracy in undergraduate curriculum in higher education. The purpose of the study was to understand how numeracy is developed and explore its inclusion within undergraduate programmes at a university of technology.

When conceptualising the study, I felt that such a study could contribute to an understanding of the peculiarity and historical specificity of numeracy in higher education. It is a phenomenon that has gained increasing political and social traction in higher education yet remains amorphous and is not well understood.

The study of this case offers insights into how numeracy is conceptualised within higher education, how it is implemented within the constraints of the fixed timeframe of an undergraduate programme and an indication of how the forces that act on this field within higher education impacts it. The study therefore contributes to an understanding of the extent to which the design of undergraduate curriculum embedding numeracy is constrained on "one end by structure of knowledge of numeracy and also by the structure of wider social interests" (Young, 2014, p.201).

1.7 Critical questions

This case study was designed to respond to the following critical questions:

- How is the development of numeracy planned for in selected undergraduate programmes at a university of technology?
- Why is the development of numeracy planned for in these ways?

These questions were addressed from two interrelated perspectives: participants' conceptions of numeracy and the external contextual forces impacting on the process of planning for numeracy in the curriculum.

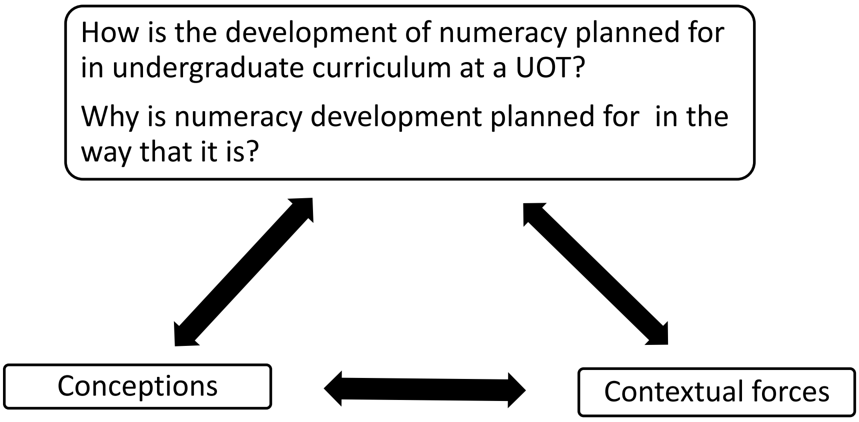


Figure 1-1 Critical questions addressed by the study and perspectives from which they were addressed

1.8 Focus of the study

The current 'status' of numeracy is of concern in South Africa and also globally. Numeracy is considered to be a crucial component of a transformative agenda for society. This study is positioned within higher education with this broad societal context.

This study was undertaken at one South African University of Technology across four different faculties which had varying disciplinary knowledges, skills and practices: The Faculty of Management Sciences (FMS), Faculty of Health Sciences (FHS), Faculty of Applied Science (FAS) and the Faculty of Arts and Design (FAD). The programmes chosen from these faculties had not included mathematics in their curricula previously.

As the title suggests, this study focusses on the 'Planning' of the formal Curriculum for undergraduate programmes and the influences on that design and not on the enactment of the curriculum.

The main aim of the study is to understand the complexities of planning for numeracy in the undergraduate programmes at a university of technology.

The objectives of the study were:

1. to explore how an institutional imperative to include numeracy in undergraduate programmes was translated into the planned curriculum

2. to analyse the conceptions of numeracy that influenced the planning for numeracy in the undergraduate curriculum
3. to analyse the internal and external contextual forces and dynamics that impacted on the inclusion of numeracy within the undergraduate programmes in the study
4. to make explicit the underlying organising principles of planning for numeracy within the context of this case study

1.9 Points of clarity concerning the study

This section provides context for a number of aspects of the study.

1.9.1 Use of terms

The term 'numeracy' is associated with numerous other terms. Numeracy, quantitative literacy, quantitative reasoning and mathematical literacy are all used in the literature to refer to a core concept based on the use of certain mathematical/quantitative concepts and process within a real context.

As indicated in the title of the study, I have used the term 'numeracy'. In Chapter 2, I describe the different variations in the use of terms in the literature. Some authors make distinctions between them, but this is less common in practice; often these terms are used interchangeably.

Another term found in the literature is 'academic numeracy practices' which Galligan and Taylor (2005) describe as a "critical awareness which allows the student to situate, interpret, critique, use and perhaps even create mathematics in context" (p.87). Academic Numeracy is appropriate to the study because of the context of the study being in formal educational setting.

At the institution in the study, the terms 'quantitative reasoning', 'numeracy' and 'quantitative literacy' appeared to be most commonly used. Within the curriculum documents the terms 'numeracy' and 'quantitative reasoning' were identified. As one of the objectives of this study was to explore the conceptions of numeracy, no predetermined definitions of numeracy were used. Participants were asked in the interviews whether they differentiated between these terms and in most cases, they indicated that they saw them to be one and the same.

Therefore, for the purposes of this study the terms 'numeracy', 'quantitative reasoning' and 'quantitative literacy' are used synonymously.

1.9.2 Philosophical assumptions, research methodology and design

According to Kuhn (1977), a paradigm refers to a common set of values or beliefs among researchers that inform the methodology. Historically, two broad categories of research developed: those driven by a quantitative orientation and those driven by a qualitative orientation. Within the qualitative space, many paradigms have emerged.

This study falls within the qualitative approach and is most aligned to an interpretive paradigm. The interpretive paradigm allows for explaining the subjective reasons and conceptions that lie behind social action. It brings to the fore understanding, describing and explaining particular realities.

Each paradigm is underpinned by views about what reality is (ontology) and how we come to know such reality (epistemology). On the one extreme, within the positivist paradigm reality is seen to be objective and absolute. It therefore remains free of the influence of social factors. On the other extreme, within a constructionist relativism world view, reality is seen as being influenced by social factors and it rejects the notion that any knowledge can be truly objective (Moore, 2004).

Critical realism lies between these two extremes. It views reality as socially constructed but also acknowledges that there is a reality that is not limited to an individual's own interpretation (Bhaskar, 2008). Critical realism allows for the research to unpack the underlying "generative mechanisms that give rise to events in the world and our experience of them” (Bharath, 2015, p. 116). In this study, a critical realist approach allows for an exploration of the planning for numeracy development in the curriculum to provide understanding of the phenomenon through social interpretations using existing theories.

1.9.2.1 *Research design and methodology*

The research design used in this study, including the methods used to generate, analyse and represent data, is presented in Chapter 4 (Methodology). A brief orientation to the research design is provided in this section.

For this research, the case study approach was selected. The ‘case’ in this study was numeracy planning in the undergraduate curriculum of selected programmes at a specific higher education institution: Durban University of Technology in KwaZulu-Natal, South Africa. Gerring (2004 as cited in Baskarada, 2014) claim case study research is well suited for “extensive and in-depth descriptions of complex social phenomena” (p.4). The study is a descriptive case study since the purpose is to describe comprehensively the different characteristics of the implementation of an institutional imperative and therefore contribute to theory building around the nature of numeracy in higher education, how is it developed and how the external contextual factors influence its inclusion or exclusion in curricula. The population of the study included the new undergraduate programmes designed as part of the CRP that was initiated in 2011 at the institution. At the time of data production not all programmes had completed the curriculum planning for their new programmes. A qualitative approach was chosen as it is suitable for research that is focused on understanding particular phenomena within their social, political and historical contexts (Creswell, 2003). The exploratory nature of qualitative research allowed for the inclusion of numeracy in undergraduate programmes to be understood from various perspectives.

1.9.2.2 *Research methods*

The programmes included in the study were selected through purposive sampling. The study focussed on the development of numeracy across programmes that did not include study of mathematics as part of their curriculum. Programmes which build on a foundation of mathematics, such as engineering, were excluded from the study. A total of seven programmes across four faculties were selected based on this criterion as well as the extent to which they had completed their planning of the curriculum.

Data sources

The data was generated from the following sources:

- Programme documents and interviews with curriculum developers and/or HODs of the seven programmes
- Interviews with the developers of institutional modules dedicated to numeracy or quantitative reasoning
- Interviews with key informants (managers and staff from the mathematics department)
- Institutional documents

Data analysis

Both inductive and deductive approaches were adopted. Firstly, thematic analysis was undertaken of the documents and interviews. Secondly, analysis using all five dimensions of Legitimation Code Theory (LCT) were used to make explicit the underlying principles of legitimation of the practices of planning for numeracy. The Epistemic Pedagogic Device (EPD) was used as an explanatory framework to explore the curriculum planning process. The process of identifying the themes, and a description of the tools and their relevance to the study are discussed extensively in the methodology chapter.

The analysis is presented across three chapters where each chapter responds to a particular objective. Each chapter includes a presentation of the data, a thematic analysis and a deductive analysis using the different dimensions of LCT.

1.9.3 Trustworthiness

A research study must always ensure that it meets the criteria of fairness and quality in the way the study is conducted, and the findings presented. In qualitative research, the quality of the research is determined by demonstrating the trustworthiness of the research.

Following the recommendations of Baskarada (2014) to ensure trustworthiness in descriptive case study research, the rigor and quality of this study were enhanced by using multiple sources of evidence, maintaining a study protocol, maintaining a chain of evidence, reviewing my analysis of data with my supervisor and other experts and by providing a 'thick' description of the context and phenomenon.

In the next section I present an outline of the thesis.

1.10 Organisation and structure of the study

In this section I present the structure of the dissertation. The 9 chapters are organised to present the research journey from the rationale of the study and methodologies chosen to the findings of the study and their analysis and abstraction. A description of each chapter is presented below.

Chapter 1: **Overview of the study**

This chapter introduces the study. It includes a brief overview of the importance of numeracy in different spheres of life and the possible consequences of not having particular numeracy practices. A brief summary of students' performance on international and national assessments is discussed, highlighting the need to enhance students' numeracy practices, to establish the background, context and rationale of the study. The critical questions, purpose of the study, objectives and methodology are introduced, providing an orientation to the research process. The terminology related to numeracy that is referenced in the study is introduced and explained. An overview of the structure of the thesis is also provided.

Chapter 2: Literature review

This chapter explores the various terms used in the literature that relate to numeracy. While this study focusses on numeracy in higher education, the literature on this specific area of numeracy was limited. As the study aimed to understand how numeracy is conceptualised, the search was broadened to include terms related to numeracy and alternative definitions. This is followed by an examination of the practices used to develop numeracy across academic sectors and the recommendations made by these studies. The chapter ends with a discussion of the social practice perspective of numeracy, which is one of the theories influencing this study.

Chapter 3: Theoretical orientations and conceptual framework

This chapter begins with a discussion of social realism and the realist ontology which is the overarching theory underpinning this study. Within this broad overarching theory, it is possible to understand different numeracy practices. Legitimation Code Theory (LCT) is presented as a methodological and analytical toolkit. Each of the LCT's five dimensions is presented. The Epistemic Pedagogic Device (EPD) which is used in the study to follow the curriculum process, is also discussed.

Chapter 4: Research methodology

This chapter provides a detailed description of the **qualitative** used and the associated paradigms, including their philosophical assumptions. A justification for the use of the interpretive paradigm is provided.

The research process is presented in detail, including the methodologies used for collecting and analysing the data. The structure that was used to present, analyse and interpret data is also discussed. The chapter also includes a description of each programme that was included in the study.

Chapters 5,6, 7 **Data presentation, data analysis and interpretation of the findings**

Three chapters were dedicated to the results and analysis. Each chapter presents, analyses and interprets the data generated from the thematic inquiry and the LCT analysis. Each chapter addresses a particular objective of the study.

Chapter 5 This was the first chapter dedicated to the presentation, analysis and interpretation of the data and addressed the question: How was numeracy planned for in the undergraduate curriculum? The chapter explores how the imperative to include numeracy in undergraduate curricula was implemented. The thematic analysis of the practices of planning for numeracy and use of the LCT dimension of Autonomy to gain theoretical insights on the principles underpinning the plans are presented.

Chapter 6 Chapter 6 and 7 investigate why particular practices were adopted in the planning for numeracy. In Chapter 6 the focus is on the exploration of the conceptions of numeracy. The chapter describes the data and presents a thematic analysis of the conceptions of numeracy described in the data and an LCT analysis using the dimensions of Specialization and Semantics. Cognitive demands of the conceptions of numeracy is also presented.

Chapter 7 Chapter 7 is the third chapter focussing on the presentation and analysis of data. This chapter focusses on the external contextual and situational factors that impact on the choices made in respect of including numeracy in the design of curricula. The data is presented and analysed thematically. This is followed by an exploration of the insights yielded by using the LCT dimensions of Density and Temporality.

Chapter 8: **Discussion**

This chapter integrates the findings presented in Chapters 5, 6 and 7 to offer an understanding of the generative mechanisms that informed planning for numeracy in this case study. The chapter highlights the complexities of planning for numeracy as a result of the nature of numeracy and the relationship with other contextual factors. The chapter presents a gap highlighted between the scholarship in numeracy education and the curriculum planning of an undergraduate programme.

Chapter 9: **Conclusion**

This chapter concludes the thesis. I present a reflection of the research journey, contributions and limitations of the study and suggestions for possible future research.

1.11 Conclusion

This introductory chapter has presented the rationale and importance of the study and introduced the research process. The next chapter reviews the literature relevant to the research topic.

Chapter 2
Literature review

2.1 Introduction

The purpose of a literature review is to make explicit the main published work related to a particular phenomenon. As indicated in the previous chapter, this study aims to contribute to an understanding of how numeracy is developed in undergraduate programmes at a university of technology (UoT) and why it happens in the particular ways that it does. One of the factors influencing the decisions about numeracy initiatives in these formal contexts, is the conceptions that those making the decisions have about numeracy.

In this chapter, a review of literature as it relates to the development, or plans for developing, numeracy in academic contexts is presented. The chapter includes a review and analysis of literature that engages with conceptions and definitions of numeracy together with a broad review of numeracy education, with special focus on the development of numeracy in higher education.

The literature broadly identifies three approaches to developing numeracy in academic contexts. These are through (i) offering it as a subject or distinct module/s; (ii) including it in cross-curricular activities by integrating basic mathematics with other subjects; or (iii) making it explicit and developing it across the curriculum in all subjects by finding 'numeracy moments' within the subjects (Bennison, 2015). Although these approaches have been identified primarily in the context of secondary education, similar approaches are described in higher education as well.

Castro (2009) highlights several "habits of mind" (p. 127) based on the 2003 Programme for International Student Assessment (PISA) model which he terms "cognitive competencies or processes" (p. 127) as being important to numeracy in higher education: thinking and reasoning; argumentation; communication; modelling; problem posing and solving; representation; and using symbolic formal and technical language and operations.

Based on this, developing numeracy in curricula in higher education should involve including 'organized' and 'structured' legitimate numeracy knowledge. This should provide the conceptual depth needed to solve original problems within differing contexts by stimulating the cognitive competencies described above (Castro, 2009). This process is impacted on by what is considered legitimate knowledge and what 'degrees' of conceptual depth are required and are achievable within the social, cultural, political and historical context.

In South Africa, the University of Cape Town is the only university with a dedicated numeracy centre. In personal communication with colleagues from the centre it was established that the terms 'numeracy' and 'quantitative literacy' are used interchangeably. This centre promotes numeracy through both the module approach, which involves separate modules for numeracy and an embedded approach, where the centre engages students and/or staff to respond to numeracy moments within their disciplinary courses. The centre works with lecturers across disciplines to identify the quantitative literacy challenges that their courses present and design interventions to enable students to develop the necessary quantitative literacy practices. From the centre's website (UCT Numeracy Centre, 2020) it appears that the more popular approach appears to be the module-based approach where the centre offers specific numeracy modules for certain programmes on request. However, based on the articles written by some of the staff that work, or have worked at the centre it appears that the embedded approach is favoured (see for example Frith, 2012) due to the orientation that numeracy practices across disciplines are different.

As very little research has been done on numeracy development in higher education, I expanded the literature review to include numeracy development in adult education and secondary education to provide a broader and more nuanced understanding of numeracy across academic contexts. While the term 'numeracy' is used in this study, a number of other terms including 'quantitative literacy' and 'quantitative reasoning are used in relation to numeracy in higher education and thus were included in the review in order to more fully understand the different domains, or features of numeracy.

This chapter begins with an exploration of the terms used in the literature on numeracy, followed by a discussion of different perspectives on what constitutes numeracy – with a focus on the social practice perspective. Finally, and most importantly to this study, the literature addressing how numeracy is developed across academic contexts is discussed.

2.2 The use of the term 'numeracy'

The term 'numeracy' was first introduced in the Crowther Report (1959) which was compiled at the request of the Minister of Education in response to the changing needs of society. Two aspects were identified:

> On the one hand (it) is an understanding of the scientific approach to the study of phenomena – observation, hypothesis, experiment, verification. On the other hand, is a need in the modern world to think quantitatively, to realize how far our problems are problems of degree even when they appear as problems of kind (p. 270).

The term 'numeracy' is sometimes used interchangeably with other terms, such as 'quantitative literacy' and 'quantitative reasoning'. For example, the American Journal *Numeracy* is subtitled "advancing education in quantitative literacy". Similarly, the Numeracy Centre at the University of Cape Town uses these terms interchangeably. It states, for example: "The importance of the role of quantitative literacy (or numeracy) in higher education curricula is increasingly being recognized internationally" (UCT Numeracy Centre, 2020, para. overview).

Some authors, however, distinguish between these terms. For example, Madison (2019), in a personal addendum on working with scholars, Lynn Steen and Robert Orrill, notes that Orrill made a distinction between numeracy and quantitative literacy, describing quantitative literacy as a much broader concept than numeracy as it was "a cultural field where language and quantitative constructs merge and are no longer one or the other" (p. 45).

Cardetti, Wagner & Byram (2019) also distinguish between quantitative literacy and quantitative reasoning. The authors state that while both terms make reference to dispositions, quantitative literacy refers more to ease, competency and habits of mind, while quantitative reasoning refers to the higher order cognitive reasoning needed to understand and construct arguments that contain quantitative information.

A distinction between the meanings of different terms is also noted in the findings of Karaali, Villafane-Hernandez, & Taylor (2016), who argue that the terms ‘numeracy’, ‘quantitative literacy’ and ‘quantitative reasoning’ could be ranked hierarchically, based on a critical review of their meanings. While they focus on these three key terms, they also include other related terms, such as ‘statistical literacy’, ‘mathematical literacy’, ‘mathemacy’ and ‘matheracy’ in their review. While Karaali et al. (2016) note that all of these terms share a core understanding, they analysed them for nuanced differences in meaning using a four-dimensional framework to assess quality of desired outcome, knowledge domain, display of expertise and context. They argue, using the framework, that numeracy, ‘quantitative literacy’ and ‘quantitative reasoning’ could be seen as a hierarchy of terms, with numeracy referring to the lowest level.

Similar distinctions were noted with statistical literacy and statistical reasoning by Garfield, delMas, and Zieffler (2010), who placed statistical literacy, statistical reasoning and statistical thinking on a hierarchy. The said authors described statistical literacy as being focussed on understanding and using the basic language and symbols, procedures of statistics and recognising and interpreting different representations. Statistical thinking was described as expecting higher cognitive engagement such as critiquing evaluating and/or generalising

Karaali et al (2016) propose that terms such as ‘mathematical literacy’ and ‘statistical literacy’ are more strongly linked to the content domain of specific disciplines, such as mathematics and statistics while ‘mathemacy’ focusses on mathematics for society and ‘matheracy’ described culturally based, being defined through an ethnomathematical framework.

Another distinction that arises in the terminology as it relates to university numeracy is the use of the term ‘academic numeracy’. Galligan and Taylor (2005) define academic numeracy as a “critical awareness which allows the student to situate, interpret, critique, use and perhaps even create mathematics in context” (p. 87); the context, in this case, being higher education. The addition of the word ‘academic’ limits the reference to those practices that are experienced or expected within the academic context. For instance, the numeracy practices expected of a street vendor would not necessarily be the same as those that are discussed within the higher education context. Galligan (2011), extending the work of Coben (2000), adds notions of confidence and competence specifically to numeracy in the field of nursing, but subsequent attempts at defining numeracy also include these dimensions as well. Brady (2014) defines academic numeracy as the "capacity to confidently and competently use mathematics at university level, and to be able to apply, interpret, critique and communicate mathematical concepts in particular disciplinary contexts" (p. 1); this refines the concept to bring the disciplinary context to the fore. Within the literature, there are further distinctions made in respect to particular professions: for example, health numeracy and nursing numeracy.

While a variety of terms are found in the literature, 'numeracy', 'quantitative literacy' and 'quantitative reasoning' are most common and in most instances these are used interchangeably. This study uses the term 'numeracy' because it is the term used by the institution which is the subject of the study. The terms 'numeracy' and 'being numerate' were found in senate documents and were used during the General Education Task Team meetings. The term 'quantitative reasoning' did, however, appear in module descriptor templates. Although it could be argued that 'academic numeracy' would be an appropriate term, given that the study is situated in the context of higher education, 'numeracy' was considered to be more familiar to, and thus more easily understood by, participants in the study.

To gain insight into the varying definitions of numeracy, I explored the literature in respect of definitions of numeracy, quantitative literacy and quantitative reasoning to broaden my understanding of numeracy. In the next section, I begin with a brief sample of definitions found in the literature. This is followed by an exploration of numeracy as understood through social practice theory, which is a guiding theoretical perspective adopted in the study. Thereafter, I present a review of approaches to developing numeracy in formal curricula reported in the literature.

2.3 What is numeracy? Insights from the literature

Madison (2019) states that it is difficult to convey to others what we mean by quantitative literacy, quantitative reasoning or numeracy. Gilman (as cited in Fischer, 2019) describes numeracy/quantitative literacy as being one of those things about which one can say, "I know it when I see it" (p. 3). This suggests that numeracy may be understood tacitly but is difficult to articulate.

Given its tacit nature, numeracy is sometimes seen as common sense. Common sense, according to Davis (2006), lacks formal structure. Common sense understandings often come with an expectation that everyone should be able to practice it with the same level of proficiency and disposition. This, then, could be why numeracy as a form of common sense is difficult to articulate.

Nonetheless, there are scholars who have provided definitions of numeracy. Initially, researchers in the area were concerned with investigating and advocating for the importance of numeracy for personal, vocational and civic engagement. It became important, at that time, to attempt to define numeracy. As indicated earlier, the term numeracy was first used in the 1959 Crowther report. It was coined as a mirror image of literacy. Subsequently, the term featured again in the Cockcroft (1982) report, in which being numerate was described as possessing two attributes:

> The first of these is an 'at-homeness' with numbers and an ability to make use of mathematical skills which enable an individual to cope with the practical mathematical demands of his everyday life. The second is ability to have some appreciation and understanding of information which is presented in mathematical terms, for instance in graphs, charts or tables or by reference to percentage increase or decrease (p. 11).

Geiger, Goos & Forgasz (2015) distinguish this definition in the Cockcroft report from previous definitions of numeracy because of its inclusion of the second characteristic, which they claim places emphasis on the prevalence of mathematical representation in real life contexts. They note that with the increase in digital technology, authors such as Steen (1999) have advocated for the importance of individuals being quantitatively literate so that they are equipped to deal with the emergence of a “data drenched society” (p. 534).

Steen (2001 as cited in Geiger et al. (2015)) identifies seven dimensions within numeracy, as follows:

- confidence with mathematics;
- appreciation of the nature and history of mathematics and its significance for understanding issues in the public realm;
- logical thinking and decision-making;
- use of mathematics to solve practical everyday problems in different contexts;
- number sense and symbol sense;
- reasoning with data; and
- ability to draw on a range of prior mathematical knowledge and tools (Geiger et al., 2015, p. 533).

It can be seen from Steen’s dimensions of numeracy that the focus was not on mathematical procedure but rather on problem-solving using mathematics. Beyond this, there is also an identification of higher-level cognitive reasoning and the suggestion of affective attributes.

As far back as the Crowther Report, the point was made that numeracy referred to more than a mastery of basic mathematical operations (Crowther, 1959). Johnston (2007) defined numeracy as a “critical awareness which builds bridges between mathematics and the real world, with all its diversity” (p. 54) and argued that to be numerate means more than to succeed in mathematics at school or university. Very importantly, Johnston (2007) challenged the thinking that numeracy is about basic mathematics and argued that different levels of mathematics are associated with numeracy, depending on the requirements of the context.
After the emergence of the term ‘numeracy’ other terms also arose, such as ‘quantitative literacy’ and ‘quantitative reasoning’. Schoenfeld (2001) defines quantitative literacy “as the predilection and ability to make use of various modes of mathematical thought and knowledge to make sense of situations we encounter as we make our way through the world’’ (p. 51). This is similar to Weist et al.’s (2007) definition of quantitative literacy as an

“inclination and ability to make reasoned decisions using general world knowledge and fundamental mathematics in authentic, everyday circumstances” (p. 48). The Association of the American Colleges and Universities (AACU, 2009) defines the terms as synonymous:

> Quantitative Literacy (QL) – also known as Numeracy or Quantitative Reasoning (QR) – is a "habit of mind," competency, and comfort in working with numerical data. Individuals with strong QL skills possess the ability to reason and solve quantitative problems from a wide array of authentic contexts and everyday life situations. They understand and can create sophisticated arguments supported by quantitative evidence and they can clearly communicate those arguments in a variety of formats (using words, tables, graphs, mathematical equations, etc., as appropriate) (quantitative literacy VALUE rubric, para. 1).

These definitions highlight attitude or dispositions as a feature, using terms such as ‘inclination’, ‘predilection’, and ‘habit of mind’ – together with ability – as being fundamental to numeracy, quantitative literacy or quantitative reasoning. ‘Habit of mind’ suggests a practice orientation rather than a skills or procedural orientation. It is likely to expect attributes such as an ease and confidence to engage with quantitative demands.

Recently, Fisher (2019) has critiqued these earlier definitions of quantitative literacy, arguing that the phrase ‘habits of mind’ offers little guidance to educators in terms of *what* content, *what* habits of mind, or *what* is comfortable. Fisher (2019) offers an alternative definition of quantitative literacy as the “facility to participate in the intersecting quantitative practices of many different communities (each with its own practice of discourse)” (p. 4). Mast (2019) raises the same concerns with Fisher’s definition that Fisher has raised with previous definitions: it is vague and challenging to implement – although she proposes that it could provide a stimulus for scholarly dialogue.

While this discourse on definitions may be important in numeracy scholarship, for numeracy educators who need to plan a curriculum that caters for the development of numeracy, ambiguous or contested definitions of numeracy can pose a challenge. More explicit definitions which can be useful in this regard are provided in national or international frameworks addressing numeracy.

The Programme for International Student Assessment (PISA), which assesses the mathematical literacy of 15-year-old learners, uses the term ‘mathematical literacy’ which it defines as an

> individual’s capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to recognise the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective citizens (OECD 2013, p. 17).

The Programme for the International Assessment of Adult Competence (PIAAC), another international assessment test, is an adult assessment of numeracy and literacy that can be used to assess individuals between 16 years and 65 years of age and is thus less directly linked to mathematics at the secondary education level. Within the PIAAC assessment framework, numeracy is defined as “the ability to access, use, interpret and communicate mathematical information and ideas, in order to engage in and manage the mathematical demands of a range of situations in adult life” (PIAAC Numeracy Expert Group, 2009, p. 21). The PIAAC framework defines numerate behaviour as involving “managing a situation or solving a problem in a real context, by responding to mathematical content/information/ideas represented in multiple ways” (PIAAC Numeracy Expert Group, 2009, p. 21. See also PIAAC, 2012).

According to Geiger et al. (2015), the PIAAC definition of numeracy is more closely aligned to earlier definitions of numeracy that see numeracy as similar to literacy, focussing on interpreting and communicating mathematical information, while PISA extends the definition to include logical reasoning, problem solving, drawing inferences and justifying decisions. There are varying definitions of literacy that range from viewing it as a skill of communication to a practice of meaning making. This will be discussed further in Section 2.4 on ‘numeracy as social practice’.

Returning to the PISA and PIAAC comparison, Tout & Gal (2015) describe how mathematical literacy and numeracy are constructed within both the tests. Although all terminologies make reference to the contextual application, it is explained that mathematical literacy as assessed in the PISA has a focus on school mathematics knowledge and processes. Numeracy is seen as being a broader concept.

The South African National Benchmark Test, which is used to assess university applicants' quantitative literacy, uses a definition of quantitative literacy as the

> ability to manage situations or solve problems in practice, and involves responding to quantitative information that may be presented verbally, graphically, in tabular or symbolic forms; it requires an activation of a range of enabling knowledge, behaviours and processes and it can be observed when it is expressed in the form of a communication in written, oral or visual mode (Frith and Prince, 2006, p. 30)

This definition is influenced by the PISA and PIAAC understandings of numeracy. The definitions of numeracy, quantitative literacy and mathematical literacy used for these assessment purposes are less ambiguous than many of the broader definitions found in the literature. However, in 2017 a task team including renowned scholars in the field of adult numeracy education reviewed the PIAAC framework in light of theoretical developments in the field and found that it failed to assess several key aspects of numeracy: the disposition to use mathematics; the ability to see mathematics in a numeracy situation; the ability to engage in critical reflection and action; and the degree of accuracy of responses (Tout, Coben, Geiger, Ginsburg, Hoogland et al., 2017).

The review report highlighted, among other things, gaps in the understanding of what constituted numeracy. Relevant to this study is the task team's recommendation that the notion of dispositions should be included explicitly in any framework for understanding numeracy and not exist only in the background. Tout et al. (2017) also make reference to maths anxiety and talk of the affective domain of numeracy. The current assessments have not catered for such non-cognitive aspects of numeracy. They make the point that the assessment looks across contexts that are very varied. For example, work place numeracy is seen as very different to school numeracy. This was not catered for, or could not be catered for in large scale assessments.

Another point made by the reviewers that is relevant to this study, is the notion that the numeracy expected in adult life requires the ability to read and understand texts that include mathematical content and to speak and write about these mathematical aspects. This, they claim, is crucial for dealing with activities in a real-life context, as details of contexts or quantitative information are sometimes experienced through texts. Making sense of text is therefore an important numeracy practice (Tout et al., 2017). International tests underplay the importance of the texts that are used because of the varied language practices of test takers. This might, however, limit their conceptualisation of numeracy or mathematical literacy. It is easy to be swayed by the definitions or criteria stipulated in national and international tests since these tend to be explicit. However, because the assessment does not reflect the affective domain and the varying contexts of numeracy practices and it simplifies the language demands of numeracy, it runs the risk of promoting a perception of numeracy as generic and limited to cognitive processes. Coben (2000) describes being numerate as being

> competent, confident, and comfortable with one's judgments on *whether* to use mathematics in a particular situation and if so, *what* mathematics to use, *how* to do it, *what degree of accuracy* is appropriate, and *what the answer means* in relation to the context (p. 35, emphasis in original).

Coben notes, as other scholars have, that being numerate is not only a cognitive action but includes affective characteristics. Coben also highlights the point that not all situations may be resolved best with mathematics and being numerate involves being able to recognise these situations. Brooks (2015) stresses that confidence building is crucial to the development of numeracy; in fact, she argues that confidence is the "single most important contributor" (p. 28) to numeracy competence, thus placing greater emphasis on the development of a 'particular' disposition. Referencing the work of Marr, Helme & Tout (2003), she describes numeracy competence as comprising the cognitive domain (indicated on the left of the Figure 2-1) which increases in complexity from bottom to top and the affective domain (on the right hand side) that increases in complexity as well.

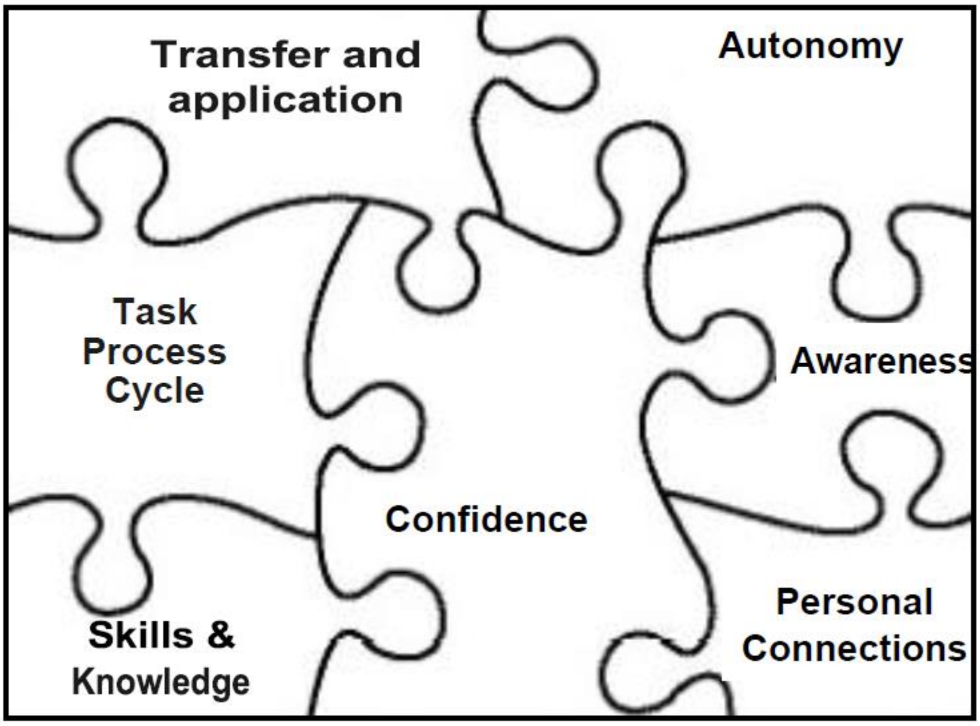


Figure 2-1 Model of holistic numeracy competence
(Marr, Helme & Tout, 2003, p. 4)

Brooks (2015) argues that teachers could use these as building blocks – moving students from skills and knowledge to real life applications and developing students' autonomy to take control of their own learning by establishing links to their personal goals. The role of a numeracy educator, then, in Brooks' view, is to move between mathematics skills and knowledge and the particular contextual settings where they are applied and meaning is made, while providing opportunities for students to develop their confidence and, ultimately, their autonomy. This process is not seen as linear or one directional. Brooks (2015) provides an example in which teachers achieved the same results moving from context to mathematical skills and knowledge as they did working in the other direction.

Goos, Dole & Gieger (2012) propose another model of numeracy which highlights the complex components of numeracy and includes both cognitive and affective characteristics, shown in Figure 2-2.

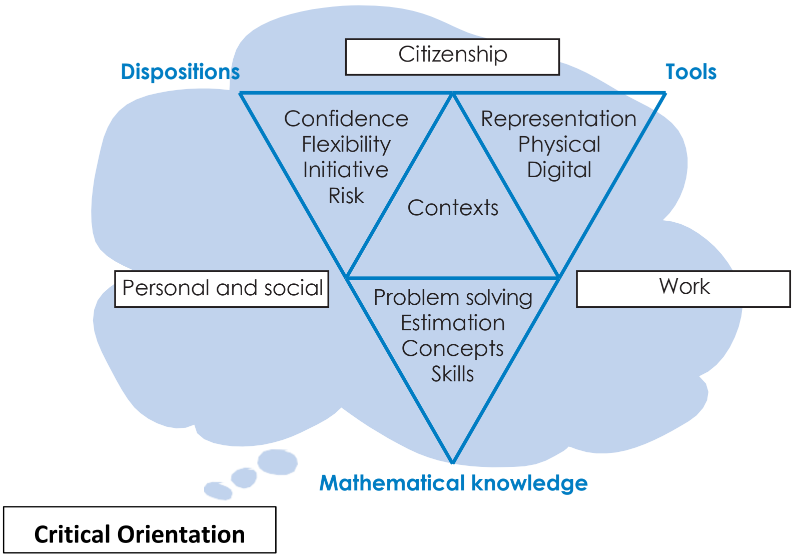


Figure 2-2 Numeracy model (Goos et al., 2012, p. 4)

Goos et al. (2012) describe a numerate person as someone who not only has knowledge and skills of mathematics but is able to use this to problem solve. The model emphasises the central role of context: a numerate person is seen to be able to problem solve across contexts with confidence, flexibility, initiative and risk using the necessary knowledge and skills with insightful use of tools that may be representational, physical or digital. The framework places emphasis on the use of tools to make sense of and solve real life problems.

2.3.1 Common features of numeracy

Through the process of reviewing the various definitions, frameworks and models of numeracy, a set of features consistently associated with numeracy (or quantitative literacy or reasoning) can be identified:

- Numeracy includes mathematical concepts, skills and procedures. (This is discussed in greater detail below.)
- Numeracy is linked to literacy. Different models and definitions describe this relationship differently. (This is also discussed below)
- Numeracy is applied in a specific context. The contexts seem to vary across the definitions from work place applications to everyday practices. In formal education,

the contexts referred to are profession-based applications and academic applications within the courses in a programme.

- Numeracy has a critical orientation. Some authors link numeracy to a social justice agenda and argue that numeracy cannot exist without criticality. A dimension of criticality is brought into mathematics education through the area of Critical Maths Education.
- Numeracy relies on affective dispositions and attributes, such as confidence.

These characteristics of numeracy point to links to other fields or disciplines such as mathematics, literacy, critical mathematics education or critical thinking. The strength of connection to these other fields or disciplines impacts on what becomes legitimated as numeracy and therefore influences what gets included and how it is included in a formal curriculum. These relationships, and their implications for planning numeracy development, are discussed below.

2.3.2 Numeracy and mathematics

There are varying understandings of how mathematics relates to numeracy. Coben (2006) makes the point that definitions of numeracy "typically assert or assume some relationship between the two" but that "the nature of the relationship between mathematics and numeracy is elusive" (p. 21). She argues that it is not a relationship of equals, since numeracy always includes some aspects of mathematics, but the converse is not true. In some instances, numeracy is conceptualized as being contained in mathematics, while in other instances numeracy is seen as a way of negotiating the world through mathematics. Coben (2006) notes that scholars such as Johnston and Yasukawa (2001) view numeracy as being *more* than mathematics. O'Donoghue (2003) also holds the view that numeracy and mathematics are not congruent; neither is numeracy a subset or accidental by-product of mathematics. O'Donoghue (2003) states that when "focusing on a goal of numeracy some mathematics will be involved but mathematical skills alone will not ensure numeracy" (p. 8). Steen (2001) explores the origins of the distinction between numeracy and mathematics. He argues the traditional approach to a school mathematics curriculum plan that starts with arithmetic and progresses to more abstract algebra, geometry, trigonometry, eventually arriving at functions and calculus towards the end of secondary schooling, is a product of colonialism. While this progression from simple to advanced processes using concepts which build on each other makes sense in the context of formal education, this logic makes less sense outside of formal education since the problems that require mathematical expertise in the real world are not confined to discrete areas of mathematics.

Secretary's Commission on Achieving Necessary Skills (SCANS, 1991 as cited in Steen, 2001) describes a different approach to the categorisation of mathematical ideas in respect of the competence expected by employers as “"basic" skills (e.g. arithmetic, estimation, graphs and charts, logical thinking, understanding chance) and others as "thinking" skills (e.g. evaluating alternatives, making decisions, solving problems, reasoning, organizing, planning)” (p. 3). These different perspectives, he argues, can be used to describe the difference between numeracy and mathematics. Essentially, Steen (2001) distinguishes mathematics from numeracy as follows:

- Mathematics focuses on abstraction; numeracy on practicality.
- Mathematics is based on categorisations inherited from the past (arithmetic, algebra, etc.); numeracy is based competencies expected in the information age.
- Mathematics is encountered mainly in schools; numeracy is experienced in real life contexts.

Fisher (2019) draws similar distinctions between numeracy and mathematics: the discourse of mathematics is “abstract rather than situational, impersonal rather than empathetic” (p. 9) which is far removed from the conceptions of quantitative literacy (numeracy). Ginsburg, Manly & Schmitt (2006) see numeracy as being personal, since it is concerned with the disposition to act on “situational mathematics” (p. 3) and therefore will be particular to a person or community within a context. These perspectives suggest that while mathematics appears to be rational, objective and cognitively framed, numeracy includes affective features within its conceptualisation. North (2015) also refers to numeracy (mathematical literacy) as comprising affective features since it is considered to be more intuitive and more concrete, and less formal and less symbolic.

A further distinction is made by FitzSimons (2006), who uses Bernstein's concept of horizontal and vertical discourses to make explicit a fundamental difference between school mathematics and the field of adult numeracy. She shows that adult numeracy can be described as a horizontal discourse which Bernstein (1999) describes as being closely linked to context and having specific immediate goals; school mathematics, on the other hand, is best described as a vertical discourse which is structured and formal. Each discourse has profound implications for curriculum and pedagogy.

While I agree that adult numeracy, developed informally, can be described as a horizontal discourse, I am not convinced that numeracy development planned by an educational institution which is the focus of this study – falls neatly within the horizontal discourse.

Maguire and O'Donoghue (2002) describe the development of numeracy in relationship to mathematics on a continuum, as shown in
Figure 2-3.

Adult Numeracy Concept Continuum of Development		
PHASE 1	PHASE 2	PHASE 3
Increasing levels of sophistication →		
FORMATIVE (basic mathematical skills)	**MATHEMATICAL** (mathematics in context of everyday life)	**INTEGRATIVE** (mathematics integrated with the cultural, social, personal and emotional)

Figure 2-3 A continuum of numeracy development showing increasing levels of sophistication (Maguire & O'Donoghue, 2002, p. 155)

Although this representation by Maguire and O'Donoghue's (2002) provides a description of the development of numeracy on a continuum of sophistication across three different phases, it also highlights the differing relationship between mathematics and numeracy within the varying conceptions of numeracy. In the formative phase, numeracy involves basic arithmetic skills. By implication, then, numeracy is subsumed within mathematics – dealing with procedural skills related to numbers. In the mathematical phase, numeracy is viewed as 'mathematics in context'. This phase highlights the combination of both mathematics and contexts. Finally, in the integrative phase, numeracy is seen as "a complex multifaceted sophisticated construct incorporating the mathematics, cultural, social, emotional and personal aspects of each individual in a particular context" (Maguire & O'Donoghue, 2002, p. 155).

In summary, although conceptualisations of numeracy suggest a relationship between mathematics and numeracy, the nature of that relationship is not clear and varies based on what is legitimated as numeracy. What is clear, though, is that mathematics and numeracy are not the same construct. The various definitions of numeracy and comparisons of numeracy and mathematics in the literature position conceptions of numeracy on a spectrum from basic mathematical skills to making choices about whether to use mathematics or not to respond to a contextually-bound situation for a particular purpose. Such a purpose-driven conception of numeracy suggests that numeracy has a "use value" (North, 2015, p. 62). As highlighted in the literature, formal mathematics is concerned with abstraction and generalisable principles and processes and therefore can be focussed on the knowledge of mathematics without any lean towards a "use value". Knowledge building in mathematics can be described as moving vertically from basic concepts and procedures to higher levels of abstraction. Numeracy requires that knowledge building occurs through conceptual development and contextual understanding.

The takeaway point from this review is that the principles of legitimation of numeracy and mathematics are different. Numeracy is a relatively newer field of research and practice with varying conceptions of what constitutes numeracy. Mathematics, on the other hand, is a well-established discipline with specific knowledge structures and discourses. The perceptions of the strength/nature of the relationship between the two will then impact on what is selected and how it is sequenced in a curriculum. The differences between the two suggest that the development of numeracy will be limited if it strictly follows the traditions and principles of meaning making in mathematics.

2.3.3 Numeracy and context

As mentioned earlier, a characteristic which is common to different conceptualisations of numeracy is its contextual nature. The contexts in which numeracy is applied in higher education are the academic disciplines as well as professional, civic and personal contexts. Bansilal (2011) states that within a context there are “specific resources which need to be recognised and used in specific ways” (p. 202). Although her observation is made in the context of assessment tasks for the school subject mathematical literacy (ML), the concept of context-specific resources is useful in shedding light on the contextual domain of numeracy in higher education.

Bansilal (2011) argues that success in assessment tasks in mathematical literacy is impacted by the context-specific resources such as “context-specific terminology, context-specific rules; context-specific reasoning; context-specific visual mediators and context-specific objects and signifiers” (p. 202). In each of these aspects, the particular characteristics of the context determine what can be deduced and how it can be acted on. The context-specific resources appear to refer to making meaning of the “problem” and do not speak to the context-specific actions explicitly, either in respect of reflecting on the solution to the assessment task in the subject mathematical literacy or the performing of a professional act in which numeracy is implicitly embedded in higher education.

One of the greatest challenges that is encountered when planning for numeracy is that the phenomenon of numeracy as a contextually-bound practice suggests that the practices are particular to that context. However, the context-specific resources identified by Bansilal (2011) provide a useful set of criteria that could serve as a ‘framework’ to make explicit resources that may be developed.

2.3.4 Numeracy and critical mathematics education

Mathematics is sometimes portrayed as absolute and neutral – divorced of opinions, beliefs and politics. In some instances, mathematics education has also adopted similar positions – being sometimes blinded to the influences of the dominant political agendas. However, as Skovsmose (2004) points out, mathematics education can be structured in ways that serve social or political agendas to either empower or oppress. For example, through its role as a gatekeeper, it can ensure that certain people or societies are included or excluded. It can also create an unquestioning trust in numbers. Skovsmose (2004) describes critical mathematics education as "an expression of concerns for what socio-political roles mathematics education might play" (p. 1). This can constitute a 'use value' for the study of mathematics.

Critical mathematics education is concerned with mathematics, democracy and social justice. Ernest (2002, as cited in Ackland, 2014) states that critical mathematics education develops

- critical understanding of the uses of mathematics in society
- awareness of the extent to which mathematical thinking exists in everyday actions
- awareness of the historical development of mathematical concepts, procedures, symbols and understanding the social context of their origin
- understanding that there are multiple perspectives of the nature of mathematics and 'controversy over the philosophical foundations of its knowledge' (p. 10).

Yasukawa, Johnston & Yates (as cited in Kemp, 2005) link critical mathematics education to numeracy in terms of the social responsibility linked to both. Askew (2015) notes that unlike mathematics, which has the potential to be abstract only, numeracy education cannot exist without criticality, which is more in line with critical mathematics education. Similar thoughts are expressed by Ackland (2014) who sees the "power dimension" (p. 10) as central to numeracy.

This has implications for numeracy development. Within the critical mathematics education debate, Vithal (2012) argues, there is a need to "re-examine (and be critical of) what constitutes and counts as mathematical knowledge [to be included as part of numeracy] together with what is excluded, question how it has been and continues to be produced and legitimated and raise issues about who is recognised for its production and why" (p. 4).

2.3.5 Literacies and numeracies

In addition to its link to mathematics, from its beginnings, numeracy has been described in relation to literacy. O'Donoghue (2002) notes that literacy and numeracy are often "bracketed" (p. 48) together. Discussions about the development of numeracy are often subsumed within literacy, or are strongly influenced by literacy. O'Donoghue (2002) describes what he calls the "evolutionary trail" (p. 48) of numeracy in the following steps:

1. mirror image of literacy
2. literacy (no explicit concern for numeracy)
3. literacy (concern for 3R's [sic] and basic mathematical skills)
4. functional numeracy (detached from literacy)
5. literacy (numeracy is recognised as an aspect e.g. quantitative literacy)
6. types of literacy (e.g. mathematical literacy, scientific literacy, etc.)
7. numeracy (independent life skill detached from literacy/equally important).

In the first three stages, literacy is included as a part of literacy. In the fourth stage, it is understood to be basic mathematics skills. Only after that is it seen as a separate area in its own right. Exploring the development of the discourse around numeracy brings several important issues to light. First, the fact that numeracy was initially understood to be a component of literacy may have limited its independent development and shaped it according to the logics of literacy instead of its own particular characteristics. Second, because numeracy was viewed as a subset of literacy efforts to invest in the development of literacy may have been perceived as also addressing the development of numeracy. Third, only recently numeracy seems to be gaining equal importance as an independent field. While this is a positive development, I think it is still useful to explore the links to literacy and the lessons and implications of the research and practice in this area for numeracy.

There are cases, however, of scholars who have described literacy as an aspect of numeracy in the context of texts that include numeracy information. Gal (as cited in Coben, 2006), for example, discusses the role of mathematics as language, the influence of language on the study of mathematics and the use of language in the real-life contexts in which numeracy is practiced. Whether literacy is seen to be an aspect of numeracy in certain instances or numeracy is understood as part of literacy, there is undeniably a relationship between the two. In cases where numeracy is addressed as an aspect of literacy, the prevailing understanding of literacy will influence how the development of numeracy is designed.

A number of different perspectives exist on literacy. Over time, the discourse in the literature broadened from a view of literacy as 'the ability to read and write' to be more nuanced in a similar way to the expansion of the discourse on numeracy to encompass higher cognitive demands and non-cognitive dispositions.

Some continue to view numeracy as the mastery of basic mathematical skills, however, believing these skills to be technical, generic, neutral, universal and easily transferable to different everyday contexts and carrying "assumed cognitive as well as economic benefits" (Lillis & Scott, 2007, p. 11) in line with the autonomous model. The development of literacy, or, in this case, numeracy in this context will focus on reducing the deficiencies identified in the acquirer (McKenna, 2010) and therefore leads to interventions that are framed by a discourse of student under-preparedness (Boughey, 2010).

An alternate view is presented by the New Literacy Studies perspective. Numeracy, like literacy, is viewed as more than an acquisition of skills, but rather a social practice (Gee, 1991; Street, 1996). The next section expands on the notion of numeracy broadly and within the New Literacies Studies perspective as one of the theories of social practice influencing literacy and numeracy.

2.4 Numeracy as social practice

The need to pin down a definition of numeracy is driven by the assumption that something can only be improved or developed if it is explicitly defined or articulated and can be assessed. While dictionary and everyday definitions of numeracy remain focussed on the basic mathematical operations with numbers, Yasukawa, Jackson, Kane & Coben (2018) make the point that the definitions of numeracy have evolved considerably, especially within the literature. Nonetheless, Yasukawa et al. (2018) claim that numeracy still remains "a notoriously slippery term" (p. 1) – an observation that had originally been made by Coben (2003).

Yasukawa et al. (2018) argue that developments in the scholarship of numeracy are not reflected in the ways we approach the teaching and learning of numeracy, which often continues to reinforce a narrow conception of numeracy. Narrow concepts of numeracy often view numeracy as autonomous (Street, 2001). Street (2001) describes an autonomous framing of literacy as suggesting that literacy can be described by a set of generalizable skills that can be learnt in decontextualized settings and are free of contextual, social and cultural influences. Within this orientation, numeracy, like literacy, is seen to be based on the possession of a neutral set of skills while lack of numeracy is seen as an individual's lack of mastery of these skills. Within this perspective, individuals are either numerate or innumerate.

Street (1995) advocates, instead, for a social practice approach to literacy. Within this perspective, he introduces an ideological model of literacy that describes literacy as a practice and not as a technical or neutral skill. Literacy is thus viewed as being positioned within particular worldviews that value particular, or specific, practices that may not be valued in other social spaces. Literacy within a social practice framing is viewed as contextually, socially, culturally, historically and politically bound or influenced. Street's work on literacy as social practice has become known as the New Literacy Studies.

Baker (1998) applies Street's work on literacy to the framing of numeracy. Baker describes an autonomous model of numeracy as mastering a set of neutral skills that is context and value free which could be transferred seamlessly to any context or used under any set of conditions. The ideological framing of numeracy, in contrast, describes numeracy not as a set of skills, but as a practice that is not limited to an observable set of behaviours, but also involves "values, attitudes, feelings and social relationships" (Kane, 2018, p. 21).

This implies that numeracy practices are influenced by, and constructed within, the norms and values of communities or of society. Being literate, and in this case, numerate, implies having "mastered a set of social practices related to a set of signs which are inevitably plural and diverse" (Prince & Archer, 2008, p. 65). Thus, within this framing, students are described as being numerate in different contexts and never really innumerate. Even mathematical equations, especially in the context of numeracy practices, can be understood as a socially constructed practice, ideological in nature, dependent on a range of shared understandings and not as a neutral activity which is autonomous from any context.

This socio-cultural orientation forces the acknowledgement of numeracy as a "socially embedded practice, inseparable from the historically specific ideologies and institutional frameworks" (Collins, 2000, p. 71) within which numeracy events are given shape and significance. Many other social practice theories of numeracy are found in the literature. Yasukawa et al. (2018) highlight four overlapping theories of social practice that have particularly influenced social practice views of numeracy. These include a situative perspective on cognition, cultural-historical activity theory, New Literacy Studies and ethnomathematics. Yasukawa et al. (2018) state that although the origins of numeracy as social practice are multiple, there are distinctive characteristics that distinguish numeracy from a social practice theory perspective:

- Numeracy as a social practice focusses on what people do in particular social interactions and not on how well they perform mathematical computations isolated from context. All social practice theories describe numeracy as being situated in context.
- Numeracy as a social practice views numeracy as ideological in nature, implying that numeracy activities are culturally, socially, historically and politically influenced.
- Numeracy as a social practice has an interest in both the visible and invisible mathematics that is part of the numeracy practices.
- Numeracy as a social practice draws on ethnographic approaches to studying the numeracy practices and the voices of the participants are foregrounded.

It is worth noting that Yasukawa et al. (2018) do not see a social practice perspective of numeracy as negating skills, per se, but criticise approaches that foreground skills without adequate consideration for the context or community in which they are practiced. For the purpose of this study, I have adopted a New Literacies Studies perspective to numeracy. New Literacies Studies have been used more extensively in literacy research but also by many scholars of numeracy, including Galligan (2011), Prince & Archer (2008), Frith & Prince (2006) and Paxton & Frith (2015). Kane (2018) states that the New Literacies Studies perspective does not fit numeracy as neatly as it does literacy, because within literacies individuals more often speak the language already, while with numeracy individuals do not already 'speak the language' of mathematics: it has to be taught.

In the context of higher education, New Literacies Studies has been used extensively in studies of academic literacy. Within the social practice orientation to literacy, Lea & Street (2006) introduced the concept of academic literacies and described the skills model, the socialization model and academic literacies model of academic literacy. The shift from academic literacy to *literacies* was indicative that the academic literacies model acknowledges multiple literacies and not the dichotomy of literacy and illiteracy.

Similarly, Craig et al. (2019) introduce the concept of 'new quantitative literacies'. They raise important points around the dynamic nature of numeracy and argue that the burst in digital and technology exposure brings with it new practices beyond what was previously conceptualized as numeracy or quantitative literacy. The authors describe quantitative literacies as **"**the social and cultural practices that co-emerge with use and creation of quantitative information" (Craig et al., 2019, p. 17). They use a media literacy framework that uses dimensions to highlight new practices that have emerged. They envision new quantitative literacies within each of these dimensions as "more access to quantitative information and arguments, proclivity to analyse quantitative informative faster and more readily, changes to the analytical strategies used, new or transformed, concern about evaluating the credibility of arguments and agency to use the internet as content creators" (Craig et al., 2019, p. 17).

There are a number of criticisms of the social practice orientation to numeracy which must be considered as the study has been situated within a social practice perspective.

2.4.1 Critique of social practices lenses of numeracy

Although many authors, as discussed above, have adopted the social practice orientation to numeracy there are also critiques of this position. First, while the social practices approach privileges the localness of the numeracy, policy makers argue that it is difficult to use research based in these specificities to inform national or international policies and frameworks.

Second, this contextually-bound understanding of numeracy practices may be limiting in the development of the numeracy practices that are expected in unfamiliar contexts. Also, from a 'global perspective' on literacies, the assumption is that a literacy practice "travels, integrates and endures across contexts" (Brandt & Clinton, as cited in Evans, Yasukawa, Mallows & Creese, 2017, p. 20).

These two concerns are important to planning for numeracy in undergraduate programmes as it is unlikely that programmes will be able to expose their students to all of the contextual applications that may arise in their future careers. This study aimed to gain a deeper understanding of the underlying organising principles that result in the approaches to planning for numeracy from a social practice perspective.

In summary, then, the very nature of numeracy appears to be dynamic. There are varying positions and definitions of numeracy and each of these impacts how numeracy development is planned. One of the greatest tensions exists in being able to articulate exactly what is meant by numeracy. The most explicit articulations are often found in national and international assessment frameworks. However, these definitions do not adequately reflect the affective, critical and contextual features of numeracy that have been identified as core aspects of numeracy. A social practice orientation enables the contextual and meaning-making dimensions of numeracy to be incorporated. It also acknowledges the multiple practices of numeracy that students bring to the academic experience and the nuanced differences across disciplinary contexts.

The next section reviews the development of numeracy. Although the focus is on the development of numeracy in higher education, some perspectives on numeracy from the contexts of secondary education, adult numeracy and mathematics education that may be worth considering are noted.

2.5 Numeracy education

In 2006 Coben described the field of adult numeracy and mathematics education as a “moorland” (p. 20) that is “wild and uncultivated” (p. 20). Wedege (1999, as cited in Coben, 2006) describes adult numeracy education as an interdisciplinary space that is most closely linked to maths, adult education and mathematics education, but also falls within the broader social science research fields of sociology, philosophy, psychology and literacy. While some of these are strongly established disciplines, others such as literacy itself exist in an interdisciplinary space where they are influenced by multiple disciplines and also by engagement with language. This highlights, again, the possibility that if the development of numeracy is guided by the principles of legitimation of any one of these disciplines exclusively, it is likely to be limited by the boundaries of that discourse. A key challenge in numeracy education, then, is to successfully negotiate the influence of the multiple disciplines that have bearing on numeracy in such a way that its development is optimised, rather than restricted. The literature on developing numeracy in academic contexts within a varying understanding of what it is and its interdisciplinary connections for future professional, personal and civic engagement highlighted the complexity of the process. Whether the approach adopted involved a numeracy-specific module or was embedded in other modules within a programme, the process of deciding what should be included, who is best suited to plan the curriculum, how it should be enacted and how it should be assessed is dependent on multiple factors. The most important of which is how numeracy is understood by those involved in the process.

For example, if numeracy is understood as a set of generic mathematical skills that can be applied to any context, then a programme for numeracy development could focus on basic mathematics skills and could, arguably, best be planned by a mathematician. If, however, a social practice orientation to numeracy is adopted, then the plan for numeracy development should provide opportunities for students to engage in discussions about numbers and include the development of academics that are involved in numeracy; such a plan would need to be developed by an interdisciplinary team (Fisher, 2019).

Mast (2019) notes that scholarship on numeracy initially focussed on demonstrating the importance of numeracy and defining numeracy, quantitative literacy and/or quantitative reasoning. The shift to a focus on how to *educate* for numeracy (or quantitative literacy or reasoning) only began to occupy a prominent position among scholars from 2007. Numeracy is thus a very recently established area of research.

Within the limited literature in this area, there have been studies recommending approaches to developing numeracy based on a variety of explorations, from empirical investigation of modules or approaches to embedding numeracy to an exploration of the implications of particular theoretical framings. Evans et al. (2017) argue that approaches to numeracy development must be grounded in an understanding of the numeracy demands of adults. They distinguish between the 'top down' (generalising) and the 'bottom up' (grounded) processes of exploring adult numeracy practices. The PIAAC framework, for example, is considered a top down approach as the numeracy demands of adults and the context of application are assumed across broad categories; numeracy practices are seen to be generalizable across contexts and cultures. The bottom up, or grounded, approach, however, is more aligned to a social practices orientation as it focusses on the particular numeracy demands within a specific social and cultural context.

Currently, the approach to numeracy development in higher education appears to be influenced by both 'top down' and 'bottom up' approaches. For example, standardized tests assessing numeracy are sometimes used to inform the selection and placement of students at universities or, more broadly, to inform institutional and sectoral policies which is in keeping with the 'top down' orientation to numeracy and a generalized perspective of the numeracy expected of adults. On the other hand, within higher education some research has focussed on establishing the numeracy demands of particular qualifications and strategizing to develop these practices within programmes (see, for example, Frith, 2011, or Galligan, Loch & Lawrence, 2010). These 'top down' or 'bottom up' approaches are also influenced by what is legitimated as numeracy. This is likely to further impact the type of initiatives planned.

As discussed earlier, the literature seems to cluster around two broad ways of developing numeracy: by providing specific modules on numeracy or by developing numeracy within the modules within a programme. Where numeracy is developed within other modules this can be deliberate – as evident in an integrated approach which includes explicit outcomes to develop numeracy – or it can be embedded.

2.5.1 Developing numeracy through dedicated modules

The literature provides numerous examples of module-based approaches to numeracy both in South Africa and internationally. Jain & Rogers (2019) describe an approach to the numeracy development of university students adopted at the University of Tasmania that is based on Watson's (2009) Four Resource Model for critical numeracy. They state that their previous module which had focussed on repeating aspects of secondary school mathematics, had yielded limited benefits. The Four Resource Model prioritises critical thinking as a core outcome of a numeracy module. They raise a point that is important to this study as well: while numeracy is not limited to mathematical computational, mathematical conceptual and procedural understanding, these still need to be included in numeracy development. They suggest that a module on numeracy development needs to provide explicit teaching of mathematical concepts while concurrently engaging students in thinking critically about mathematical information (Jain & Rogers, 2019).

The Numeracy Centre at the University of Cape Town offers four numeracy modules which are available to students across specific academic programmes (UCT Numeracy Centre, 2020). Frith (2012), in her analysis of one of these modules, notes that in designing such an intervention three aspects need to be given attention: the context in which the practice is needed, the mathematical and/or statistical content needed and the underlying reasoning skills that are expected. The disciplinary context can be brought into the numeracy modules through case studies and the use of content based on the mathematical concepts required in the discipline. Frith (2012) cautions, however, that although discipline-based texts are used in these dedicated modules, this may not be the most suitable approach. She states that embedding numeracy directly into course modules where students engage with numeracy as a secondary discourse within their discipline could be more effective. She argues that students may experience difficulty applying the numeracy practices learnt in 'stand-alone' numeracy modules to their professional roles because of the 'decontextualized' ways in which they were learnt. At the same time, however, Frith (2012) notes that when numeracy development is embedded in other courses the mathematical concepts may not be adequately developed. Within the South African context this is an important consideration because many students lack an adequate conceptual foundation in mathematics. This highlights the dilemma that numeracy curriculum developers face within higher education: should conceptual development or contextual application be prioritised; or how can both be developed without either being compromised?

A study by Marks, Hodgens, Coben & Bretscher (2015) focusing on numeracy in nursing illustrates the disjuncture between the numeracy developed in a programme and what is required by a practicing professional. Numeracy is considered a core competency for the effective practice of nursing. In fact, since 2008 the regulatory body for the nursing profession in the United Kingdom has required students to achieve 100% in numeracy in their practical assessment in order to register as a nurse (ibid).

The challenge is to identify what numeracy practices are expected in the professional context and determine how these can be developed within the university programme. The Marks et al. (2015) study, which was part of a bigger research project on numeracy in nursing, focussed on the experiences of nursing students with numeracy development at university and numeracy requirements in professional practice. Students reported that the university numeracy education emphasized mathematical calculations which were sometimes not relevant to their practical context. Marks et al. (2015) argue that the simulated contexts provided during the teaching of numeracy did not assist students in developing the numeracy practices valued by practicing professionals. The study raises a very important distinction: numeracy in training is typically more individually focussed and is highly mathematised, while numeracy in practice is social and collaborative, with a stronger emphasis on contextual considerations (Marks et al., 2015). Marks et al. (2015) recommend that instead of the current hierarchical approach to university numeracy development, which starts with decontextualized numeracy at the beginning and results in numeracy in the context of the profession, numeracy courses should introduce authentic application from the beginning of the programme. They argue that it is possible to reduce the disjuncture between the numeracy expected in practice and that offered at university by allowing students time and space to engage with “what will happen in reality” through engaging in practices such as “applying common sense or double checking” (Marks et al., 2015 p. 56), as well as profession-specific practices.

While this recommendation makes sense, it is not easily achievable for a lecturer or someone planning a curriculum. ‘Common sense’ mathematical understandings and procedures are so tacit in professional contexts that it is difficult to recognise them and then plan for their explicit development in the context of an undergraduate programme.

2.5.2 Embedding numeracy within other modules

In order to address the need for numeracy to be developed through authentic activities, the embedded approach to numeracy development is often favoured over the module-based approach. Winter (2019) identifies a range of ways in which numeracy may be embedded and places these on a spectrum from ‘numeracy-saturated practice-based’ embedding to ‘opportunistic’ embedding. Embedding numeracy can thus be structured through deliberate activities focussed on developing particular numeracy practices or, on the other extreme, be approached by recognising ‘numeracy moments’ implicit within vocational tasks and providing students with support to develop their numeracy when these occur. Winter (2019) notes that embedding numeracy presents a dilemma: on the one hand, linking numeracy strongly to the vocational context enhances understanding; on the other, it can result in piecemeal development of mathematical concepts, resulting in limited mastery of numeracy. To embed numeracy development in discipline-specific modules is thus a challenging task and requires a skilled and committed educator to plan and implement such an initiative. Who the academic is and their readiness to undertake this initiative plays a significant role. Bennison (2015) states that the educators responsible for planning embedded numeracy "need to have appropriate knowledge (mathematical, pedagogical, and curriculum), a rich personal conception of numeracy, and a belief that numeracy is an integral part of the subjects they teach" (p. 572). Although Bennison is speaking to the basic education context, these points bear consideration for academics designing or implementing embedded numeracy in the higher education context, as well.

This is actually a very tall order. In the university context and particularly in a university of technology, many academics are professional practitioners and may lack one or more of these characteristics. This suggests that staff development is a crucial component of planning for developing numeracy. Winter (2019) also highlighted the importance and benefits of staff development or professional learning as expressed by the numeracy tutors who were responsible for numeracy development.

Hughes-Hallett (2001) suggests that as it is difficult for individual educators to take on the task of embedding numeracy development in their courses and this could better be organised through interdisciplinary, collaborative partnerships in which insights can be developed and shared between educators, leadership, policy makers and even professional and governmental sectors, in order to effectively integrate mathematical understanding and procedures into subject-specific courses. It is likely to be equally challenging to embed numeracy across the subjects of a university undergraduate curriculum without collaborative partnerships with all stakeholders, including school educators, academic staff, university and sector leadership and the sectors in which students will be employed after they complete their education.

Galligan (2013) proposes a model for developing numeracy in university programmes that recognises the value of partnerships and collaboration. Drawing on the models for numeracy development put forward by Keimig (1983), Taylor & Galligan (2002) and Willison & O'Regan (2007), Galligan's (2013) model focusses on the levels of the university, the programme and the course and includes input from teachers and students, as illustrated in Figure 2-4.

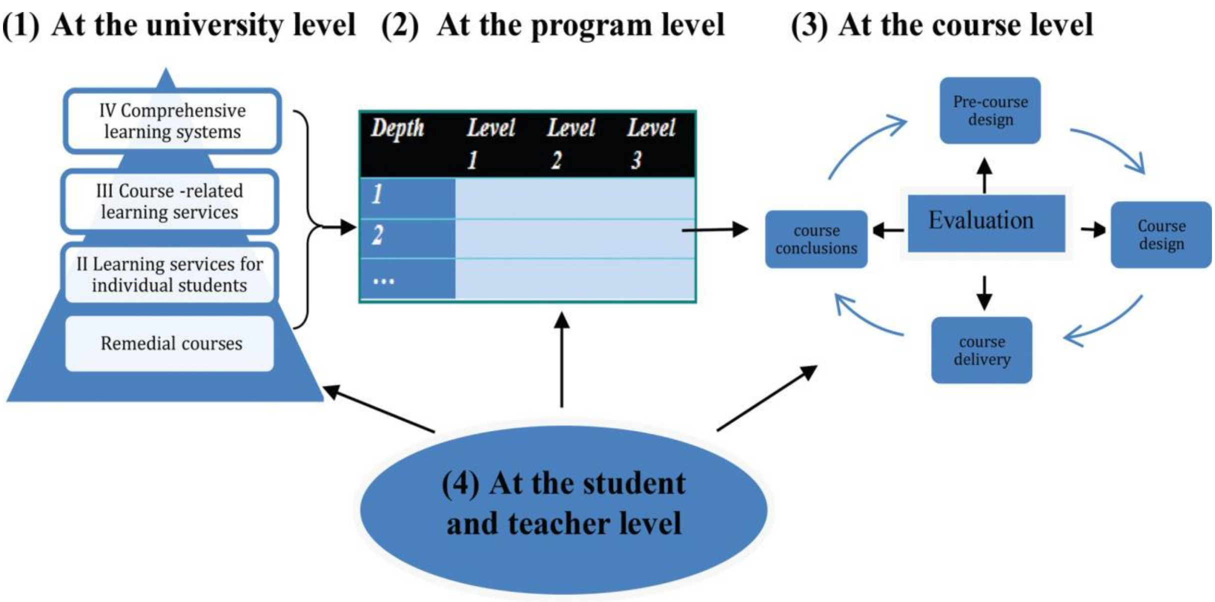


Figure 2-4 Model for embedding academic numeracy (Galligan, 2013, p. 739)

Galligan (2013) argues that at the university level, comprehensive learning systems need to be established which are implemented through a range of strategies, such as offering of numeracy courses or tutorials or through inclusion in enabling programmes (similar to the extended curriculum programmes offered in South Africa that provides developmental support to students within the programme that is extended by a year). Concurrently, at the programme level there should be strategies for the development of numeracy at different levels that build towards the professional numeracy expected of students on graduation. At the course level, the strategies of the university could be implemented through, for example, a dedicated numeracy course or a specific programme for improving academic numeracy. These interventions should be informed by evaluation and input from students and staff and assessment of students' prior numeracy practices as well as of the numeracy practices expected in the professional context.

Galligan's (2013) model is comprehensive and highlights the importance of numeracy agendas permeating university programmes at every level. The challenge, though, is that such an approach is likely to be 'diffused' through the different systems if not properly planned for in partnerships across the university. Galligan (2013) recommends that curriculum developers tasked with developing numeracy should ensure that they understand three things: what students already know; how to embed numeracy; and how to deliver embedded numeracy programmes. Galligan provides suggestions for each of these. To understand what students know, she recommends the use of pre-tests; she notes, however, that these should be developmental tests that consider affective attributes together with cognitive domains and should be based in the professional context. In addition, she notes that input from staff and students is important in order to gain understandings of "stuck points" (Galligan, 2013, p. 742) in the curriculum so that they can be addressed specifically in the curriculum plan.

Coben and McCartney (2016) propose a 'whole organisation' approach to support managers and other professionals in the task of embedding numeracy in which "numeracy provision is central to the whole organisation at all levels ranging from strategic management to delivery of practice" (p. 120). This approach is modelled in
Figure 2-5.

Figure 2-5 Whole organisation approach to embedding numeracy (Coben & McCartney, 2016, p. 123)

Coben and McCartney (2016) explain that the "inner circle represents systems and processes", the "outer circle represent outcome measures as defined by New Zealand Qualifications Authority (2009) and the wavy components represent those processes that happen across components and binding the organisation together" (p. 122). The whole organisational framework, and accompanying model, serve not only as a tool to guide the embedding and improving of numeracy, but can also be used to assess the effectiveness of initiatives to embed numeracy into the strategic vision of the institution, in terms of observing the impact on students' achievement of outcomes.

Although Coben and McCartney's framework was designed for the context of New Zealand and relates to the outcomes specified by the New Zealand qualifications authority, the model highlights the complexity and level of structured collaboration required to embed numeracy. It draws attention to the importance of the entire organisation buying into the agenda of numeracy development. In line with this, central to their model is the articulation of a vision, aims and targets of a numeracy agenda within the institution. Interestingly, it is noticed that although this is impacted on by academic activities such as curriculum development and learning, teaching and assessment, it is also impacted on by other less directly related academic influences such as human resources, external partnerships or resources and facilities.

The whole organisation framework may be useful in creating a 'numerate environment'. Drawing on the concept of a 'literate environment' as a prerequisite for literacy, Evans et al. (2017) suggest that numeracy also develops effectively in a numerate environment. They describe key features that influence the quality of the numerate environment. These are the demands that the practices make or do not make of participants, the opportunities that engaging in the numeracy practices affords the participants and the resources and support afforded, or the barriers inherent, in these practices that impact on numeracy development. They go on to argue that "opportunities and support go hand in hand" (Evans et al., 2017, p. 22). Opportunities without support may go by unnoticed since not everyone will engage in the numeracy environment in the same way. Numeracy development should provide support that helps make visible the opportunities or barriers to numeracy development to provide opportunity for everyone to engage. For example, interacting with experts may help students to understand the origin, purpose and implications of quantitative information and thus assist in making explicit opportunities to develop numeracy. This highlights the need for strategic leadership, communities with a shared vision of improving numeracy and systems and processes to support the development of staff to embed numeracy in their programmes.

2.6 Conclusion

While the literature on numeracy development in higher education is scarce, reviewing the literature around the broader topic of numeracy development in academic contexts brings to light the complexity of this topic. This complexity is due, to a large extent, to the multiple terms in the literature, varied understandings of numeracy that exist and its interdisciplinary nature.

There are differences identified by certain scholars in the literature between the terms numeracy, quantitative reasoning and quantitative literacy which have been presented in the chapter. Mostly, however, these terms are used synonymously as is the case in this study.

An exploration of the definitions of numeracy and related terms was presented which highlighted the close links between numeracy and both mathematics and literacy. This has resulted in a continuum of conceptualisations of numeracy reflecting different views of what mathematics is important to numeracy and a range of perspectives on literacy.

Exploring definitions of numeracy also draws attention to the fact that numeracy practices engage cognitive, affective and contextual domains. The understanding of how numeracy involves these domains determines what numeracy is needed which, in turn, determines how it can best be developed.

This study draws on the social practice orientation to numeracy, which acknowledges that numeracy is shaped by the particular characteristics of the specific social, cultural, political or disciplinary contexts in which it is practiced. This results in multiple numeracies for multiple contexts; from this perspective a view of individuals as either numerate or innumerate becomes inappropriate and irrelevant.

Two approaches to developing numeracy within academic contexts which appear in the literature have been discussed: a module-based approach and an embedded approach. The chapter presents studies that discuss particular approaches, highlighting the challenges and recommendation from the different researchers. Considering the recommendations of scholars, it appears that the embedded approach is most congruent with a social practice orientation to numeracy. However, this does not negate the benefits that can be gained from providing dedicated modules on numeracy. This presents a dilemma for curriculum developers, as each approach has benefits and drawbacks.

Scholars in numeracy education have highlighted that successful development of numeracy in higher education requires engagement within and across different communities in higher education. Staff development and organisational assessment and development are described as important to achieving success in developing numeracy in higher education.

This study aims to contribute to the discourse by advancing the understanding of the underlying principles that legitimate what is numeracy in a higher education context at an institution were the primary offerings are professional qualifications. By exploring how and why curriculum developers plan for numeracy development in particular ways, the study aims to add to the body of knowledge around the forces and dynamics that impact on curricular choices with respect to numeracy.

The following chapter presents the theories and analytical framework that enable the generative mechanisms that result in particular practices of numeracy development to be identified.

Chapter 3
Theoretical orientation and conceptual framework

3.1 Introduction

Chapter 2 provided an overview of the literature relevant to the design of initiatives to address numeracy development in higher education. In Chapter 2, a discussion of numeracy from a social practice perspective was presented. Numeracy within this framing is described as a practice that is more than a set of skills, is contextually-bound and is informed by social, cultural and political factors. Social practice theory was discussed in the previous chapter since it assisted in broadening the understanding of what is numeracy as highlighted by the varying definitions of numeracy.

Theories of social practice such as New Literacy Studies provide useful insights into the complexities of numeracy and broaden the understanding of numeracy beyond the boundaries of mathematics. However, to understand the process of curricular choices in respect of numeracy in the undergraduate curriculum, I needed theoretical tools that could help me explore the process of curriculum planning and the dynamic nature of the specific phenomenon of planning for numeracy in higher education.

For this purpose, Karl Maton's (2014), theory of the Epistemic Pedagogic Device (EPD) – which is an extension of Basil Bernstein's pedagogic device is useful for tracking the curriculum process from its conception to the actual planning and implementation of numeracy within the higher education undergraduate curriculum. Maton's epistemic pedagogic device was used along with his Legitimation Code Theory (LCT) in this study to explore the underlying principles of legitimation of numeracy and the forces influencing numeracy development within the undergraduate curriculum.

Both of Maton's theories are aligned to the broader theory of social realism. Within social realism, reality is viewed as stratified into the experienced, the actual and the real dimensions of reality and not limited to individual experience or knowledge of it. It therefore does not subscribe to an either/or position of absolute reality or complete relativist subjectivity, but rather encompasses aspects of both. In the context of this study, social realism allows the complexities inherent in planning for numeracy in higher education to be understood within the context in which planning is done.

This chapter discusses social realism as a theoretical frame and its relevance to this study. Bernstein's theory of the pedagogic device and Maton's Epistemic Pedagogic Device and Legitimation Code Theory are described and their usefulness as a framework for understanding how numeracy is developed and planned for in undergraduate curriculum is discussed.

3.2 Social realism

Social realism was adopted as an overarching theory to guide this study since it provides an alternative to viewing knowledge beyond the binary of positive absolutism, on one side, and constructivist relativism, on the other. Positivist absolutism views knowledge as value free, neutral, generalizable and therefore universal. On the other hand, extreme relativism describes knowledge as being contextually bound and socially constructed. These polarised positions are not useful to understanding the phenomenon of numeracy in higher education and do not align with my own theoretical stance. As a researcher, I come to this study grounded in the sciences, which are oriented to a positivist approach; as an academic developer involved with curriculum planning, however, I am keenly aware of the social, cultural, political and historical factors which influence curricular choices. More importantly, though, as indicated in the literature, numeracy is a complex phenomenon; an interdisciplinary space that draws on the field of mathematics but is also contextually bound. Approaching this study from an absolute positivist perspective would tend toward a view of numeracy as a set of generalizable, neutral and value-free mathematical facts and skills which would not adequately capture the reality that numeracy is applicable to contexts. Adopting a completely relativist orientation, however, would tend toward a view that numeracy can never really go beyond its context and the interpretation given by individuals, which would suggest that numeracy could not be developed for unknown and unpredictable futures.

Maton & Moore (2010), notes that social realism resolves the “epistemological dilemma” (p. 5) posed by the positivist/relativist dichotomy, allowing for the study of both the knowledge and the meaning which individuals make of their experiences. Maton & Moore (2010) state that social realism acknowledges the “rational objectivity” (p. 2) of knowledge and that knowledge does actually exist. However, this knowledge is

> also recognised as a *social* phenomenon (it is something that people do in socio-historical contexts) and it is *fallible* rather than absolute or merely relative. This allows knowledge to be seen in itself, not merely as a reflection of either some essential truth or social power, but as something in its own right, whose different forms have effects for intellectual and educational practices” (emphasis in original) (Maton & Moore, 2010, p. 2).

Social realism thus places emphasis on knowledge as ‘real’ and as “possessing properties, powers and effects” (Maton, 2014, p. 32). It draws heavily on the philosophical orientation of Critical Realists such as Bhaskar (2008) and Archer (1998). Arbee (2012) states that social realism advocates a “realist ontology and a relativist epistemology” (p. 58). Together with these two principles of ontological realism and epistemological relativism, social realism also commits to judgmental rationality (Maton, 2014; Clarence, 2014; Arbee, 2012; Hlatshwayo, 2018). Luckett (2014) states that epistemological relativism acknowledges that different knowledges exist but that not all knowledge is valued as legitimate which raises the issue of judgmental rationality. Judgmental rationality, according to Luckett (2014), requires that rational approaches are adopted to make judgements on the legitimacy and value of that knowledge at that time.

Applying the three principles of realist ontology, relativist epistemology and judgmental rationality to this study allows for, first, a study of the knowledge of numeracy and its influence on the planning for numeracy within an undergraduate curriculum that is not limited to individual experiences of it; second, valuing of the different ways of coming to know it; and third, an exploration of the rationality of arriving at decisions to plan for it. The next section elaborates further on realist ontology and its relevance to this study.

3.2.1 Realist ontology

Critical realists and social realists describe reality as existing beyond an individual's knowledge of that reality. Knowledge of reality is not seen as reality in itself but as part of it. Realists subscribe to a stratified understanding of reality. This understanding of reality, as adopted by Social Realism, brings to the fore an acceptance that there are underlying generative mechanisms that result in particular events and experiences. This study aims to understand those mechanisms and tensions that give rise to planning, or lack of planning for numeracy in undergraduate programmes.

The stratified reality adopted within social realism is described at three levels: Real, Actual and Empirical, as shown in Table 3-1.

Table 3-1 Three domains of reality (Bhaskar 2008, p. 13)

	Real	Actual	Empirical
Experiences	x		
Events	x	x	
Mechanisms	x	x	x

The three levels of reality are hierarchical. The real is described as giving rise to the actual, which gives rise to the empirical (Hlatshwayo, 2018, p. 38). Bhaskar (1998) describes the actual as the events happening in the world which is not necessarily limited to one's own knowledge or experience, while the empirical is limited to one's own experiences and perceptions of these experiences. The domain of the real refers to the structures and the generative mechanisms that give rise to these structures. The events and experiences are seen to be a consequence of the combination of the associated "causal powers" (Wilson & Dixon, 2006, p. 262).

Olsen (2009) states that critical realists are concerned with "why things appear as they do" (p. 6), in other words, understanding the underlying structures and mechanisms that result in particular experiences and events. This study is concerned with understanding the generative mechanisms resulting in the current practices of planning for numeracy in undergraduate programmes. A social realist perspective that is underpinned by an understanding of reality as understood by critical realism is thus appropriate. Conducting a case study of a particular institution allows for the exploration of the experiences and perceptions of those at the institution, using both inductive and deductive methodologies to offer a plausible explanation of the combination of "causal powers" that result in particular events and particular experiences.

Mistri (2016) notes that the concept of cause, within critical realism, "places emphasis on more than the cause and effect relationship amongst the discrete events" (p. 20). According to Lewis (2000), critical realist research attempts to identify and provide explanations of the causal forces at the ontological levels of reality. What is important is the understanding that these causal forces act together in different ways; they may complement each other in some instances and counteract each other in other instances. The same forces may not always result in the same outcome; rather, it is likely they will create different events or experiences. On the other hand, similar events or experiences may result from different causal mechanisms (Sayer, 1992, pp. 78-79).

This study is situated within a social realist perspective that brings together realism, relativism and criticality to study the underlying organizing principles or generative mechanisms resulting in curricular choices in respect of numeracy development. As described by Luckett (2014) this orientation allows me, as the researcher, to not only capture multiple practices of developing numeracy at the empirical level and detail the events within the curriculum renewal process that have occurred at the actual level, but also to identify the multiple generative mechanisms and causes from which such events and experiences have emerged in an open system that is sure to include the principles of legitimation of what is numeracy and the contextual factors that influence its embedding in curricula. Similar to Mistri (2016, p. 28), adopting this orientation allowed me to accept and engage with the "messiness" and complexities of the experiences, perceptions and practices of planning for numeracy and explore the actual current plans and the potential causal influences.

Social realism, with its critical realist ontologies, provides a useful meta-theory for this study. However, to understand the generative mechanisms, or underlying principles, at the domain of the real that gives rise to the events and experiences, I needed to investigate other explanatory frameworks. Figure 3-1 highlights the relationships between meta-theories and research studies.

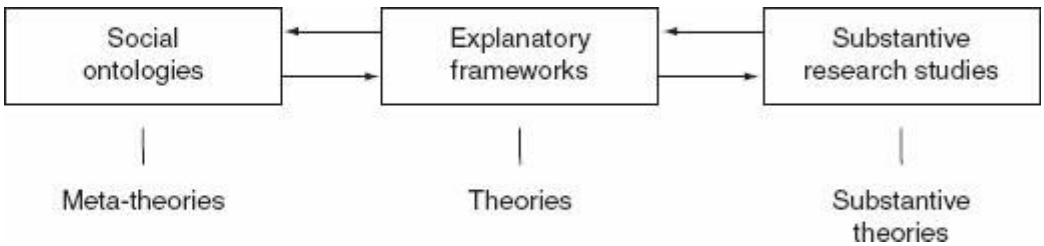


Figure 3-1 Representation of relationship between meta-theories, theories and substantive theories (Maton, 2016, p. 26)

This study uses Maton's Epistemic Pedagogic Device (which is an extension of Bernstein's pedagogic device) and Legitimation Code Theory as explanatory frameworks to connect the specificities of the study to the ontologies of the meta theory of social realism. In the following sections each of these frameworks is discussed, along with its relevance to this study.

3.3 The Epistemic Pedagogic Device (EPD)

The Epistemic Pedagogic Device provided a useful explanatory framework for understanding the curriculum planning process. It provided the tools needed to understand the influences of the scholarship on numeracy, on the one hand, and the teaching and learning of numeracy, on the other, on the choices made in curriculum planning. Maton developed the Epistemic Pedagogic Device (EPD) as an extension of the pedagogic device conceptualized by Bernstein

(Maton, 2016). A discussion of Bernstein's pedagogic device will thus provide a basis for understanding Maton's EPD.

3.3.1 The pedagogic device

Bernstein's pedagogic device is a theoretical framework that is used to describe the development of knowledge in educational settings. It highlights, or makes explicit, the "logic of the relational processes in the construction of educational knowledge as represented through pedagogic discourse" (Bernstein, 1990, as cited in Mtombeni 2017, p. 66).

The pedagogic device comprises three related, hierarchical fields of practice: the field of production, which informs the field of recontextualisation, which, in turn, informs the field of reproduction (Bernstein, 2000). Within this framework, the actors three fields are viewed as being strongly insulated from each other. For example, the field of production is seen to be engaged by higher education and private research institutions; the field of recontextualisation by state departments, curriculum authorities or teacher training colleges; and the field of reproduction by schools or tertiary institutions. This results in engagement by specialised agents or agencies that adopt particular discourses that are different across the fields (Singh, 2002). Each field is regulated by the rules of that particular field. Although all of the three fields are related, the regulative principles need not be exactly the same. These regulative principles or rules are also hierarchically organised in respect of the three fields of the pedagogic device. Distributive rules regulate the principles producing new knowledge; recontextualising rules regulate the "delocation; relocation and refocusing of knowledge to become pedagogic discourse"; and evaluative rules regulate "the principles of teaching and evaluating learning" (Maton, 2005, p. 50). The fields of the pedagogic device are represented in Figure 3-2.

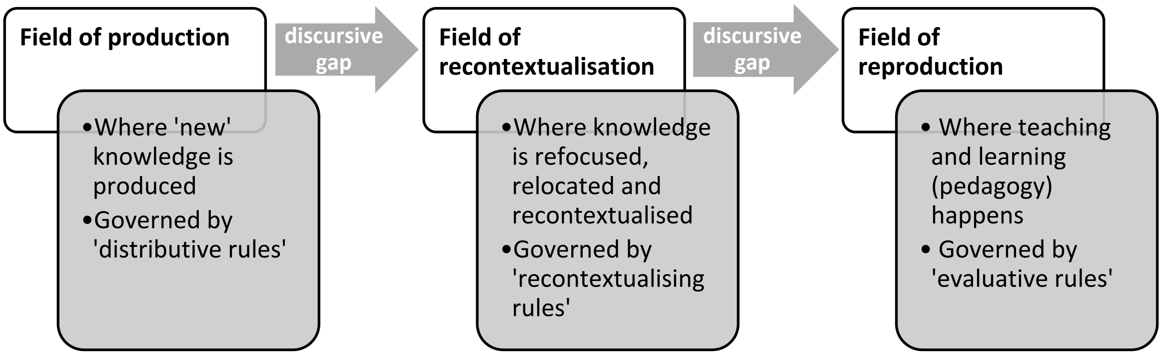


Figure 3-2: Bernstein's pedagogic device (Bernstein, 2000, as cited in Clarence, 2014)

Unlike the introduction of the pedagogic device in school education where the agents engaged in the sites of the three fields are distinctly separated as described above, the case study in this research involves a higher education institution where staff (agents) can act across the three fields, engaging in knowledge production and dissemination (scholarship), design of curricula (recontextualisation) and the teaching of knowledge and evaluation of its acquisition (reproduction). With a focus on understanding the planning for numeracy in undergraduate curriculum, the study has a particular lean to the field of recontextualisation. A brief discussion of each of the different fields will situate the study more clearly within the context of the relational framework.

3.3.1.1 *The field of production*

The field of production is the site where everyday, mundane knowledge is differentiated from the specialized disciplinary knowledge that is generated through research by higher education institutions or legitimate research organisations. The field is governed by distributive rules that regulate access to specialised knowledge production and distribution. Bernstein (1990, as cited in Mtombeni, 2017) states that the questions within this field focus on "who gets access to what type of knowledge, when, how and why" (p. 66). These are very important considerations when planning for numeracy in an undergraduate curriculum. The question, though, is the degree to which curriculum developers in this case study or at another university of technology engage with these questions in the field of production of numeracy in higher education.

As mentioned earlier, Bernstein (1999) draws a distinction between a ‘horizontal’ discourse and a ‘vertical’ discourse, which is helpful. Horizontal discourse refers to the everyday, non-specialised knowledge which is mainly focussed on the individual social reality and mainly applicable in that context. Knowledge within this discourse is often described as ‘common sense’. This particular phrase is pertinent to this study since numeracy is sometimes described as common sense. Authors such as FitzSimons (2006) have, in their research in workplace numeracy, described numeracy as functioning within a horizontal discourse. Although this may be so in certain spaces of adult numeracy education and vocational settings, I am not sure that the higher education numeracy or academic numeracy particular to this study can actually be described as a horizontal discourse.

Bernstein (1999) describes vertical discourse, on the other hand, as comprising specialised knowledge which is produced mainly at universities or research institutes. The vertical discourse is constituted of abstract, theoretical and powerful knowledge (Hlatshwayo, 2018). It is a space that allows for the exploration of new possibilities and new futures that are not confined only to the current context and that are beyond everyday ‘common sense’ knowledge. According to Wheelahan (2012), vertical discourse is a site of power where those who have accessed and mastered such knowledge have the power to influence the structuring of such sites.

The field of production within the pedagogic device constitutes this vertical discourse that is described as abstract, theoretical and powerful knowledge. In this study, the focus on development of numeracy within higher education can be seen as a theoretical, structured learning space, which suggests that numeracy development lends itself to being located, to some extent, within this vertical discourse. As this is explored in the context of this study, however, a tension emerges in terms of the polarisation of the two discourses.
Within the vertical discourse, Bernstein (2000) further distinguishes between horizontal and vertical knowledge structures. The knowledge discourses and structure are represented in Figure 3-3.

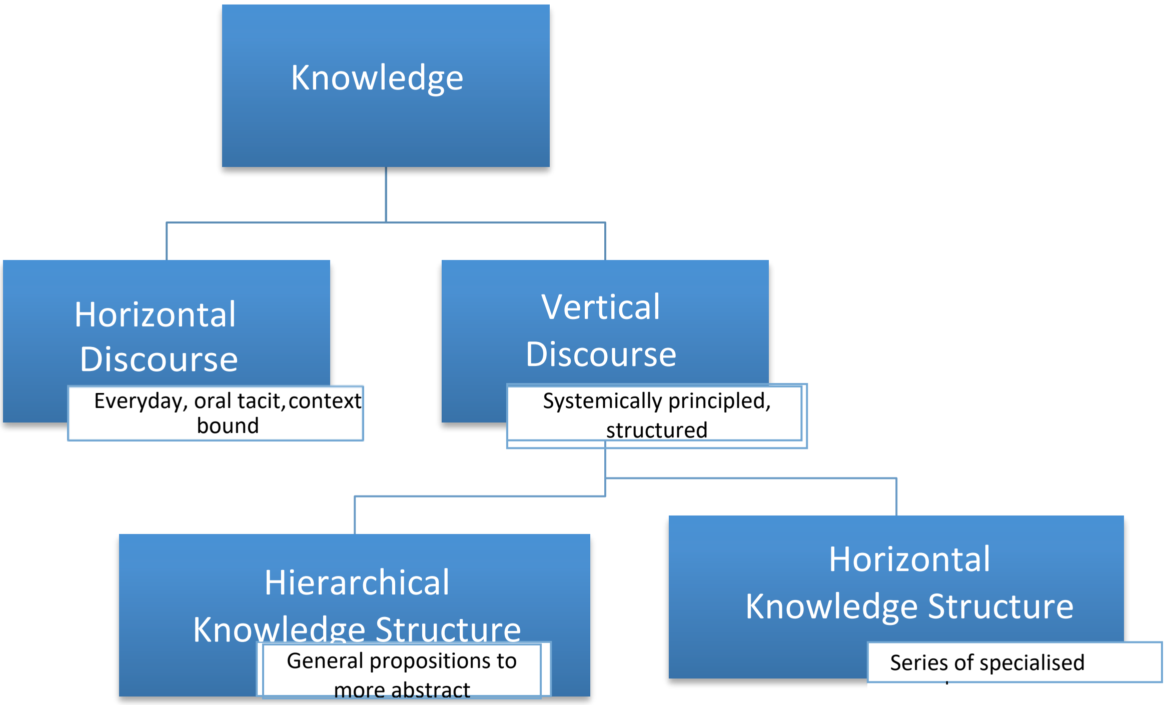


Figure 3-3: Bernstein's differentiation of knowledge (Luckett, 2014, p. 102)

Hierarchical knowledge structures, according to Bernstein (2000), resemble a pyramid with a broad base of more generalised fundamentals and theories that are integrated, connected and subsumed systematically to achieve higher levels of abstraction and specialisation.

Moore and Maton (2001) provide the example of physics as a hierarchical knowledge structure. Wheelahan (2010) notes that knowledge is built within this structure through integrating new meanings within existing frameworks to generate new or revised frameworks. She argues that this structuring principle of knowledge building (producing new knowledge) has implications for how curricula based on knowledge within these hierarchical knowledge structures are designed. So, for example, a physics curriculum needs to start with fundamental theories and foundational knowledge; more abstract theories and applications later in the curricular map must build on the fundamentals.

In contrast to the hierarchical pyramid characterizing vertical knowledge structures, horizontal knowledge structures are flat. Bernstein (1996) describes a horizontal knowledge structure as “a series of specialised languages, each with its own specialised modes of interrogation and specialised criteria . . . with non-comparable principles of description based on different, often opposed, assumptions" (pp. 172-3). Maton (2005, p. 52) notes that horizontal knowledge structures are comprised of a series of segmented theories. Horizontal knowledge structures are more common in the humanities and social sciences where new knowledge does not need to be built on the foundation of earlier frameworks. These structures 'produce' knowledge by adding perspectives or theories that do not need to complement each other and are not dependent on the mastery of other theories or knowledge bases within the structures. New knowledge that is added to the structure can even oppose existing theories within the structure. Hlatshwayo (2018, p. 44) provides the example of the field of Africanisation within South African higher education as an example of a horizontal knowledge structure. Within this field, he notes, knowledge produced through the research of different scholars reflects their differing theoretical perspectives and one scholar's work may critique another's.

If we consider whether knowledge in the field of numeracy in higher education is built primarily through hierarchical or horizontal structures, it becomes apparent that this field does not neatly fit into either of these structures.

Within the horizontal knowledge structure, Bernstein (2000) made a further distinction between disciplines with "strong grammar" as those with "explicit conceptual syntax capable of relatively precise empirical descriptions and/or of generating formal modelling of empirical relations" (p. 162) and those with "weak grammar". Bernstein described mathematics as a discipline with "strong grammar" indicating that it was explicit and relatively precise conceptual description. Fields such as cultural studies are described as possessing "weak grammar" (Maton, 2010) as would the example of Africanisation in South African higher education due to the varying conceptualisations of particular phenomena within the field.

If we apply these concepts to the field of numeracy education, numeracy, as has been discussed, is often considered to be 'common sense' and not part of the academic or theoretical world. While some studies relating to other contexts argue that numeracy is within the horizontal discourse (FitzSimons, 2006), within the context of the higher education institution, numeracy appears to go beyond everyday common sense and inclines more towards the vertical discourse.

Within the vertical discourse, numeracy is not characterised by clearly hierarchical or horizontal knowledge structures. The field of numeracy in higher education appears to expect certain levels of conceptual understanding that are manifested in its contextual applications. In the field of production, numeracy in higher education is thus complex and not easily characterised.

Having explored the field of production which is concerned with developing new knowledge in particular disciplines or fields – as the first field in Bernstein's pedagogic device, I now turn to the field of recontextualisation, which is influenced by the field of production.

3.3.1.2 *The field of recontextualisation*

The field of recontextualisation is the site that arises from the "de-location" and "re-location" of knowledge (Bernstein, 2000). Knowledge is selected from the field of production (from which it is 'de-located') and included in curriculum in different configurations (in which it is 're-located'). The distributive rules of legitimation of knowledge in the field of production do not transfer to the field of recontextualisation seamlessly because there are multiple forces that act together to determine which knowledge is selected from the field of production and how it is structured within a curriculum (the site of recontextualisation) (Mtombeni, 2017). The field of recontextualisation is influenced by recontextualising rules that generate principles from which the "pedagogic discourse manifests" (Mtombeni, 2017, p. 67).

According to Bernstein (1990), pedagogic discourse refers to "a principle for appropriating other discourses and bringing them into special relation with each other for the purposes of their selective transmission and acquisition" (p. 183). This field of recontextualisation is the site of concern in this study and therefore understanding how the different discourses are brought together for the purposes of developing numeracy requires an examination of the discourse of numeracy and the forces and tensions that act on the choices that are made with regard to numeracy in a curriculum.

3.3.1.3 *The field of reproduction*

In this field of the pedagogic device, knowledge is recontextualised from the curriculum into pedagogy. This is the site where the curriculum is enacted. The field of reproduction is concerned with the successful outcomes of teaching resulting in learning that can be evaluated. This field is 'governed' by evaluative rules.

Although this study is not concerned with the enactment of curriculum but, rather, focuses on the planning of the curriculum, the lecturers in this study who were responsible for teaching and learning practices were, in most instances, also responsible for curriculum decisions. As I observed that the choices of curriculum developers were informed by pedagogical experiences, I considered using Maton's Epistemic Pedagogic Device instead of Bernstein's pedagogic device as an explanatory framework to frame the study, as it allows for the curriculum design process to be considered from the perspective of knowledge production and pedagogy.

3.3.2 The Epistemic Pedagogic Device: An extension of the pedagogic device

Building on Bernstein's pedagogic device, Maton (2014) introduced the Epistemic Pedagogic Device (EPD) which is also structured around the fields of production, recontextualisation and reproduction, as shown in Figure 3-4.

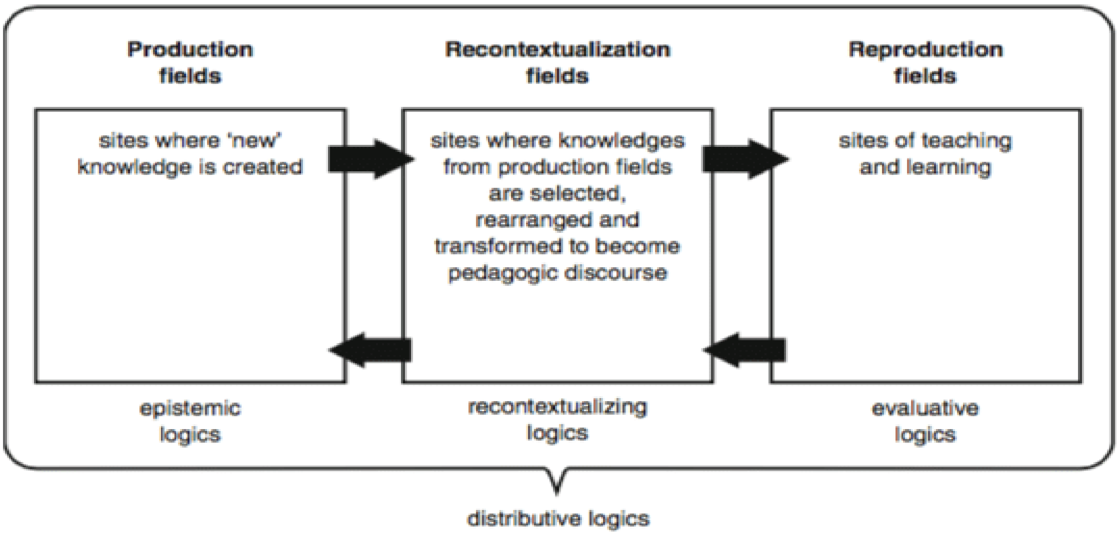


Figure 3-4 Epistemic Pedagogic Device (Maton, 2014, p. 74)

The EPD allows for an exploration of what is considered legitimate knowledge claims and whether "claims are legitimated on the basis of relations of power or by principles intrinsic to knowledge itself" (Moore & Maton, 2001, p. 156). Maton (2014) highlights the following differences between his Epistemic Pedagogic Device (EPD) and Bernstein's pedagogic device (PD):

- The PD device refers to three 'rules': the distributive rules, recontextualising rules and evaluative rules. The rules associated with each of the fields are replaced by 'logics'. Within the three fields of the EPD the associated logics are the epistemic logic which 'replaces' the distributive rules within the field of production. The distributive logic is seen to encompass activities across all fields of the EPD thereby acknowledging and allowing for an exploration of the logics of who gets access to what knowledge in all fields of the pedagogic device.
- In the EPD framework recontextualisation happens in both directions as indicated by the arrows in the figure 3-4 unlike the PD which is one directional. In the PD the recontextualisation of knowledge into curriculum is informed by the field of production and this curriculum is then enacted in the field of reproduction - the site of teaching and evaluating. The EPD on the other hand recognises that particular

pedagogies from the field of reproduction can influence the de-location and relocation into curriculum and can even be theorised and contribute to the field of production.

The EPD offers a useful framework for understanding the 'structure' of pedagogic practices. This study is primarily concerned with the field of recontextualisation, which is common to both the PD and EPD. However, the EPD facilitates the exploration of the knowledge and dispositions brought to curriculum planning from previous experiences in the teaching and learning space and from the site of knowledge production.

The field of numeracy in higher education is not clearly defined, it remains 'vague' and therefore the 'logics' underpinning the curricular choices are impacted on by multiple forces. The EPD provided me with the framework to understand that the curricular choices required an exploration of the knowledge of numeracy in higher education and understand the "basis of relations of power" (Moore & Maton, 2001, p. 156) in terms of the contextual forces resulting in curriculum choices.

While the EPD provides the lens to follow the process of curriculum design, it does not provide the analytical tools to understand the organising principles that underpin plans to develop numeracy. To provide that deepened analysis of the legitimating principles of what is numeracy in this case study and the tensions at play in planning for numeracy in the curriculum, another explanatory framework developed by Maton, Legitimation Code Theory (LCT), was used.

3.4 Legitimation Code Theory (LCT)

Legitimation Code Theory (LCT) provides a framework with multiple tools that are useful for investigating the different practices of planning for numeracy, the principles that legitimate numeracy in the context of higher education undergraduate qualifications and the tensions that influence the choices that are made in planning for numeracy.

Maton (2014) states that LCT draws on and extends Bernstein's work on educational knowledge codes, knowledge structures and the pedagogic device, and also incorporates Bourdieu's 'field' approach. Clarence (2014) notes that LCT uses

> Bernstein's work to examine knowledge as a visible object with its own properties and powers that emerge from, but cannot be reduced to, social practices, and Bourdieu's work to examine the effects of lived practices and social context on a field (p. 41).

Thus, the use of LCT in this study allows for an integration of aspects of Bernstein's work on knowledge discourses and structure and code theory and Bourdieu's work on the social practices of the field of numeracy, so as to deepen analysis. As illustrated in Figure 3-1 above, LCT is an explanatory framework. According to Maton (2014, p. 11), LCT is a "multidimensional conceptual toolkit and analytic methodology rather than a paradigm". By embracing the bi-directional relationship between the explanatory framework and substantive research studies, LCT is able to be used in the study of "substantive problems" and also to be extended from use in research of substantive problems (Maton, 2014, p. 21). LCT is used across various fields, including education.

Maton (2014) notes that LCT is not a "specific substantive account of knowledge or education" (p. 21), but rather that studies using LCT provide particular inferences of the concerns of research problems. The explanations and inferences are not the framework but rather the outcomes based on the creative use of the framework to address a particular research problem. In this way, LCT is constantly required to re-invent itself based on issues arising in its application in the research arena. In other words, the use of LCT tools in research studies is not based on a 'cookie cutter' approach of applying theory to research.

Maton (2014) also states that LCT is neither an ontology nor an epistemology. As an explanatory framework, it is linked to both the meta-theories and the substantive research studies. While some theories may be concerned with the connection to ontologies primarily, LCT is described as a practical theory with a focus on problem solving. LCT is an appropriate framework to apply to this study, which is concerned with understanding the underlying organising principles that give rise to the planning for numeracy in undergraduate curricula.

While LCT provides the researcher with tools to explore a phenomenon within a context, it allows for the findings not to be limited to a particular problem or context. The framework allows for an unpacking of the organising principles underlying practices, dispositions and contexts and, where appropriate, a comparison across studies (Maton, 2016). Its tools facilitate theory and context being brought together in "dialectical relationships in order for the theory to make sense, for the empirical context to be theorised, and for the theory to continue to grow and develop" (Clarence, 2014 p. 50). Maton (2016) claims that LCT "enables both the exploration of knowledge-building and the cumulative building of knowledge" (p. 3) that can contribute to "overcoming segmentalism in understanding education and society" (p. 3), facilitating a more integrated account of educational fields.

LCT comprises five dimensions which include concepts and tools for analysing the organising principles particular to specific fields, which will be discussed in the following section. Maton (2016) states that these dimensions are 'simultaneous'. He explains that "they explore not different objects of study but rather different organizing principles that may underlie the same object" (Maton, 2014, p. 26). These dimensions are built on the "conceptual foundations of different forms of classification and framing" (Maton, 2005, p. 86). Maton (2005) further elaborates that the dimensions provide "depth ontology that goes beyond the empirical to both capture the underlying generative mechanisms of realised possibilities and generatively conceptualise unrecognised and unrealised possibilities" (p. 86).

By examining the organising principles of the planning for numeracy within curricula from the different perspectives offered by the LCT framework and the integration of these perspectives, it is possible to illuminate and make explicit the peculiarities of the field of numeracy as it relates to its inclusion in higher education curricula. The use of the five tools of the LCT toolkit in the study simultaneously makes it possible to explore "what is possible for whom, when, where and how, and who is able to define these possibilities, when, where and how" (Maton, 2014, p. 18). In this case study, this aids the exploration of how the principles of legitimation of what numeracy is and how other contextual forces work in combination to impact on curricula choices.

LCT has been used extensively in educational research in South Africa with the intent of making the tacit explicit and thus enhancing access to the knowledge building and meaning making logics of different educational fields. (For example, see: Wilmot, 2019; Clarence, 2014; Mtombeni, 2017; Arbee, 2012; and Luckett, 2014). Research focusing on curricula has also used LCT. (For example, see Case, 2011 and Shay, 2015.) LCT has been used in numerous international studies in education as well. (For example, see: Maton, 2014; Maton, 2016; and Clegg, 2015).

3.4.1 The LCT dimensions

The LCT toolkit comprises five dimensions: Autonomy, Specialization, Semantics, Density and Temporality.[1]

3.4.1.1 *Autonomy*

Autonomy refers to the extent to which the field is impacted upon by external forces. It builds on the premise that "any set of practices comprises constituents that are related together in particular ways" (Maton & Howard, 2018, p. 6). Autonomy is an LCT dimension that allows an exploration of the relation among these sets of practices. Where a field is strongly influenced or controlled by external forces, the field may have very weak autonomy to determine what is legitimate in the field. A field's autonomy can be described in terms of positional autonomy and relational autonomy. Positional autonomy (PA) describes *who* 'runs' the field and how insulated this is from other fields of practice. Relational autonomy (RA) examines how the constituents relate within the field of practice: *how* the field is 'run'. Positional autonomy and relational autonomy can either be stronger or weaker than each other and can be combined to generate four codes, as shown in Figure 3-5.

[1] The dimensions retain their original spelling and capitalisation throughout this thesis.

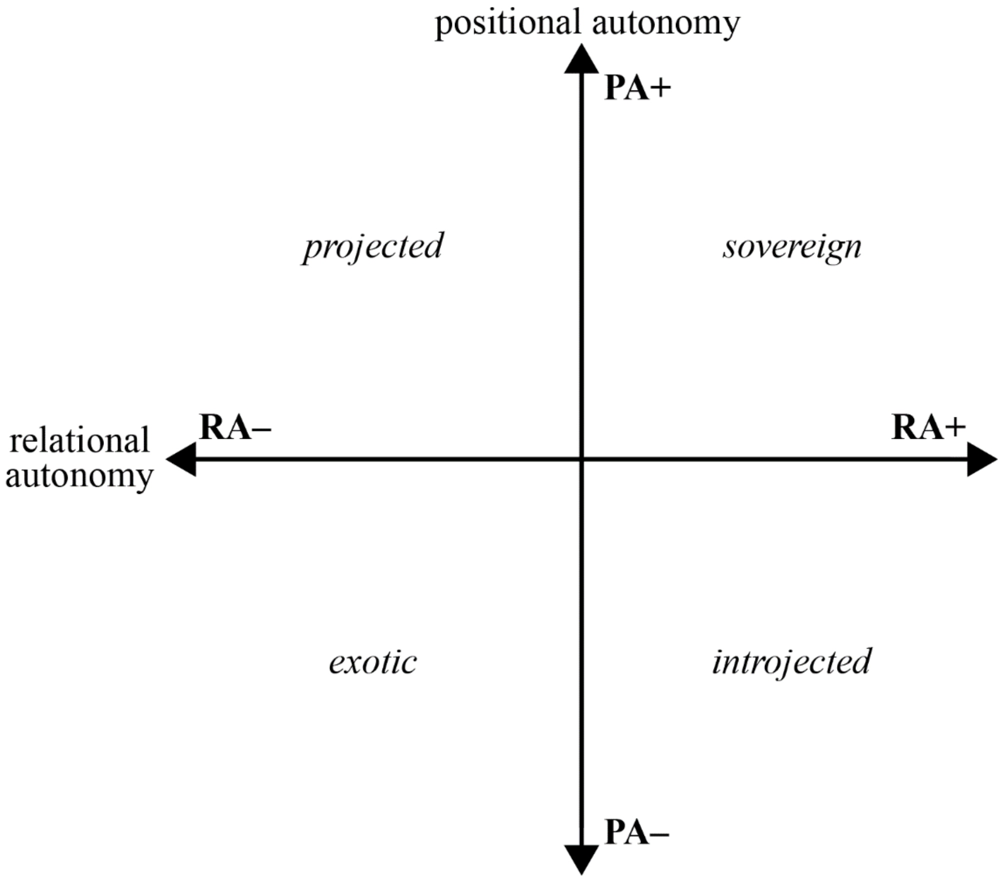


Figure 3-5 LCT Autonomy Plane (Maton & Howard, p. 6)

The dimension of Autonomy has been used in recent studies to explore how different forms of knowledges can be integrated to enhance or challenge knowledge building (Maton & Howard, 2018).

One of the objectives of this study is to explore how the imperative to include numeracy or quantitative reasoning in undergraduate programmes is translated into curriculum plans. The Autonomy dimension of the LCT toolkit is used in this study to understand the organising principles underlying the choices of development of numeracy approaches in undergraduate programmes. This is discussed in greater detail in Chapter 4 (Methodology).

3.4.1.2 *Specialization*

Specialization refers to the extent to which the intellectual field is legitimated through specialised knowledge and/or special 'knowers'. Specialization allows for an analysis of knowledge, practices and beliefs which Luckett (2014) describes as being "about something and by someone" (p. 106).

This dimension focusses on two concepts. Epistemic relation (ER) refers to what is considered legitimate knowledge and how we get to know it, while social relation (SR) refers to the legitimate 'knowers' in the field. Analysis of knowledge practice claims thus involve an exploration of the "epistemic relations between knowledge and its objects of study, and social relations between knowledge and its authors or subjects" (Maton, 2014, p. 29). These concepts are combined to generate Specialization codes, as shown in Figure 3-6.

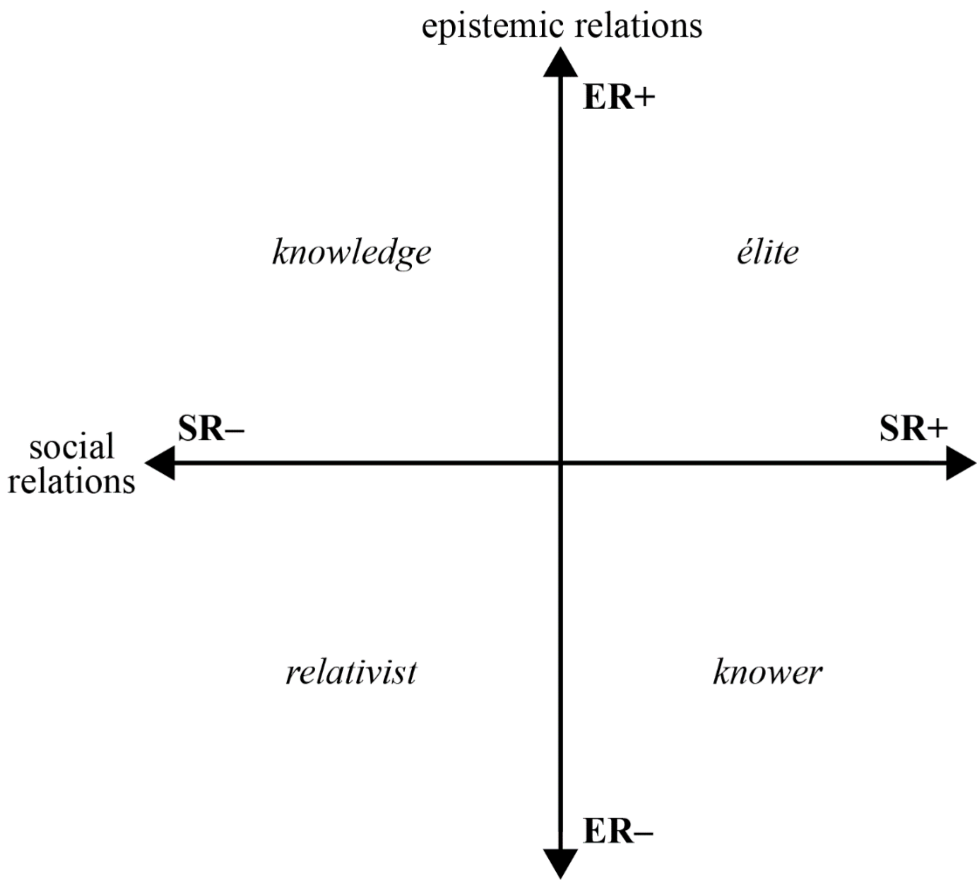


Figure 3-6 LCT Specialization Plane (Maton, 2014, p. 30)

The knowledge code is indicative of a prioritising of specialised knowledge with little, if any, influence of 'who' the person is, such as would be the case in the physics content covered in a module. The knower code, on the other hand, involves legitimation of knowledge, practices or belief claims based on particular social beings. This could be instances where the knowledge claim is based on someone being male, or from a particular cultural context, for example. The elite code suggests that there is dominance in a practice where both specialised knowledge and particular knowers are legitimated at the same time. These could be evident in professional practices such as health professions. For the relativist code, the knowledge base is not specialised and specific, or particular characteristics of the social being are not seen to be the dominant legitimating principle. What is often described as everyday common sense is often placed in this code. For example, the process of combining ingredients to cook a meal could be different for different people and may not be based on sophisticated knowledge of measurement. Another example could be diluting detergents. All of these are seen to be legitimate in this code. This common sense knowledge does not mean the relativist code is inferior to the others. Maton (2014) states the codes in themselves do not have importance and no one code is 'better' than another. Their existence and importance derive from the context of the practice or phenomena being examined. Different fields of practice have differing principles for establishing what, and who, is considered legitimate. These are often tacit. The Specialization dimension has the potential to make these underlying principles explicit. The Specialization dimension was the first dimension to be taken up in research studies and has been one of the more popular tools used from LCT. It has proven very useful for making explicit the legitimating principles of different fields of study. An example of this is the use of Specialization to make tacit practices overt in the design and teaching of marketing (Arbee, 2012).

Analysis using Specialization was useful in highlighting students' challenges in a foreign university (Chen, 2010). A code clash was found between Chinese students' dispositions to studies and the practices of learning valued at the Australian university at which they were studying. The Chinese students' study practices were dominated by a knowledge code and the approach to learning valued at the university was legitimated through a knower code. No matter how much effort students made they experienced difficulties with their studies because of the code clash. There are also instances of code match. Code match occurs when the field's legitimate principles match that of the actor (Wilmot, 2019, p. 43). For example, Maton (2016, p. 14) makes reference to a study where the matching of a large scale policy drive to integrate educational technology into subjects was successful where there was a code match and not as successful where there was a code clash.

It is important to note that the dominant Specialization code does not have to remain static. It can change across contexts: for example, across different sections of a module or between curriculum documents and their implementation. The changes can also be traced through a Specialization analysis indicating either code drift or code shift. Code shift implies that there is a move into a completely different code: for example, if one is plotting a teaching lesson it is possible to identify strong knowledge codes which then transition into relativist code when a discussion that is irrelevant to the particular specialised knowledge arises. Code drift, on the other hand, describes movement within the same code. Within any one of the codes, for example, the knowledge code, strengthening or weakening of the epistemic relations or social relations could result in a shift in the code. The knowledge and knower codes can be further analysed using another set of tools. For the purposes of this research, an exploration of the different knower codes through a description of the varying gazes is used. I present below a description of Gazes as understood within the LCT framework.

Gazes

Similar to the hierarchical and horizontal knowledge structures which contain strong and weak grammars discussed earlier, there also exist horizontal and hierarchical knower structures with weaker or stronger grammars. Bernstein (2000, p. 165) brings to our attention that in the case of hierarchical knowledge structures with strong knowledge grammars the knower structures are "weaker". However, in the case of horizontal knowledge structures where knowledge builds segmentally and legitimation of practices is based on a prioritizing of particular gazes, the knower structures are stronger. The relationship between knowledge and knower structures is represented in **Figure 3-7**.

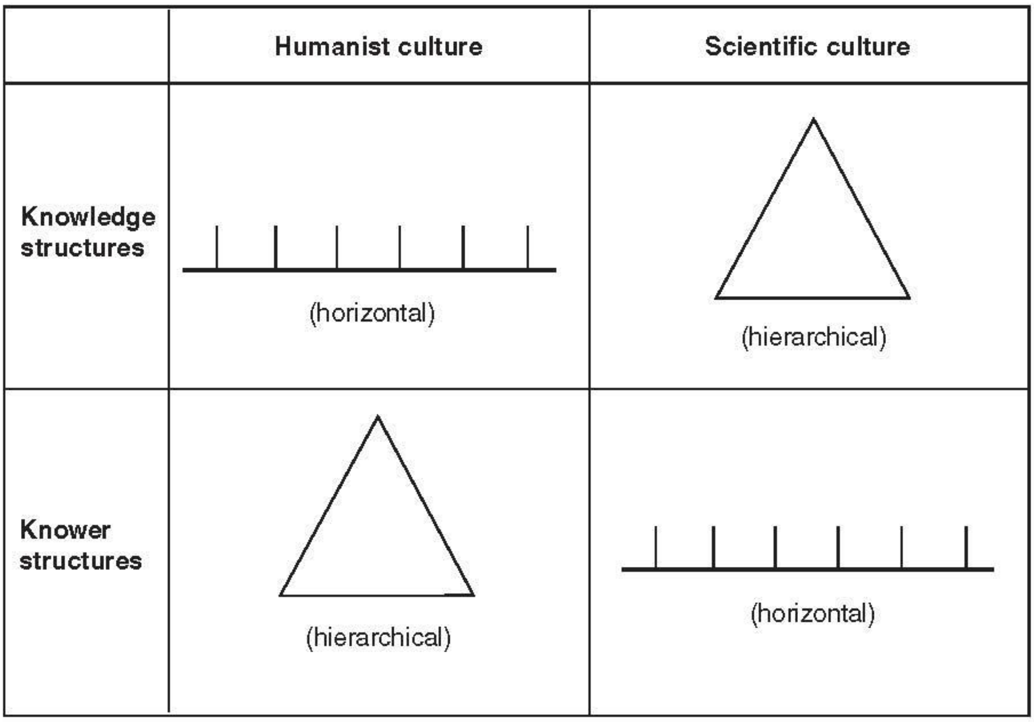


Figure 3-7 Knowledge and knower structures (Maton, 2004, p. 95)

As shown in Figure 3-7, in the hierarchical knowledge structures, such as those found in the natural sciences, the emphasis is on knowledge building; in the horizontal knowledge structures the emphasis is on developing particular knowers and therefore indication of knower building through developing gazes.

Maton (2013, p. 95) differentiates four different types of gazes on a continuum, as indicated in Figure 3-8.

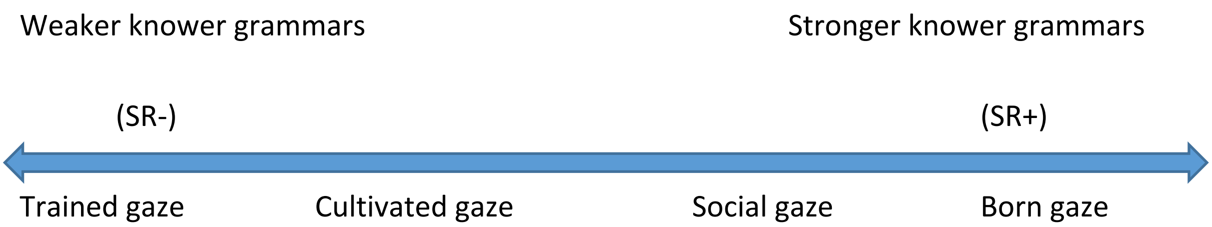


Figure 3-8 Different gazes on a continuum of social relations (Maton, 2014, p. 95)

Practices, dispositions or knowledge claims that are legitimated on particular 'born' characteristics such as gender, for example, have very strong social relations and value most who the 'actor' is. This often occurs were the knower is seen to have 'natural talent', for example. Within social gaze, the knowers' legitimacy arises from their 'socialization' within certain cultures or communities and adoption of particular ways of being or possession of particular beliefs. In this instance, social relations remain strong, however, not as strong as in the instance of the born gaze.

Weaker social relations are evident in the instances of the cultivated gaze and the trained gaze. With the cultivated gaze, legitimacy is gained through a developed gaze within the knower through extended exposure to skills and dispositions. The trained gaze is legitimated through the successful acquisition of specialised knowledge, skills and procedures.

In this particular case study, the Specialization dimension yields useful insights into conceptions of numeracy. Through a specialisation analysis it is possible to explore what numeracy is and make explicit the principles of legitimising numeracy within the case study. This exploration can also contribute to the conceptualisation of numeracy in higher education and its implications for curriculum planning. So far, what is evident from the literature discussed in Chapter 2 is that it has some relationship to mathematics and literacy; different perspectives view these relations in different ways.

I found Maton's gazes a particularly important concept because the view is sometimes expressed that individuals either have ability or they do not. If this was true, it would suggest that only those knowers with the born gaze would successfully engage with the numeracy demands of the programmes and the professions they enter. This, then, would imply that higher education would have no real responsibility to develop numeracy, a notion which contradicts the premise of this study and, of course, the social justice agenda of higher education.

3.4.1.3 *Semantics*

Semantics focuses on how knowledge is advanced in a field. This dimension allows for “fine grained exploration of knowledge and meanings in fields and the capacity of fields to build cumulative knowledge” (Arbee, Hugo & Thompson, 2014, p. 46). There are two key concepts within Semantics. Semantic gravity (SG) refers to the degree to which meaning is dependent on its context. The stronger the sematic gravity, the more dependent it is on context. The weakening of the semantic gravity results in higher levels of abstraction as it moves away from dependence on context.

Semantic density (SD), on the other hand, is concerned with the complexity of a concept or practice. Weaker semantic density (SD-) is evident in simple concepts, while stronger semantic density occurs where a concept or phenomenon is made up of a constellation of other concepts. Strong semantic density (SD+) implies that there is greater condensation of meaning within particular concepts or symbols. The complexity of the concept is, of course, dependent on the context as well. Maton (2016, p. 17) highlights this point using the example of gold. In an everyday understanding, gold represents a bright yellow shiny metal used to make jewellery: it is a simple concept with low semantic density (SD-). However, in the context of chemistry the concept of gold represents a higher condensation of meaning. Gold in this context is associated with atomic weight, atomic number and other inherent meanings. These, in turn, also have meanings within them, resulting in the semantic density of the concept of gold being much higher in chemistry.

A research study could focus on semantic gravity or semantic density alone, however usually the concepts are used in combination. For example, in teaching practice a teacher can make an abstract phenomenon more accessible by contextualising it within students’ experience – thus increasing semantic gravity and unpacking the phenomenon to make it simpler to understand, thus reducing semantic density. Semantic gravity and semantic density, when combined, generate a set of codes, as illustrated in Figure 3-9.

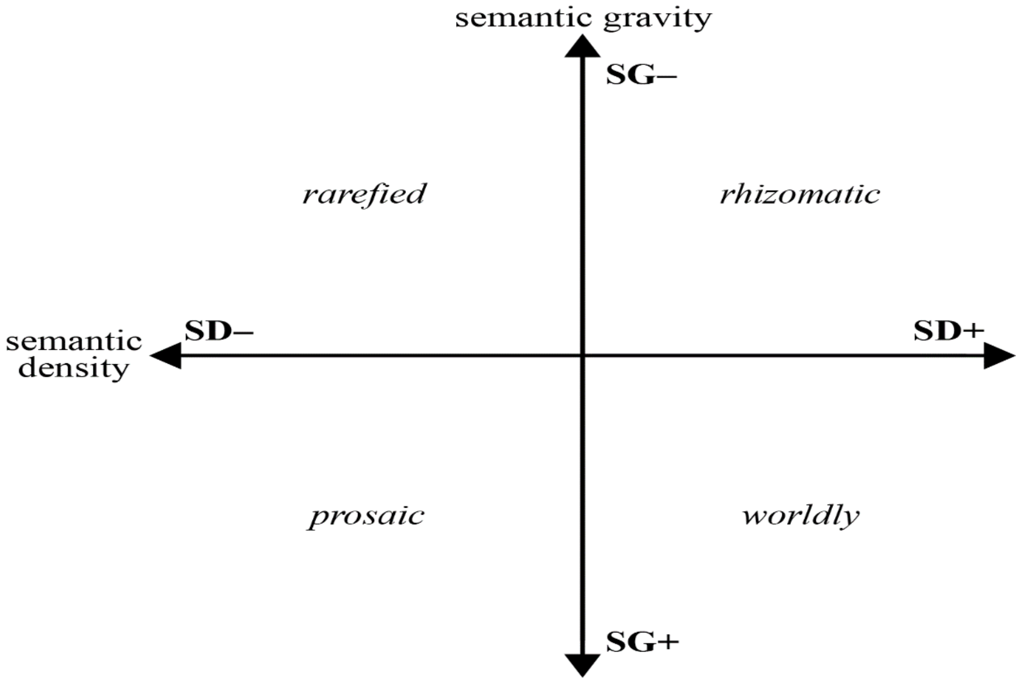


Figure 3-9 LCT Semantic Plane (Maton, 2014, p. 131)

The rarefied code indicates a valuing of knowledge claims, practices or beliefs that are very simple and are not really special to any particular context. In the field of numeracy, this could be something like counting from 1 to 10. The prosaic code represents knowledge claims or beliefs that value simple concepts that relate to a particular context, for example, adding money or calculating change. The rhizomatic code indicates a dominance of more complex phenomena that are abstract or theoretical in nature for example computing complex mathematical procedures. The worldly code is concerned with concepts that have other concepts integrated into their meaning and are contextually bound. Representing my analysis of semantic gravity and semantic density in this form, allowed for the possibilities of going beyond the dichotomy of contextual versus conceptual.

Semantics is another commonly used dimension of LCT. It is most common in research studies focussing on pedagogy. Similar to the Specialization and Autonomy dimensions it is possible to highlight code clashes and movement across codes. In this study, the Specialization and Semantics dimensions of the LCT framework facilitated new insights into the principles underlying conceptions of numeracy and the generative mechanisms that give rise to these conceptions in several ways. Through the use of Specialization, it was possible to explore the relationship between numeracy and specialized knowledge and understand the knower gazes and who became legitimate knowers. Analysis using Semantics was especially valuable since numeracy (as discussed in Chapter 2) brings together abstract mathematical concepts and contextual application. This enabled the underlying principles of legitimation around contextual application and the complexity of mathematical concepts to be exposed.

Maton (2005) included two other dimensions in the LCT which had not yet been used as extensively as Autonomy, Specialization and Semantics. These are Density and Temporality, which are useful in this study to understand the influence of the field of numeracy in higher education on the planning of curriculum at the institution.

3.4.1.4 *Density*

Density refers to the cohesion and differentiation within a field. It focusses on examining internal diversity within a field in respect of what constitutes the disciplinary knowledge domain, focus and purpose. The key concepts within the dimension of Density are material density (MaD), which relates to the diversity of content within a field, and moral density (MoD), which relates to beliefs. The combinations resulting from these two variables are represented in Figure 3-10.

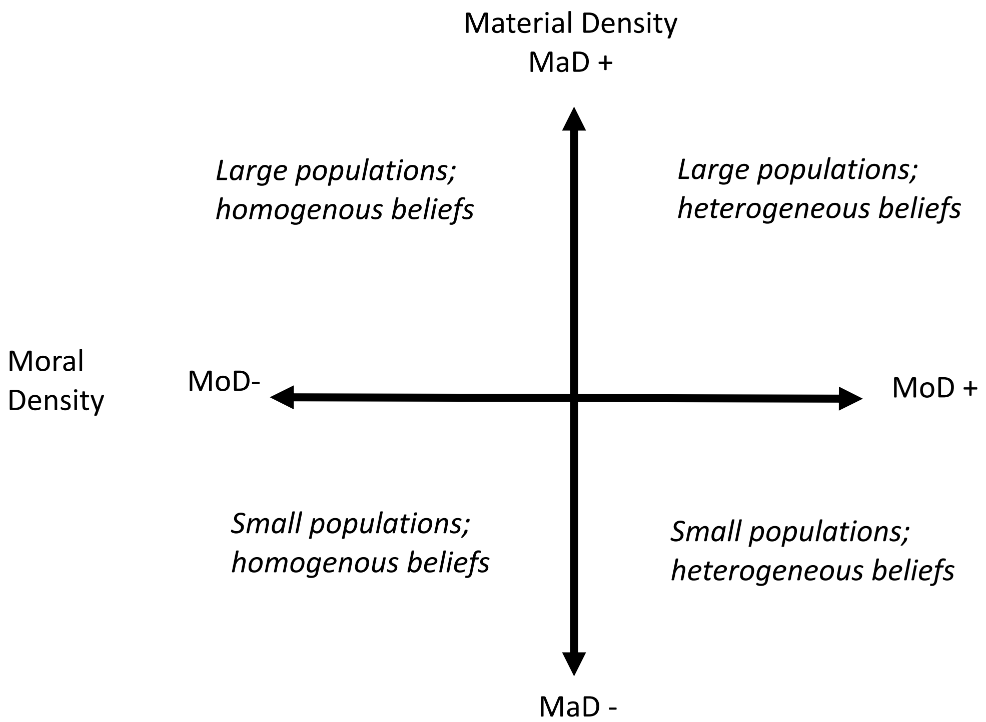


Figure 3-10 LCT Density Plane (Maton, 2005, p. 90)

In this study, the Density dimension of Maton's LCT was used to understand the underlying principles of legitimation in the field of numeracy in higher education in order to understand the tensions and forces that influence its recontextualisation in curriculum.

3.4.1.5 *Temporality*

Temporality refers to exploring the field in terms of whether it is an 'old', well-established field or discipline such as psychology or a newer, contemporary field such as cultural studies and whether it is forward or backward looking. Again, there are two key concepts within this dimension: temporal positioning (TP) and temporal orientation (TO). The combinations resulting from the intersecting of these two variables are represented in Figure 3-11.

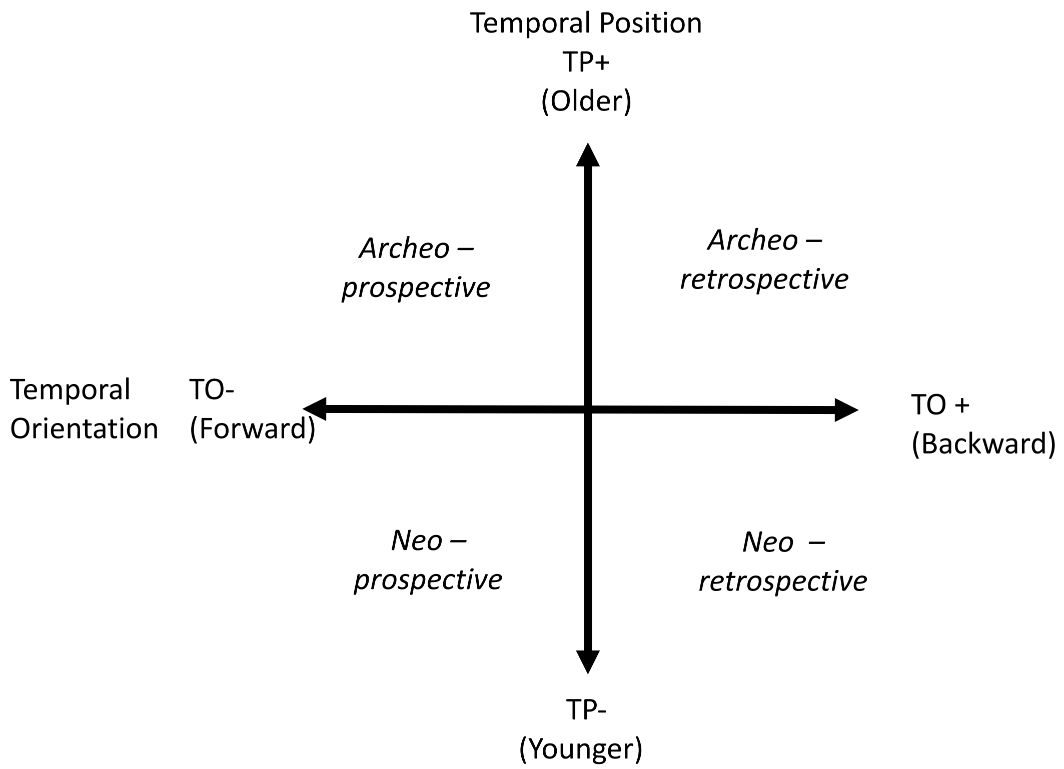


Figure 3-11 LCT Temporality Plane (Maton, 2005, p. 94)

Temporal position is said to be stronger where knowledge claims or beliefs are influenced or steeped in older traditions. Temporal orientation is stronger when the field of practice is 'backward looking'. The codes above, as with the previous dimensions that have been discussed, can clash or match and each of these have implications for curricular choices.

The LCT Temporality dimension proved useful in this study for exploring the links between numeracy and other disciplines such as mathematics that are steeped in older traditions and to understand to what degree this resulted in tensions or otherwise influenced planning for numeracy.

It is important to note that the concepts and codes used in the five dimensions of the LCT are not binary, but each represents a continuum. The LCT thus provides a toolkit which transcends dichotomies and provides both a typology of four codes per dimension as well as a topology of possibilities.

In summary, this study uses all five dimensions of Maton's Legitimation Code Theory – Autonomy, Specialization, Semantics, Density and Temporality to explore the particularities of numeracy in higher education as a field of research and practice. Many studies which have employed Maton's LCT have used only one or two of the five dimensions. In fact, only one or two known studies have used all five dimensions. For example, Arbee (2012) used the dimensions to understand what was legitimated in the marketing programme at an institution and how this compared to the theorised field of marketing. Although I agree with Wilmot (2019) that in most cases an exhaustive analysis using all five dimensions' tools is not necessarily beneficial, I chose to use all five dimensions of the LCT in this case study for the following reasons.

The field of numeracy education in higher education is a fairly under-theorised field and the use of the multiple tools allowed for theorisation at multiple levels. The different dimensions proved useful in investigating different key questions. The Autonomy dimension was used to gain insight into the organising principles underlying the planning practices used for numeracy in undergraduate programmes. The Specialization and Semantics dimensions provided insights into the principles of legitimation of the conceptions of numeracy across the institution. The Density and Temporality dimensions facilitated the exploration of how the nature of the field of numeracy can contribute to the forces that influence curricular choices. The conceptual and analytical framework provided by the five dimensions of the LCT thus facilitated a deeper investigation into the complex factors that influence curriculum planning for numeracy in higher education.

3.5 Conclusion

This chapter has presented the theoretical orientations which guided this study. The theoretical considerations and explanatory frameworks adopted in the study needed to allow for an exploration of the complexities of the curricular choices made in respect to the planning for numeracy. The chapter therefore started by describing the meta-theory of social realism and the alignment to a realist ontology as adopted within critical realism. This was followed with a discussion of the explanatory frameworks that are used in the study. First, the Epistemic Pedagogic Device was discussed as a framing explanatory framework to understand the curriculum planning engagement within the pedagogic structure. Second, Legitimation Code Theory was used as the explanatory framework that provided tools that allowed for exploration in terms of the principles of legitimation of what is numeracy, the understanding of the influences of the structure of numeracy and other contextual factors on curriculum planning. All five dimensions of Maton's LCT were introduced, with a brief indication of how each could address the research questions.

The next chapter presents the methodology used in this study, explaining how the theoretical tools discussed in this chapter were used to address the critical research questions and describing the research approach and the methods that were used to collect and analyse data.

Chapter 4
Methodology

4.1 Introduction

The previous two chapters have reviewed the research, discourse and theoretical and philosophical orientations relevant to the phenomenon of numeracy and how it is planned within a curriculum. This chapter provides a description of the research design adopted in this study and the rationale for the methodological choices that were made.

The chapter begins by locating the methodology within the ontological and epistemological landscape that was discussed in Chapter 3 and discusses the implications of this for the design of the study. The research approach is presented, along with the strategies and methodologies adopted for reviewing the literature, selecting a sample and the collection and analysis of data. The rationale for these choices is provided. My positionality as a researcher and ethical considerations are also discussed.

4.2 Ontological and epistemological considerations for the choice of methodologies

Research choices are influenced by the researcher's perceptions of what reality is and how we come to know it. As Wheelahan (2010, p. 53) states, the methods chosen to explore "reality" are impacted on by the orientation of the researcher to theorising the nature of the reality. The ontological and epistemological positions that inform this study thus needed to have bearing on the design and methodological choices.

Ontological and epistemological assumptions are aligned to the paradigm within which the research is undertaken. According to Schwandt (1989, 2001) paradigms are worldviews and relate to beliefs about the nature of reality, knowledge and values. It is these beliefs that guide researchers' choices (Guba & Lincoln, 1994). According to Hitchcock and Hughes (1995, as cited in Dieronitou, 2014) ontological assumptions give rise to epistemological assumptions, which lead to the methodology which, in turn, guides the choice of the instruments used in data production.

This study is grounded in a theoretical perspective of stratified ontology, epistemological relativism and judgmental rationality. Within this perspective neither absolute positivism nor extreme relativism is prioritised: it is acknowledged that reality is not limited to one's experience or knowledge of it and is also fallible. The theoretical framework used in this research, Legitimation Code Theory (LCT), allows for a plausible explanation of experiences and events through an exploration of the generative mechanisms that result in these, based in theory.

4.2.1 Ontological considerations

In this study, the focus is on finding plausible explanations for the ways numeracy is planned for in the undergraduate curriculum as observed in this case study. It is accepted that this phenomenon has been influenced by historical, cultural, political and social factors. It is also accepted that the subjectivity of the curriculum developers and their understanding of how numeracy can be developed legitimately influences the planning of numeracy development in undergraduate programmes.

Another key factor which influences the phenomenon is the reality which exists outside or beyond individuals' perceptions. This study is grounded in a social realist perspective which is aligned to the critical realist ontology of reality. Realism is a perspective that is seen to be between absolute objectivism and extreme relativism (Guba, 1990). Critical realism allows for the research to unpack the underlying "generative mechanisms that give rise to events in the world and our experience of them" (Bharath, 2015, p. 116). Wheelahan (2010) suggests adopting a realist worldview implies accepting that there are theories that allow access to the natural and social world while being aware that these are not absolute and may not be perfect. Within this ontological position, it is accepted that it is not possible to describe the world exactly how it is, but it is possible to use theories to guide a more reliable interpretation (ibid).

Grounded in this view of reality, this study can use theory to generate possible understandings of why the institution uses particular approaches to develop numeracy in undergraduate curricula, within the limited context of the study. A social realist orientation to this study allows the actual practices used by the institution to plan for numeracy to be explored with the intention of going beyond the description of the practice to explore the possible underlying causable forces that result in the planned practices while, at the same time, not claiming that the findings represent all plausible explanations. This means that the findings of the study are not generalizable to other contexts but, rather, contribute to the discourse on numeracy education by providing insight into some of the organising principles of the conceptions of numeracy and the development of numeracy in undergraduate programmes.

4.2.2 Epistemological considerations

In this study, multiple perspectives need to be taken into account to gain a comprehensive understanding of the process of 'coming to know'. Within the social realist orientation, I placed emphasis on understanding the power of the academics to decide on particular practices in the curriculum, as well as how internal and external forces create tensions that impact on choices.

The literature review highlighted important considerations in the conceptualisation of numeracy in higher education. These included understanding that numeracy, unlike mathematics, is a multi-disciplinary educational field where classification is elusive because of the many influences of other fields.

Adopting knowledge structure associated with mathematics can be very limiting, it is important to examine the knowledge structures within numeracy. The literature also highlights the importance of understanding and examining the impact of contextual factors influenced by social, cultural, historical and political forces on implementing change, curricular decisions and conceptualisations of numeracy in higher education. In light of this, a study of this nature requires a methodology that enables knowledge structures to be examined, is aligned to the principles of recontextualization and recognises the impact of contextual and societal forces, dynamics and agendas.

4.3 Strategy for literature review

The review of literature, presented in Chapter 2, was an integral part of the research plan. Having established the importance of the study and the key research questions, I engaged in the literature review to understand the current discourse on the development of numeracy in higher education. As part of this process it was important also to gain insights into the different conceptions of numeracy that have informed how it has developed. The strategies used are discussed in this section.

Initially, an electronic search was conducted that focussed on 'numeracy in higher education'. This search generated a number of articles but there were few that related directly to the area of research. Rephrasing this search generated the same few articles.

Drawing on the work of Bell (2005), a mind map was created to generate keywords or phrases that could be searched. According to Burns and Grove (2005), brainstorming key words that could be used to search the literature helps to focus the search and reduces the risk of omitting relevant research. The following is a sample of some of the keywords or phrases that were used in the search:

- development of numeracy in higher education
- numeracy development at universities
- what is numeracy
- how can numeracy be developed in undergraduate programmes
- frameworks of numeracy assessments
- importance of numeracy development
- numerate graduate

- approaches or strategies used to develop numeracy in higher education.

As I browsed the publications identified by these searches, it became evident that I needed to include related terms such as 'quantitative literacy' and 'quantitative reasoning'. The search was broadened to include phrases such as:

- what is quantitative reasoning or quantitative literacy
- differences and similarities between numeracy, quantitative reasoning and quantitative literacy
- development of quantitative literacy/quantitative reasoning.

Most of the results generated through the search were articles from the United States, United Kingdom, Australia and New Zealand. There is other literature from around the globe but this is scattered and not abundant. Adding "South Africa" to the search yielded just a few publications addressing numeracy as it relates to higher education; most of these focussed on the only South African university with a numeracy centre. Other relevant South African research was found, however, by searching for research on numeracy in secondary education and particularly on 'mathematical literacy' a secondary school subject which is offered as an alternative to mathematics in the South African curriculum.

Reading the publications identified through these searches yielded new leads to works cited. Through these searches I identified key journals for publications on numeracy as well as conference proceedings that addressed numeracy. These included *Numeracy*, the *Journal of Literacy and Numeracy Studies*, *ZDM: International Journal of Mathematics Education* and the *Adults Learning Mathematics* (ALM) online journal and conference proceedings. These publications, in turn, led to the online resources of the Association for Mathematics Education of South Africa (AMESA) and the Mathematical Association of America (MAA), which included publications such as 'Democracy and Numeracy' and 'Shifting context common core'.

Numeracy is the open access, peer reviewed journal of the National Numeracy Network (NNN) which was launched in the United States in 2008. Its mission is to advance the vision of the NNN of "a society in which all citizens possess the power and habit of mind to search out quantitative information, critique it, reflect upon it, and apply it in their public, personal and professional lives" (National Numeracy Network, 2020, About this journal, para. 1). The journal publishes two issues each year which include evidence-based perspectives on numeracy, teaching and learning, assessment, curriculum design and faculty development. The journal also includes commentaries.

The *Adults Learning Mathematics* forum was founded in 1994. The ALM journal and conference proceedings are outputs of the annual ALM conference. The journal's focus is the research of knowledge, teaching and learning and uses of numeracy and mathematics. The forum and conferences facilitate the sharing of insights on adult learning of mathematics and numeracy at all levels across educational sectors. Although the forum has promoted scholarship in this area for over two decades, it describes the field of numeracy and adult mathematics as "under-researched and under-theorized" (Adults Learning Mathematics, 2020, journal, last para).

The *Journal of Literacy and Numeracy Studies* is an international peer reviewed journal which exists to promote research and advance the scholarship of literacy and numeracy and understands literacy and numeracy as being "locally situated and influenced by the cultures and contexts of use" (UTS ePress, n.d. "Literacy and Numeracy Studies, para. 1). It focusses on exploring the different understandings of numeracy and literacy within policy and practices across different contexts.

Inclusion and exclusion criteria

This study is situated within an interpretive paradigm and, at its core, seeks to understand a specific phenomenon: planning for numeracy in the undergraduate curriculum of a university of technology. Research across different academic sources was considered in the review to allow for a broader understanding of the complexities of designing a curriculum that includes the development of numeracy practices.

Considering Grant and Booth's (2009) typology of reviews, it was decided that initially the study could benefit from a scoping review. Given that it is often stated in the literature that numeracy in higher education is an under-researched and under-theorised field and that my initial searches did not generate a large number of relevant results, scoping the search beyond the limitations of the term 'numeracy' and the context of higher education became necessary to develop a broader understanding of the field. While this generated much more literature that was considered for the review, not all of it was relevant. A 'purposive selection' approach was taken, focussed on the following broad criteria:

- publications presenting definitions or conceptions of numeracy, quantitative reasoning or quantitative literacy
- studies focussing on the development of numeracy in academic contexts
- publications from academically reputable databases or search engines such as Google Scholar, ProQuest and the university library search engines
- studies published in English
- studies focussing on a review of the field of numeracy education.

Search results meeting following criteria were excluded:

- studies related to numeracy in the foundation phase of school education.
- studies from unknown sources or where academic credibility could not be established
- mathematics education (ME) studies that were related to specific mathematical content, such as studies on proportions.

The literature was then thematised according to the conceptions of numeracy and numeracy education. The studies cited in the literature review demonstrate that numeracy, and planning for numeracy, take a variety of forms which are largely determined by the perspectives of the curriculum developers. This study's position within a qualitative paradigm appropriately allowed for the exploration of participants' perspectives.

4.4 Choosing a research approach

The choice of a research approach needs to be made on the basis of which approach will best facilitate meeting the objectives of the study. The objectives of this study, once again, are to:

1. explore how an institutional imperative to include numeracy in undergraduate programmes is translated into the planned curriculum;

2. analyse the conceptions of numeracy that influenced the planning for numeracy in the undergraduate curriculum of a university of technology;
3. analyse the internal and external contextual forces and dynamics that impacted on the inclusion of numeracy within the undergraduate programmes at university of technology; and
4. make explicit the underlying organising principles of legitimation that inform planning for numeracy in higher education.

The focus of this study is thus to explore the practices an institution employs to develop students' numeracy in order to identify what the institution values as numeracy, identify the principles that legitimate these values, and understand how contextual forces combine to impact on the decisions that are made about how to develop students' numeracy.

In order to gain insight into the planning for numeracy in undergraduate programmes, an interpretive paradigm and qualitative methodology were used. The interpretive paradigm, which is premised on a sociocultural interpretation of reality, allows the subjective reasons and conceptions that lie behind social action to be examined without prescribing set ways of unpacking the reality (Elshafie, 2013).

4.4.1 Qualitative approach

Qualitative research is most common in studies within the interpretive paradigm that aim to explore a particular phenomenon within its social, political and historical context (Creswell, 2003). Leavy (2017) states that qualitative approaches allow for the generation of a "robust" understanding of a topic and unpacking the meanings people ascribe "to activities, situations, circumstances, people, and objects" (p. 124). Within qualitative approaches to research there is a valuing of "depth of meaning and people's subjective experiences and their meaning-making processes" (Leavy, 2017, p. 124). The multiple layers of meaning are aligned to the realist perspective and allow for an understanding of the generative mechanisms which result in planning for numeracy in the study.

The field of recontextualisation described in the previous chapter is the site of curriculum planning and design selected for this study. This is not a neutral space. Curricular planning and design is a social activity. Qualitative approaches are suited to researching social phenomena that are subjective in nature to explore meaning making. Data was generated in this study through semi-structured interviews and selection of documents, which is aligned to a qualitative methodology.

Hlatshwayo (2018) identifies “participant perspectives, naturalistic research settings, the human research instruments, multiple data sources, rich descriptions, interpretations, as well as a researcher’s reflexivity” (p. 55) as being important aspects of qualitative approaches. Adopting a qualitative methodology facilitated attention to these aspects in this study as follows:

- **Participant perspectives:** The primary source of data for this study was the perspectives of participants regarding numeracy and curricular decisions. These perspectives were explored thematically and by using the multiple tools provided by LCT to enable deeper meaning making. Understanding these perspectives was central to making sense of numeracy planning in this case study.
- **Naturalistic settings:** The study was undertaken at the institution of practice. Participants’ decisions and actions within this context provided opportunities to understand the multiple forces influencing their perspectives and choices within this context. All participants who provided data for this study were fully aware of the institutional context and its curriculum imperatives. Their description of the process occurred in their usual academic environment; this allowed them access to their materials if they wished to refer to these or provide examples.
- **Human research instrument:** As the researcher, I was the primary research instrument. By conducting the interviews, editing transcriptions and analysing the data, I was able to gain deep insights as I was intimately involved with the data generation and analysis process. I was therefore able to explore contextual influences and personal experiences and understandings of numeracy in higher education. As the person doing the interviews, transcription and analysis, I was able to bring to the interviews issues that were being raised for which I was seeking clarity. In other instances, my analysis of documents prior to interviews allowed me the opportunity

to gain clarity on my interpretations of those documents during the subsequent interview.

- **Multiple data sources:** Using multiple data sources contributed to the richness of the study. The data was generated through interviews and the review of documents. The interviews were conducted with a range of stakeholders who were involved with, or influenced, the curriculum development process. The documents that were reviewed were diverse and ranged from the strategy documents of the university to module-specific documents, where necessary.
- **Research reflexivity:** Being aware of, and acknowledging, my positionality allowed for constant reflexivity which helped to reduce the risk of skewing the results to suit my subjectivity. In Section 4.8, I discuss my positionality within the research design as an insider to the institution and how this impacted the choices made in the design of the study.

4.4.2 Case study

Yazan (2015) claims that case study research is a common approach within qualitative studies. Yin, Stake and Merriam are often identified as advocates of case study research. Yazan (2015) notes that there are, however, differences between the perspectives of these three scholars in terms of their definitions and conceptualisations of case studies. I explored each scholar's perspective on case study methodology to consider its suitability as an approach for this study.

Yin (2014) defines a case study as an "empirical inquiry that investigates a contemporary phenomenon" (p. 16). Yin (2002) notes that a case study is undertaken within a real-life context in which the researcher is seen to have minimal influence. To summarise Yin's perspective, case study research is best suited to studies where:

- 'how' or 'why' questions are posed
- the researcher has very little, or no, control over events
- the focus of the study is on a contemporary phenomenon within a real-life context.

This study is aligned to all three features. First, the research questions relate to 'how' numeracy was embedded in undergraduate programmes and 'why' this was done in those particular ways. Second, although I had a certain level of insider status in terms of, for example, serving on the General Education Task Team, my work on the design of particular programmes was very limited. In terms of numeracy planning I had absolutely no input and therefore very little control. Finally, the development of numeracy in higher education is a complicated but important phenomenon that warrants investigating and this study focuses on a real-life instance of curriculum planning.

Mirriam (1998) defines a case as "a thing, a single entity, a unit around which there are boundaries" (p. 27). This is similar to Stake's understanding of a case (cited in Yazan, 2015) as a complex integrated system which has a boundary. Gerring (2004, as cited in Baskarada, 2014) considers case study research to be well-suited to "extensive and in-depth descriptions of complex social phenomena (p. 4). This study focuses on understanding a complex phenomenon in depth and is situated in a real-life context that is specific and limited to a single object of study with set boundaries: curriculum change at a single institution. It thus constitutes a qualitative case study.

Stake (1995), Yin (2002) and Mirriam (1998) agree that it is important to generate data from multiple sources when conducting a case study to enable its complexities to be explored. When a qualitative approach is used, data is usually generated through interviews, observation and/or document analysis. The analysis of the data that is generated involves a process of making meaning of the data.

In the next section, I provide an overview of the sample selection used in this study.

4.5 Selecting a sample

This study involved selecting an institution as a case, then selecting key documents, programmes and individuals which could provide the required data.

4.5.1 Selecting a case

The case selected for this study was a single university of technology (UoT) in South Africa: The Durban University of Technology (DUT). The 'university of technology' is a relatively recent institutional designation and is applied to the institutions which were previously termed 'technikons'. As an UoT, the institution in this study continued to offer vocational diplomas.

In 2011, the institution initiated a Curriculum Renewal Project (CRP). Under the leadership of the relatively new vice chancellor, the CRP expected a significant revision of the institution's conceptualization of programme offerings. All programmes at the institution were mandated to include general education as 30% of the programme content for all undergraduate qualifications. Although this project was initiated in 2011, at the time of submission of this thesis there are still a few programmes that have not yet been approved.

The institution offered over 70 undergraduate programmes across 6 faculties. These included professional degrees and 2-year and 3-year diplomas. Higher certificates were also offered, but these programmes were not subjected to the same general education imperatives as were the degrees and diplomas. In 2019, the institution registered more than 35 000 students across all programmes, including post graduate qualifications. The majority of students were registered for undergraduate programmes.

In terms of the sociocultural and political context of the institution, it is important to note that over 85% of students identified as African at registration. Highlighting this is significant in a country such as South Africa where the race of an individual had major influence on their access to educational provision during apartheid. Background information on the institution as well as information gathered during registration suggest that the majority of the student population had experienced lower socioeconomic status and a poor level of basic education due to the legacy of apartheid.

On average, the institution registered around 6 000 new students each year. Their performance on national and institutional numeracy tests had indicated that their prior numeracy practices had not adequately equipped them to deal with the numeracy demands of higher education (NBTPT, 2015; Access Project Team, 2011; 2012; 2014).

Prior to the CRP, the institution addressed numeracy development through bridging programmes and extended curriculum programmes. In certain qualifications, courses such 'quantitative techniques' were included in the programmes and taught by lecturers specialized in mathematics and statistics.

Numeracy was prioritized as one of the key imperatives of the CRP. My selection of this case was based on my interest in the development of numeracy as an initiative in higher education and the opportunity that was presented by the institution's participation in the Curriculum Renewal Project, making its numeracy agenda visible. The CRP provided a platform to explore the institution's planning for numeracy development, as this was a priority identified in the CRP. The imperative was that the development of mathematics or quantitative reasoning/numeracy would be compulsory across all programmes so as to develop students' numeracy to the level identified as necessary for programme graduates. 'Being numerate' was listed as one of the graduate attributes of the CRP in the guidelines document for the inclusion of general education.

For this case study, the planning for numeracy which was undertaken as part of the CRP was investigated across a sample of seven programmes.

4.5.2 Selecting data sources

The key research question in this study was "how is numeracy developed in undergraduate programmes?" An important data source was thus the particular programmes where numeracy was developed to engage with programme curriculum documents and the curriculum developers (individuals or teams). It was also necessary to go beyond the programme level to engage with key documents and interview academics who were involved intimately with the curriculum renewal process.

I used purposive and convenience sampling to select programmes and participants for the study. Purposive sampling enabled me to recruit particular programmes and participants that could provide deep insights into the process of planning for numeracy at the institution and in discipline specific programmes by sharing their experience with making curricular choices and their perspectives on numeracy in higher education. My 'insider' status gave me an advantage as I could easily identify participants and access the programmes that had completed the process.

4.5.2.1 *Selecting documents*

After receiving gatekeeper permission from the institution, I was able to access documents such as the guidelines approved by the Senate and the value rubrics needed for the study from the institutional website and particular task teams. After selecting programmes based on the criteria described above, programme documents were obtained from heads of department or curriculum developers. Each programme had a curriculum map that included a list of all modules in the programme with the year of study, the number of credits and indicating whether it aimed to introduce, reinforce and/or assess writing, quantitative reasoning and/or knowledge of the local KwaZulu-Natal context. (See Annexure G for an example of a curriculum map). I reviewed the programme documents in preparation for interviews with programme staff involved with the programme design. Using the curriculum map, I attempted to identify modules that indicated development or assessment of numeracy and then used these module documents, together with other programme documents, to identify where numeracy or quantitative reasoning were included explicitly in the module outcomes or where it was implied in the graduate attributes and in the module content.

Documents that were used in addition to programme documents were institutional documents. These included the strategic plan, general education senate guidelines, workshop material, value rubrics and documents related to numeracy specific modules.

4.5.2.2 *Selecting programmes*

In respect to the selection of programmes for the study, the criteria I used for purposive sampling was to select programmes that had not included formal study of mathematics or statistics previously. I understand mathematics and numeracy to be distinct areas, and while I believe that including programmes with a strong mathematics background may have yielded valuable insights about the relationship between mathematics and numeracy and revealed commonly held misconceptions, I felt that the research questions could be more clearly engaged in programmes that did not have a strong mathematics influence. Therefore, all programmes that included the study of mathematics were excluded from the study. This excluded two of the six faculties from the possible sample – Engineering and the Built Environment (FEBE) and Accounting and Informatics (FAI) – leaving the faculties of Arts and Design, Management Sciences, Applied Science and Health for consideration. Since the focus of this study was on new programmes, those programmes which had not yet completed the CRP were also excluded from consideration for the sample. Programmes offering higher certificates and post-graduate qualifications were also excluded as the CRP and its associated imperatives in respect of numeracy were limited to undergraduate diplomas and degrees.

I contacted the heads of department or programme curriculum teams across the four faculties. A few indicated they had not completed the CRP and therefore did not qualify to participate in the study. All the programmes that had completed the CRP and responded positively were included in the study. Some of these offered degrees and others diplomas. The programmes were based in four different faculties, representing a range of disciplinary fields. In addition, some used a module-based approach to developing numeracy while others used approaches which embedded numeracy in other modules.

I assigned each programme an identifier to preserve its anonymity. The breakdown of programmes chosen from each faculty is shown in Table 4-1

Table 4-1 Number of programmes selected for the study per faculty

Faculty	Number of programmes	Identifier
Arts and Design	1	PG1
Applied Science	2	PG2 and PG3
Health	2	PG4 and PG5
Management Sciences	2	PG6 and PG7

All seven programmes in the study met the requirement of not having included mathematics or statistics in the programme previously. Although two of the programmes were from the Applied Science faculty, these programmes were not based on traditional mathematics. Purposive sampling is subjective in nature; however, I was confident that the variety of programmes selected was broad enough to provide a rich understanding of the phenomenon.

Below I present a brief description of the each of the programmes to provide an overview of the sample and the context of each programme. Each programme at a university is aligned to levels on the Higher Education Qualification Sub-Framework (HEQSF) and the modules within the programme are aligned to levels on the National Qualification Framework (NQF). Further information as it relates to numeracy development is presented in Chapter 5.

Faculty 1: Programme 1

This is a diploma programme with a total of 360 credits pitched at Level 6 on the Higher Education Qualification Sub-Framework (HEQSF); 128 credits were offered at National Qualification Framework (NQF) Level 5 and 232 at NQF Level 6. General education modules were placed throughout the curriculum, some of which were prescribed and others which were offered as electives. There were no institutional or faculty numeracy-specific general education modules included in the programme.

While there had been a recommendation to this department that the new programmes include Mathematical Literacy in the entrance criteria for the programme if the applicant has not taken Mathematics as a school subject, this recommendation had not yet been implemented and there were no mathematics-related entrance criteria to this programme.

Acceptance into the programme was based on an applicant's Grade 12 results in conjunction with institutional entrance tests and interviews. The entrance tests included a numeracy test. The Grade 12 results and the entrance test scores in academic literacy and numeracy were combined and students were ranked based on the combined scores. There was no indication of a prescribed pass mark.

Faculty 1: Programme 2

This was an HEQSF Level 6 diploma programme comprising 376 credits, 168 of which were offered at NQF Level 5 and 208 at NQF Level 6. General Education institutional modules were placed throughout the curriculum. The entrance requirement to the programme did not include minimum criteria for Grade 12 Mathematics or Mathematical Literacy, but the entrance test included a section on numeracy described as 'basic mathematics skills'.

Faculty 2: Programme 1

This was a four-year degree programme with a total of 480 credits. General Education modules were spaced over the duration of the programme. The entrance criteria for the programme did not include minimum criteria for Mathematics or Mathematical Literacy. The institutional entrance test was used previously by the department, but not planned to be used for selection into the new programme in the future.

Faculty 3: Programme 1

This was a degree programme with a total 520 credits: 64 credits were offered at NQF Level 5; 128 credits at NQF Level 6; 208 credits at NQF Level 7; and 120 credits at NQF Level 8. This was one of the first programmes to have designed a new programme in response to the Curriculum Renewal Project. At the time of data collection, the programme was already being offered. The General Education requirement was addressed using both institutional and faculty-level modules across the programme, which contributed to the high credit value.

The entrance requirements for the programme included Mathematics with a minimum score of 50%; Mathematical Literacy was not accepted as an alternative. The programme also used two entrance tests, one of which was a numeracy test.

Faculty 3: Programme 2

This was a diploma programme pitched at HEQSF Level 6. The programme was designed in consultation with a national consortium across the different universities of technology (UoTs). To a large degree there was an 'agreed' curriculum with particular specialisation at certain UoTs. The General Education credits were thus additional to the programme credits resulting in a much higher credit value than is common for diploma programmes. The programme comprised a total of 408 credits made up of 148 credits at NQF Level 5, 244 credits at NQF Level 6 and 16 credits at NQF Level 7. General Education modules were placed across the programme.

The department also included an extended curriculum alternative to the completion of the programme. This involved extending the programme over an additional year and providing developmental support within that alternative offering of the programme.

Previously, the programme had not required Mathematics or Mathematical Literacy as entrance criteria, however it had been noted that some students found the numeracy requirements of the courses too challenging. In the Curriculum Renewal Project, the entrance requirements had therefore been revised to include Mathematics with a minimum score of 40% or Mathematical Literacy with minimum score of 60%.

Faculty 4 programmes

This was one of the first faculties to begin with the Curriculum Renewal Project and address the General Education imperatives from a faculty perspective. The curriculum had been designed so that seven of the programmes shared the first year which is dedicated to General Education courses, some of which are institutional and others of which are faculty-based.
Two of the programmes from the faculty were included in this study. Both are HEQSF Level 6 diploma programmes comprising 360 credits.

Faculty 4: Programme 1

The programme had a Work Integrated Learning component. Previously, the programme prerequisites included Accounting. With the revision of the programme, it was decided that a minimum Mathematics mark of 40% or a Mathematical Literacy mark of 50% was adequate.

In addition, the programme used a point system that was based on the sum of the levels of the applicant's Grade 12 passes. The minimum score required was 25 points.

Faculty 4: Programme 2

The new entrance requirements for this programme included either Mathematics or Mathematical Literacy. It was mentioned, however, that programme had been successful before this criterion was introduced. The exit level outcomes of this programme included 'being numerate' as a graduate attribute.

After selecting the programmes I wanted to include in the study, I followed the institutional protocols to seek permission from the relevant deans and heads of department. In some instances, it was adequate to write an email describing the research, its anticipated benefits and detailing the research plan. In other instances, I began with initial face-to-face conversations to clarify the research and the level of commitment I was requesting. Often these conversations involved a discussion of the nature of numeracy and how it related to the programme. The data obtained from these discussions was later analysed and included in the results of the study.

4.5.2.3 *Selecting participants to interview*

Participants were selected for interviews based on their role in planning for numeracy in the Curriculum Renewal Project. Therefore, curriculum developers from all seven programmes selected were interviewed as individuals or as a group who worked on a particular programme. I purposively selected the developers of two institutional modules on numeracy and staff from the mathematics department (due to the perceived relationship between numeracy and mathematics).

Some academics were included who were not involved with a particular programme but were able to offer insights into the conceptions of numeracy in higher education, the ways in which numeracy development could be planned and the tensions that influenced the outcomes of numeracy planning processes. These included academics who provided strategic direction to the institution, including the former Vice Chancellor, the Deputy Vice Chancellor for Teaching and Learning, and the leader of the General Education Task Team.

The participants selected for individual or focus group interviews were as follows:

- Three academic managers/leaders identified as (AM1, AM2, AM3)
- Two General Education institutional or faculty numeracy module developers (MD1, MD2)
- Curriculum developers or curriculum development teams of the 7 programmes across 4 faculties (described below)
- 2 key informants (KI1, KI2)

4.6 Collecting the data

Bowen (2009) states that “by examining information collected through different methods, the researcher can corroborate findings across data sets and reduce the impact of potential biases that can exist in a single study” (p. 29). In this study, data was generated through critical analysis of documents and semi-structured interviews with individual participants and with focus groups. Both document analysis and semi-structured interviews are commonly used in qualitative research design and each of these data collection methods has advantages and disadvantages. For example, because semi-structured interviews involve the researcher as a participant in a discussion, they carry the risk that the researcher’s perspective will become less objective. By using these approaches together, however, the advantages of each could be gained while reducing the risks associated with a particular approach. For example, document analysis enabled me to identify the approaches a programme had taken to numeracy development but it could not tell me *why* the programme had taken those particular approaches. Semi-structured interviews and focus groups, on the other hand, allowed participants to share their perspectives and experiences enabling me, as the researcher, to explore the meaning participants made of their experiences (Siedman, 2012). Rubin and Rubin (2005) note that through this process it is possible to unravel the complexities of the participants’ experience; in this study, it enabled me to gain insight into the factors that influenced curricular choices.

4.6.1 Document analysis

According to Stake (1995), document analysis is well suited to qualitative case study research. Mirriam (1998) states that documents in research can assist to “uncover meaning, develop understanding, and discover insights relevant to the research problem” (p. 118). Bowen (2009) describes five possible purposes documents can serve in a study. These include providing data on “background and context, additional questions to be asked, supplementary data, a means of tracking change and development, and verification of findings from other data sources” (p. 30).

In this study, documents served the purpose of providing context as I prepared for the interviews with participants. As an additional source of data, they also allowed for some degree of data verification. The use of documents made it possible to track changes between old and new programmes.

The documents that were selected included programme documents such as curriculum overviews for each of the seven programmes in the study, institutional documents such as senate guidelines on General Education, module descriptors and the content material of numeracy-specific modules.

Institutional documents were reviewed to provide insight into the institution’s conception of numeracy and to explore the value placed on numeracy development at the institution in its curriculum planning. They also provided information on contextual factors which may have impacted on decisions.

The documents of each of the seven programmes selected for the study included curriculum maps and programme overviews in order to get an overview of the approaches taken to the development of numeracy (quantitative reasoning). These were also useful in preparing for interviews with curriculum developers, to gain clarity on interpretations of the approaches suggested in the documents and to engage in conversations about what led to particular choices that resulted in the new programme as evident in the programme documents.

4.6.2 Semi-structured interviews

Laforest (2009) describes semi-structured interviews as two-way conversations with a set of guiding points or questions. Semi-structured interviews are useful for gaining a more comprehensive understanding of the data collected from documents. According to Bryman (2008), semi-structured interviews are well-suited to studies where the researcher has a broad overview of the topic, but is interested in understanding the phenomenon from the perspective of the participants. Structuring an interview runs the risk of limiting the depth and richness of the participant's responses, while semi-structured interviews allow participants more freedom to answer in their own way, which can provide a more nuanced understanding of the phenomenon. The semi-structured approach to interviews used in this study was congruent with the social realist orientation of the research, where the focus was on understanding generative mechanisms or underlying principles that generated particular practices. Although a list of guiding questions was used as a source, or reference, during interviews, the openness of participants' responses often led to deeper probing in different areas in different interviews. Participants sometimes gave very lengthy answers to questions; I did not attempt to limit this as in some cases they found it easier to articulate their idea with an anecdote or example. As I reflected on the interviews after conducting them, I often made revisions to the guiding questions for subsequent interviews.

In this study, semi-structured interviews were conducted with all three academic managers, the two module developers and curriculum developers in four of the programmes. See Annexure K for a list of guiding questions that was used as a reference for these interviews.

Interviews were scheduled with heads of department or curriculum developers and focus group interviews were conducted with curriculum teams. In most instances, I was able to collect enough data during one interview with each participant or group. In two instances, the participant indicated during the interview that they would like me to review the documents they had brought and continue the interview at another time after I had reviewed them. In some instances, the participants felt that another staff member would be able to add to the engagement and therefore a second interview was scheduled to include new participants. Existing participants were part of the second interview. Having reviewed the documents prior to the interview or, in some instances, having conducted a prior interview, I was familiar with the subjects that participants mentioned and therefore able to delve deeper or clarify my understandings of the programme documents as they related to numeracy, where necessary.

I arranged interviews with the Vice Chancellor who had left the institution a few years after the Curriculum Renewal Project was initiated, Deputy Vice Chancellor and leader of the General Education Task Team, who were both at the institution at the time of the interview but have subsequently retired, by contacting them by email and indicating how I felt their input would contribute to the study. All managers were interested in the study because of the need to develop numeracy in higher education. I did the same with the numeracy or quantitative reasoning module developers, although I only received the documents related to their modules after the interviews.

4.6.3 Focus group interviews

Focus group interviews are considered useful when the data to be generated is common to the group or when the group has impacted on the phenomenon (Gill, Stewart, Treasure, & Chadwick, 2008). In this institution, curriculum committees were responsible for curriculum design in some instances and, in these cases, it was useful to collect data on their perspective as a group.

Curriculum development teams from three of the programmes, as well as a group of staff from the mathematics department, were interviewed as groups. The head of the mathematics department presented my research study to the staff and invited them to participate in a focus group. Seven staff members from the department accepted the invitation and participated in the focus group interview. With respect to the group interviews with programme teams, all interested participants who had input in curriculum planning for the programme participated in the interviews.

The focus groups were also semi-structured. I used guiding questions that were designed to prompt discussion if needed to ensure that data generated responded the research questions. The questions below therefore were used to gain insights on how numeracy was planned and how the conceptions of numeracy and external contextual factors influenced the planning for numeracy:

- How would you define numeracy?
- What is the importance of numeracy?
- What is the role of numeracy within the programme?
- What are the possible consequences of being not appropriately numerate?
- How does it relate to the graduate attributes of your programme?
- Provide examples of numeracy in life; provide examples from the disciplines
- In a “perfect world” would you include numeracy in higher education programmes? Why? What would that look like?
- How did you integrate numeracy into the programme? What “drove” that decision?
- What concepts were included? Why?
- What are your perceptions of students’ numeracy practices? To what degree did these impact on what was included in the programme?

4.6.4 Preparing interviews for analysis

All interviews were recorded as audio files on my cell phone after obtaining permission from participants to record. The files were then transferred to my laptop. At the end of each interview, I wrote a short reflection on the interview, highlighting what I thought was significant or noting where I felt further information would be valuable.

All of the interviews were then transcribed verbatim. I transcribed the first three interviews myself. Thereafter, I used an online tool that uses speech recognition software to convert voice to text to generate transcriptions of some of the interviews. I then listened to the interviews and corrected the transcriptions. A professional transcriber transcribed the remaining interviews; with these too I made corrections while listening to the audio recordings. Although authors such as Giloi (2015) recommend that researchers transcribe the data themselves, I feel that working through the transcriptions painstakingly while listening to the audio recordings in order to make corrections allowed me to become intimately acquainted with the data. Focus group participants were given identifiers in the focus group transcriptions. Gestures and pauses were not captured in the transcriptions, but I made notes of these separately for reflection.

4.7 Analysing the data

Qualitative research typically generates large quantities of data. The data collected in this study comprised over 300 pages of interview data and approximately 800 pages of documents.

The process of organising the data and generating meaningful themes is an important, but time consuming, part of any qualitative study. I spent a substantial amount of time immersing myself in the data to ensure that I had an intimate understanding of it. As with other aspects of the research process, data analysis involves considering which method would be most effective. To ensure that I made an informed choice, I considered a number of data analysis options, as shown in
Table 4-2.

Table 4-2 Approaches to data analysis

Approach to data analysis	Key characteristics
Constant comparative analysis	Glaser and Laudel (2019) explain that constant comparative analysis strategy is based on focussing on one piece of data (one interview, one statement, one theme) and drawing comparisons with other data that may be similar or different in order to develop conceptualizations of the possible relationships between various pieces of data.
Narrative analysis	This approach involves the formal analysis of text and stories. The story analysis involves the 'unpacking' of the structure of the story by using interviews, documents or observations to follow participants down their trails. This style recognises the extent to which the stories people tell provide insights about their lived experiences.
Content analysis	This approach involves the subjective interpretation of the content of text data through a systematic classification process of coding and identifying themes or patterns and may include the quantification of qualitative data.
Thematic analysis	Thematic analysis is a method of identifying, analysing and reporting patterns (themes) within data. These patterns are identified through a rigorous process of data familiarisation, data coding, theme development and revision.

The first three approaches did not suit the study. The intention of the study was to gain a comprehensive understanding of planning of numeracy in undergraduate programmes so the main focus was not on comparing approaches, although aspects of this is inherent when analysing data. Narrative analysis is particular to research that is designed as narrative inquiry and therefore the analysis approach did not suit this study. I chose to use thematic analysis as a basis for organising and describing the data set in rich detail. This approach provided a framework for interpretation so that both implicit and explicit ideas within the data could be articulated and discussed in the context of practices and the relevant theoretical positions. Analysis of the data followed a multi-step process that included familiarisation with the data, coding of the data, generation of themes, a review of the themes and presentation of the findings (Assarroudi, Nabavi, Armat, Ebadi & Vaismoradi, 2018).

Document analysis

The document analysis involved "finding, selecting, appraising (making sense of) and synthesising data" (Bowen, 2009, p. 28) that can be categorised, coded and organised into themes. I used the following questions to guide my analysis of documents:

- What is being described as numeracy?
- What is numeracy as it relates to higher education?
- What is the purpose of numeracy at DUT?
- What are the legitimate knowledges; what disciplines or fields do they draw on?
- Where in the programme structure is there an emphasis on introducing, developing or assessing numeracy?
- How is numeracy structured across the programme?
- Is there a skills or generic orientation?
- How 'strongly bound' is the concept of numeracy at DUT?
- Who are the 'knowers' – the numerate?
- What are the links between the context and the concepts and how strong are they?
- What depth or levels of abstractness is evident in the numeracy concepts?
- What are the contextual considerations influencing the understandings and implementation of numeracy in the curriculum?

For example, where I analysed the value rubric, I could extract definitions of numeracy and from senate guidelines, descriptions of numerate graduates. In module descriptors, facilitator's guides and study guides of institutional numeracy modules I could extract concepts used and their applications. In this sense the selected texts, such as the definitions of numeracy or numerate graduate formed a unit of analysis that spoke to conceptions of numeracy. Each unit was not limited to one code but rather could, in certain instances generate more than one code.

The programme curriculum documents were used in identifying approaches adopted in planning for numeracy and the drivers for those decisions and for supplementing/informing the interview data. For example, the curriculum map of each programme was examined to identify if there were numeracy specific modules, Module descriptors provided information on what concepts were include in numeracy development.

4.7.1 'Listening' to the data

I followed an approach similar to that described by Erlingsson and Brysiewicz (2017) in order to transform a large volume of text into a concise summary of key results through a process of abstraction.

To familiarise myself with the data, I read each of the transcriptions several times and began to identify where I thought key or common issues were emerging. I then clustered the interviews by type of participant: programme curriculum developers, academic managers, numeracy specific module developer or key informant. I captured common, general issues that were seen across the interviews on large sheets of paper.

To identify themes, I initially went through the data line by line. I later found that a few lines (3 or 4) worked better as a unit for coding. I inserted a phrase or word in the comments in the Word document, highlighting the text that the code referred to. However, as I worked through the transcriptions, I again encountered the lengthy explanations and anecdotes some participants had provided in their attempt to make a point. Some of this data did not really relate to numeracy planning or even broad curriculum planning. As highlighted in the data collection section above, participants were allowed to answer questions in as much detail, they found necessary to help them articulate their response. Answers to a question such as "What do you think numeracy is?" for example, yielded very different explanations as the interviews progressed. Some of the data was very interesting but was beyond the scope of this study. I did, however, continue to condense the text so as to not miss out on useful revelations from the data. To ensure that my insider status was not blinding me to important data, this process was reviewed by both my supervisor and mentor. After I was confident that I was not missing important data, I selectively extracted bits of the data that related to the questions of this study and created new documents that related to each critical question with data carefully referenced to its source. These documents included the initial codes; these were reviewed and recoded where necessary. In the re-coding of the condensed texts, each extract copied from the different interviews was coded with multiple codes for example if an example of numeracy was presented to describe what it is, coding included a list of the different domains this example legitimated as being relevant to the conceptions of numeracy. As an interpretative study with a purpose of expanding understanding of the phenomenon, greater attention was paid to capturing the multiple positions on the conceptions of numeracy and the forces impacting on why it was planned for in the curriculum in particular ways rather than on providing frequency of ideas. There were instances however where "counting" was used for example in the approaches adopted to planning for numeracy, it was possible to count how many programmes adopted a particular approach. Further abstraction through clustering of codes generated categories and then themes from categories.

The themes were then grouped under three overarching focus areas that corresponded to the objectives of the study: practices of planning for numeracy, conceptions of numeracy and external contextual and situational factors. This inductive approach was expanded on through a deductive analysis using the 'toolkit' developed from Maton's Legitimation Code Theory (LCT), discussed in Chapter 3. Although the LCT toolkit is useful for engaging with the data in this study it cannot and should not be used as a "cookie cutter" (Maton & Chen, 2016, p. 28) that is just placed over the data. It was necessary to 'allow the data to speak'. However, I found that while engaging in the deductive approach I tended to try to relate the data to theoretical concepts too early – a problem which Chen (Maton & Chen, 2016) described experiencing in her research experience. My supervisor and other mentors encouraged me to stay with the data, describing it only and avoiding theorising at that stage. It required numerous drafts to do this. To deal with the links to theory which I observed as I worked with the data, I kept separate notes of these ideas and insights.

Researchers who use (LCT) as an explanatory framework (see, for example, Maton & Chen, 2016) and other qualitative researchers recommend that the researcher engages with the data first, before engaging with the LCT framework, in order to allow for the possibility that unexpected insights might arise. As the LCT framework both guides and is informed by research, it provides a link between theory and empirical studies. By allowing findings to emerge from the data before applying the framework, it may be possible to refine how the LCT concepts will be applied to the data, or even refine the concepts themselves.

The LCT dimensions are generic and need to be adapted to the research. Moss (2001, as cited in Maton & Chen, 2016) highlights the need to remain immersed in the data and be comfortable with the lack of order in the data. This, they claim, is a necessary stage in order to be able to design a theoretical apparatus that is useful to the specificity of the study. On the other hand, they caution that remaining at this stage for too long can limit engagement with the research to the level of the specific context of the study, making it impossible to explore the generative mechanisms that give rise to the objects or practices being studied.

In the next section, I discuss the deductive analysis using the different dimensions of LCT to address the objectives of the study and respond to the critical questions.

4.7.2 Using theory in analysis

As presented in Chapter 3, LCT provides a multi-dimensional toolkit which can be used to surface the underlying organising principles of a phenomenon. In this study, the LCT toolkit was used to understand the underlying principles that resulted in particular plans for numeracy. In this section, I discuss how I used each of the LCT tools to generate insights about different features of the phenomenon.

The five dimensions of the LCT toolkit – Autonomy, Specialization, Semantics, Density and Temporality – were used to address the objectives of the study. *Autonomy* enabled insights into the practices of planning for numeracy, *Specialization* and *Semantics* provided insights into the underlying principles legitimating what is considered to be numeracy, and *Density* and *Temporality* provided insights in respect of how the field of numeracy and its influence on the preparedness of various agents impacted on negotiating the external contextual factors when making decisions. As discussed in Chapter 3, each of the LCT dimensions includes two concepts: for example, *Specialization* includes the concepts of *epistemic relations* (ER) and *social relations* (SR). Placing the two concepts on a Cartesian plane generates four different codes. In the case of Specialization, these are knowledge code, knower code, elite code and relativist code. Each of the LCT dimensions is structured in this way: two concepts can be used to create four codes. Data is coded using these codes depending on the strength and/or weakness of the concepts within the dimensions. Codes use abstract concepts so that they can be used to analyse a wide range of phenomena. A detailed explanation of this was provided in Chapter 3.

In order to define the form taken by the code concepts in specific objects of study, translation devices are generated to connect the data to the theory and the theory to the data. Translation devices can be generic if they relate code concepts to very broad phenomenon, as was the case in research conducted by Maton and Doran (2017a, 2017b). Usually, however, specific translation devices are created to connect the form of the code concept to the specific empirical study.

The process of generating specific translation devices for each of the dimensions and for each of the codes within these dimensions is a complex, iterative and time-consuming process. I adopted an approach similar to that described by Maton and Chen (2016). This started with the thematic analysis described above which provided basic categories by which the data could be organised – for example, around practices of planning for numeracy or conceptions of numeracy with respect to the different stakeholders. From this point, I moved on to organisational coding of the data that generated particular approaches to developing numeracy – for example, the module based-approach, embedded approach or integrated approach – or identified certain features of numeracy that I could see related to aspects of the theory but was still very much embedded in the description and categorisation of the data. Lastly, I moved further towards the theory by looking, for example, at the conceptions of numeracy in the data and reviewing this against the Specialization dimension of LCT to analyse the epistemic and social relations of the data. I must state explicitly that this was not a linear process of moving from thematic analysis to organisational analysis to analytical analysis but involved continuously moving between data and theory and ongoing refinement as considerations were brought to light by the data or the theory.

A similar process was undertaken for each of the objectives and the particular LCT dimension that related to the objective. Translation devices were created for each of the five LCT dimensions that included the concepts, descriptions of the concepts and examples from the data. The creation of translation devices was an iterative process and one that required constant refinement.

An example of the translation device that was created to understand the principles of legitimation of conceptions of numeracy using the LCT dimension *Specialization* is shown in Table 4-3.

Table 4-3 Translation device: Specialization analysis of the institution's conceptions of numeracy

Aspect	Concept	Description of concept	How concept can be manifested in the study	Examples from data
Epistemic relation	**ER+**	Knowledge, skills and procedures that are strongly bound and controlled	Emphasis is on specialized knowledge: for example, mathematical concepts and procedures	This requires ratio and proportion background. A percentage increase and decrease where the student has to be able to apply these and perform the calculations. . . . so the mass of an object is kind of proportional to its volume, right? So you know, the bigger the volume of something the bigger the mass – this is assuming that the density doesn't change. Volume: it's length – cubed, right? So if you calculate the volume of a box, it's length times length times length: length cubed, right?
	ER-	Knowledge, skills and procedures that are weakly bound and controlled	The specialised concepts and procedures are underplayed and there is some degree of overlap with other disciplines or contexts	For us it will be like to the ability to reason clinically, so that you can base some judgments on whether you proceed with a certain action on your treatment plan, quantify things – for instance, things like blood pressure, that is similar to things like your glucose level: that is all quantity. Taking all of these qualities in account, now you have to clinically use your physiology and bring it together. So, for me, it can't be separate.
Social relation	**SR+**	The subject as the author is emphasised	Emphasis is placed on dispositions and habits of mind	there is a logical brain, confidence, everything, the men, 10 time better with machinery At what point are you numerate? To me it's more than just "Can you do ABC at this level?" It's more an issue of culture. It will be critical thinking in everyday sort of situation.
	SR-	The subject of the author is downplayed	Dispositions and attributes are downplayed	Follow the correct procedures and perform the four operations.

Different LCT dimensions were used to make explicit different principles of the practices used to plan for numeracy, conceptions of numeracy and external forces and tensions that needed to be negotiated in planning for numeracy. In the interest of maintaining a flow in the reading of the thesis, each translation device is presented before the results of the analysis. I deliberately chose not to present these separate to the findings. For reference the five translation devices are also presented in Annexures A, B, C, D, and E.

4.7.3 Presenting analysis and interpretation of data

As noted by Mattick, Johnston & de la Croix, (2018) and Babbie & Mouton (2010), the presentation of qualitative data may vary from study to study depending on the rationale offered by the researcher. Liamputtong (2011) offers three options for presenting qualitative data: option 1 – report without interpretation; option 2 – report and add some interpretation in order to make connections between the reported data; and option 3 – report, analyse in depth and interpret. Most of the social science PhD theses which I perused appeared to follow option 1 or option 2. This thesis, however, follows option 3. The choice was premised on the logic that this option allows for the presentation, analysis and interpretation of research results to be integrated in the same chapter, preserving the logical and scientific coherence of the data (Babbie & Mouton, 2010).

To ensure total immersion with each distinct area of enquiry and optimal integration of findings and interpretation, the findings of this study have been organised into three themes corresponding to the key research questions and presented in three chapters (Chapters 5, 6 and 7) together with analysis and interpretations of the findings related to that theme. This is followed by Chapter 8, which integrates the analysis and interpretations across the study. This structure is represented in Figure 4-1.

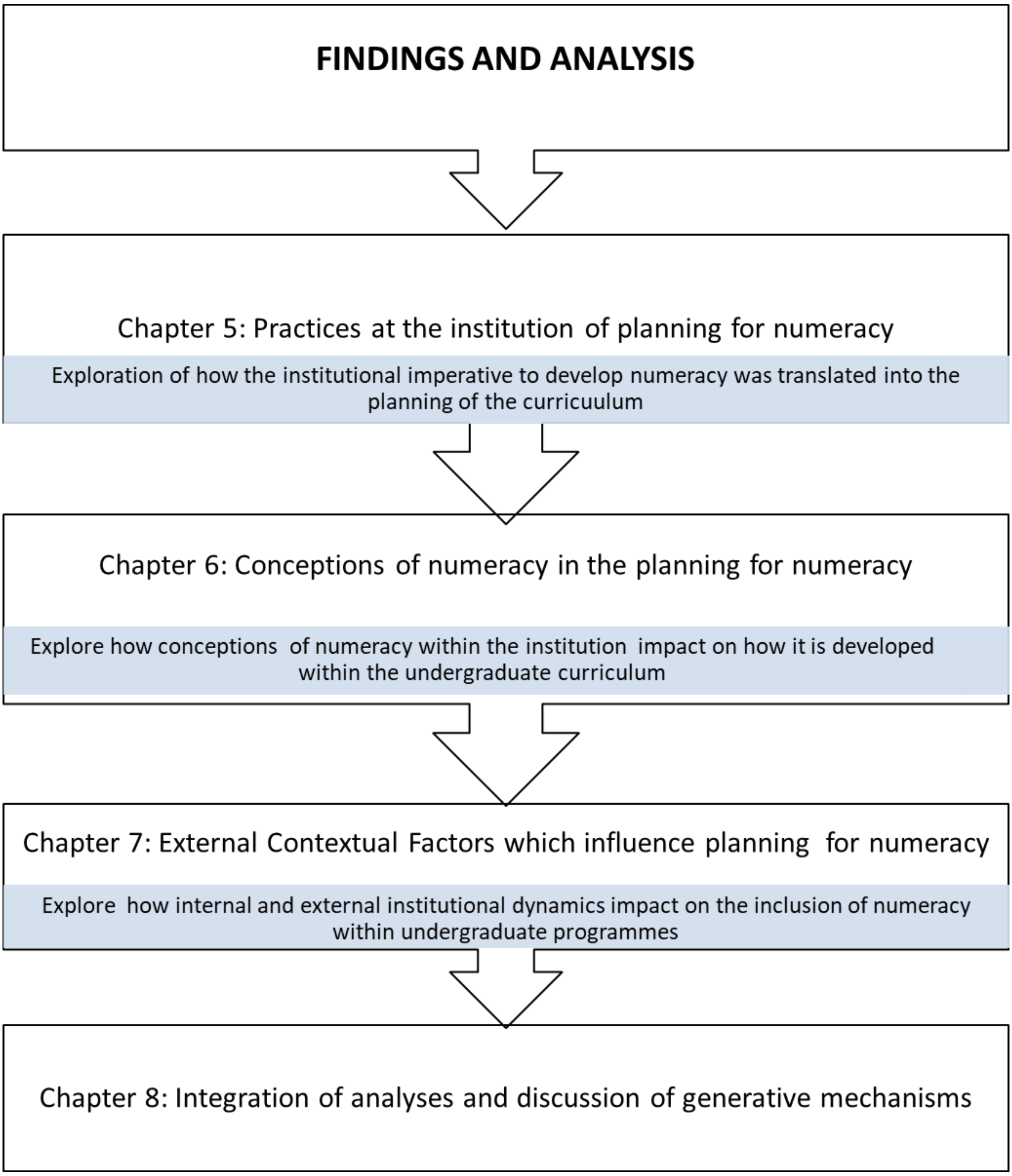


Figure 4-1 Structure of the presentation and analysis of findings in this thesis

4.8 My positionality as the researcher

Holmes (2014, 2020) highlights the importance of paying attention to the inherent positionality of the researcher in order to ensure that ethical research is undertaken. Unluer

(2012) notes that in qualitative research, especially, it is important for the researcher to state their position to demonstrate the credibility of the study.

As this study focused on understanding a particular practice, it was critical that I reflected on my positionality explicitly since, as Denzin (1986) suggests, “interpretive research begins and ends with the biography and the self of the researcher” (p. 12).

Following Hlatshwayo (2018), I explored my positionality from two perspectives. First, as an insider/outsider researcher, since the study was undertaken at the institution at which I work. Second, as an insider/outsider from the perspective of my “intellectual and epistemological positioning” (Hlatshwayo, 2018, p. 62). According to Breen (2007), an insider researcher is someone who chooses to study a group to which they belong while an outsider researcher studies a group to which they have no affiliation. These positions are not necessarily dichotomous, however, especially in qualitative research.

Being an insider researcher brings with it both advantages and disadvantages in terms of the researcher’s proximity to the phenomenon being studied, the research design and its implementation. Saidin (2016) note that as an insider a researcher often has a passion for what they are researching. In my case, I have a special interest in this area because it impacts the educational experiences of students at the institution. Understanding the planning for numeracy more deeply provided me with an opportunity to consider possibilities at the practitioner level as well.

I found that as an insider research I was also privy to the advantages highlighted by Bonner & Tolhurst (2002). First, I was better placed to understand the phenomenon as it related to this case study because of my knowledge of its contextual setting. Second, I was able to conduct the research without disrupting the normal processes of the phenomenon. Finally, I was able to probe for additional information that participants did not provide explicitly due to my familiarity with the participants and the institutional culture.
As an insider researcher I was also aware of the possible threats my position could pose to the research. Unluer (2012) explains that because of the dual responsibilities of their roles in the organisation and as a researcher, insider researchers can face challenges such as failing

to identify blind spots in the data due to familiarity, participants assuming they already know something because of their position or overlooking routine processes.

Merton (1972) states that "[i]n structural terms, we are all, of course, both insiders and outsiders, members of some groups and, sometimes derivatively, not of others; occupants of certain statuses which thereby exclude us from occupying other cognate statuses" (p. 72). This highlights the fluidity of the insider/outsider status of a researcher even within in the same study.

Similarly, I saw my positionality in this study as having both insider and outsider status. Because the research was conducted at the institution where I was employed, I was, to some extent, an insider. On the other hand, my role within the institution was external to the programmes, departments and faculties that were responsible for the development of the curriculum and thus were the subject of the study; in that sense, I was an outsider.

Arbee (2012) highlights that there are different types and "level of insiderness" (p. 64). Mercer (2007) identifies factors such as the background and identity of the researcher, the research topic, the time and location of the study and the power relations between participants and the researcher as factors which influence the level of insiderness of the researcher. I believe that the threat which the insider position of a researcher can pose to the trustworthiness of a research study is reduced if the researcher explicitly acknowledges, and critically reflects on, the aspects of insiderness that apply to their position in the study. To this end, I examine the type and level of my insiderness in this study.

I have worked at the institution which is the subject of this case study for over 25 years. To some extent, then, I am very much a part of the institution's history. In respect of numeracy at the institution, I was previously (around 15 years ago) involved with numeracy initiatives at the institution by supporting numeracy modules for foundational programmes. More recently, I participated in the General Education Task Team that contributed to the Curriculum Renewal Project at the institution in respect of conceptualising and implementing a General Education imperative, of which the inclusion of mathematics or numeracy across all programmes was one component – though not the primary objective.

As the process moved forward, there was concern that there was little indication that mathematics or quantitative reasoning or numeracy aspects were being considered. I was asked to develop a module that could be offered in programmes across the institution, which I did. Whether this was included or not in programmes and, if so, in which ways, was outside my control and knowledge. I was not aware of which programmes included the module or any others. This provides a good example of moving between roles as an insider and an outsider.

In respect of the Curriculum Renewal Project, I coordinated workshops on curriculum design considerations in respect of general principles and guidelines. However, I did not work with any department intimately on the conceptualising and inclusion of numeracy in their programmes. At the time that I selected the sample for this study I was unaware of the approaches adopted by different departments and this did not, thus, influence my selection of the sample.

Besides this, I would describe myself as a proponent for the need to develop numeracy in response to the social justice agenda of higher education. I do not subscribe to the belief that only the privileged – either by virtue of birth right or social privileging – should have access to opportunities to develop or enhance their numeracy practices. In this sense, I was an insider in terms of the agenda to promote numeracy in higher education.

Acknowledging my positionality and its potential influence on this study, I am fairly confident that its influence on the research data and findings has been minimal considering the factors which influence the level of insiderness identified by Arbee (2012):

- The research topic, research questions and objectives. This study was positioned as an exploration to understand generative mechanisms resulting in curricular plans to develop numeracy in undergraduate programmes. The research objectives were not evaluative or comparative in nature, so the influence of subjectivity on any one approach did not hinder the ethical 'answering of the research question' and achieving the objectives.

- The focus of this study was not on whether the imperative to include numeracy in the curriculum was operationalised or not, but rather how and why. This removed the element of 'checking' if an instruction was followed. This encouraged participants to be open and forthcoming with information.
- The research did not impact on accreditation, since the programmes in the study were already approved or had already completed the curriculum redesign process.
- My position in the institution was in an academic development unit where the focus was on development and support and not really on evaluation of practice. My interactions with participants were therefore open.
- As indicated, I was not involved in curriculum planning within the departments for their specific programmes; the choices they made were thus not influenced by my direct involvement.
- In terms of the timing of the study, it was undertaken after all of the programmes that were selected had completed the curriculum planning as part of the Curriculum Renewal Project, which was the subject of the study. Data was thus descriptive and reflective and the research did not threaten completion of the CRP or accreditation of the programmes.

Thus, although I was an insider to the institution and to the agenda to promote scholarly numeracy, these factors had minimal impact on the trustworthiness of the data collection or analysis or the reporting of the findings of this study and did not compromise the ethical standard of the study.

One challenge which arose due to my position at the university, however, was that participants tended to share confidential information about the institution which could not be included in the data as they reflected on the planning of the curriculum for their programmes. They also sought feedback from me, as someone involved in academic development, on the enactment of the curriculum and their observations during data collection. I have addressed this by excluding confidential information and limiting the responses that were selected for analysis to those which addressed the research questions in this study.

4.9 Ethical considerations

Clarence (2014) reports addressing ethical considerations in her doctoral thesis from two perspectives: custom and character. This provides a useful distinction for the discussion of ethical considerations in this thesis, as well.

Custom refers to the ethical requirements to which the institutions conducting the research are subject as well as any requirements imposed by the institutions or context in which the study is being conducted. This study complied with the ethical requirements of the School of Education at the University of KwaZulu-Natal (UKZN), the institution at which the thesis is submitted for examination. Ethical clearance was sought from, and approved by, the UKZN Humanities and Social Sciences Research Ethics Committee.

The Durban University of Technology (DUT), which was the site of this study, was approached for permission to conduct the study and permission was granted. Although gatekeeper permission was granted by the institution, I also requested permission to conduct the research from the deans of the relevant faculties and from the heads of department within these faculties. All of the departments and individuals who participated in the study were given an information letter providing details about the study ahead of the interviews. This gave participants the opportunity to ask me questions about the study. I was able to address their questions and assured participants of their anonymity in the study. Participation in the study was voluntary and participants were informed that they had the option to terminate their involvement. All interviews were conducted in a private space that was deemed mutually convenient to the participants and the researcher. Interviews were recorded using an audio recording device with the permission of the participants.

Clarence (2014) describes the 'character' aspect of ethics in research as concerned with the dispositions, morality and ethical conduct that is required of the *researcher* to ensure the trustworthiness of a study. I agree with Clarence (2014) that the aspect of the researcher's character is a critical ethical consideration. In this study, my positionality within the case may be viewed as posing a potential risk. I have addressed how this was mitigated in Section 4.8 of this chapter.

Rose and Johnson (2020) describe trustworthiness as the "systematic rigor of the research design, the credibility of the researcher, the believability of the findings, and the applicability of the research methods" (p. 3). Trustworthiness is not, then, a single act but needs to be engaged in all stages of the research process. Rose and Johnson (2020) encourage researchers engaging in qualitative research to align their engagement with trustworthiness to the practices aligned to the chosen "paradigmatic, theoretical, methodological, analytical and representational" (p. 1) orientations adopted in the study.

As a researcher, to ensure the risk to trustworthiness is minimal the issue of trustworthiness must be engaged with at all stages of the research. Throughout the research design, analysis and representation in the thesis detailed explanations are provided in respect of what was done, how it is done and the reasons for the choices made, and their relationship to the study objectives or questions made explicit to justify the choices. As an example, details of what methodological tools were used, how they were used, why they were chosen and how they benefitted the study are detailed in sufficient depth to allow for the study to be replicated.
In order to limit the influence of my subjectivity on the credibility of the study, at each stage of the research process I discussed my decisions and implementation strategies with my supervisor, the facilitators of the cohort of students I was registered with and an external mentor and refined or revised my approach with their guidance.

I have thus considered both custom and character aspects of ethics to ensure the trustworthiness of the study.

4.10 Conclusion

This chapter has presented the design of this study, the methodology that was used and my rationale for these choices. As a study located within a social realist orientation, the chapter began with the implications of the ontological perspective of a stratified reality and epistemological assumptions on the choice of methodology and the research design. As part of the research plans, the strategies adopted for conducting the literature review were also presented with a rationale for expanding the search for literature to include related areas. The selection of an interpretative case study research approach and selection of participants – in respect of the programmes selected for the study and other key role players in the Curriculum Renewal Project were discussed. The selection and access of programme curriculum and institutional documents and details of the participants in the study were presented and justified. The inductive (thematic analysis) and deductive (LCT) data analysis processes adopted were presented. The creation of a translation device that connects data to theory and theory to data was described and an example provided to highlight how analysis was undertaken.

Since the research was undertaken at the institution where I was employed, my positionality and the complexities of insider/outsider research were considered. The chapter ended with a discussion of the ethical considerations pertinent to this study. This was discussed from both a regulatory position as well as from my position as the researcher.

In the following three chapters, the results of the study and analysis of the data are presented together, with each chapter addressing one of three key themes. The next chapter (Chapter 5) addresses the first theme: the practices at the institution of planning for the development of students' numeracy and the underlying principles legitimating these practices.

Chapter 5
Practices of planning for numeracy

5.1 Introduction

The previous chapter (Chapter 4) provided an overview of the research design and methodologies used in this study. The strategies used to conduct the literature review, sample selection and collection and analysis of data were presented. Ethical considerations and the issues of trustworthiness, scientific integrity and my positionality in the study were discussed.

As outlined in Chapter 4, the findings and analysis of the study's three main themes, which correspond to the three main research questions, are each presented in three separate chapters. This chapter is the first of these three chapters and presents the findings on the theme of the 'practices of planning for numeracy' engaged in by the institution along with analysis of these findings. Chapter 6 addresses the theme of 'conceptions of numeracy' within the institution and Chapter 7 addresses the theme of the 'external contextual and situational factors' which impact on decisions in the planning for numeracy. In each of these three chapters the data, analysis and interpretation are integrated in respect of a particular research objective.

In this chapter, I explore how numeracy was developed, or was intended to be developed, at the institution as represented by the interviews with leaders, key informants, numeracy module developers and programme curriculum developers. I also present insights gained from a review of the curriculum documents which included curriculum maps, notes from curriculum planning and module descriptors for specific modules.

The chapter begins with an exploration of the institution's motivations for including numeracy (which was also called 'quantitative reasoning' by the institution) as an explicit institutional imperative in the Curriculum Renewal Process. The findings showed that there was consensus among the role players that it was important that undergraduate programmes facilitate the development of students' numeracy practices.

This is followed by a description of the approaches that participants considered effective in the planning for numeracy, the actual plans that were drafted and implemented by the programmes for developing numeracy and the factors that influenced the choices that were made in the planning process. Each of these aspects is presented from the perspective of the different participants involved in the Curriculum Renewal Process.

The chapter concludes with a theoretical analysis using the Autonomy dimension of Maton's Legitimation Code Theory (LCT) to provide insights into the organising principles that were legitimated in the case study in respect of the approaches to numeracy.

5.2 Prioritising the development of numeracy

The explicit imperative for the Curriculum Renewal Process at the institution in this study was motivated by the understanding that the institution needed to provide students with an educational experience that empowered them to meet the demands of a rapidly changing society. This included many key considerations, one of which was the development of numeracy. This priority was mentioned specifically by one of the respondents:

> *My argument was: What's best for our students? And is it enough for us just to do this tight technical training? Because employers are actually telling us that technical training is fine, but they really complaining about the fact that students can't write reports or are not numerate*. (AM1, L 234)

This highlights the concern that students could graduate having had no exposure to mathematics or numeracy which would disadvantage them within the workplace and society. The same participant explained:

> *All I was anxious about was that students shouldn't be leaving the university without some exposure to mathematics. I was quite happy for it to be called 'quantitative reasoning'. No problem with that!* (AM 1, L 311)

Participants highlighted that the needs of employers represented one of the considerations that influenced the decision to include mathematics, numeracy, or quantitative reasoning in all programmes. The 'social justice' imperative was another consideration noted by some staff, who felt that students had been disadvantaged by not having been provided opportunities to develop confidence with mathematical concepts or numeracy practices in their previous educational experiences. One participant explained this as follows:

> *The requirements of mathematics or quantitative reasoning is not simply about saying people need to be numerate, or something. It's a political project. It's about saying our students need to be confident that they can do mathematics*. (AM1, L138)

Other views included the perception that some of the students had not been exposed to particular types of numeracy practices in their prior experiences and thus were heavily dependent on the university to provide that exposure. One respondent explained:

> *I think that some people grew up in circumstances where they just not challenged in that way. . . . I think we have to provide the opportunity for them to engage.* (AM1, L179)

Some participants also expressed the view that if students had not developed adequate numeracy practices by the time they graduated they would be at a disadvantage as they would not be equipped to participate actively in the fourth industrial revolution. This position was expressed by one participant as follows:

> *Let's put it this way. . . . [W]hen we move into this fourth industrial revolution, if are we still producing graduates that are not numerate and we don't have a solution in mathematics and we don't know how to deal with big data and we*

> *don't write, we're in trouble: we're in desperate trouble. . . . And by the way: we're seeing that already. And so from my point of view . . . it's not simply about saying these are things that will be good for students to have, but what will be doubly true, and triply true, is: if you want those people to be effective in the new economy that's coming, my God, they better have these skills. Otherwise . . . we would be in trouble.* (AM 1, L 476)

Another participant offered an added dimension to this concern, noting how poorly-equipped students could have compromised capacity to participate actively in the society of the future:

> *So, you understand what I say about that generation, and the people that are placed there are being groomed by us now. You going to have vice chancellors making decisions that they don't understand!* (KI, L 527)

The inclusion of numeracy development in the programmes was arguably seen as necessary from a graduate attribute perspective. This underscored the acceptance that there was a need for the university to include numeracy (quantitative reasoning) in its undergraduate experiences.

Being numerate was explicitly prioritised as a critical graduate attribute in the strategic meetings and documents of the institution. The commitment to developing numeracy was evident from the inclusion of *"compulsory mathematics or quantitative reasoning"* (Gwele, 2012) across all programmes as one of the imperatives of the Curriculum Renewal Project, *"being numerate* as *an important graduate attribute*" (DUT, 2015) and the inclusion of quantitative reasoning (QR) as one of the three priority areas in the Curriculum Renewal Project. This was made explicit in the new module descriptor template that was required to be completed for every module of a programme. (See Annexure F). To create a further distinction in respect to the level at which numeracy (quantitative reasoning) and the other priority areas were engaged, three categories were introduced by the quality unit at the institution to describe whether the module was i) introducing, ii) reinforcing, and/or iii) assessing the priorities. In agreement with Tinto's (2012) assertion that student success has to be intentionally planned for and often may not occur if it is incidental, it is the contention here that, in similar ways, numeracy practices need to be planned for and may not occur if they are incidental. One of the participants in the research, a programme developer, held a similar position:

> *I think if you want to get a graduate with all those numeracy skills you need to plan for it so the graduate will be able to say, "This is what I am expected to do and I can deliver based on that"*. (PG 7, L 337)

While the importance of 'being numerate' was agreed upon unanimously, programme developers consciously acted upon this outcome in different ways. For example, among different participants the understandings of how numeracy *should* be developed within an undergraduate curriculum was not always consistent with the actual planning that took place for numeracy in the curriculum. These different perspectives are discussed next.

5.3 Espoused approaches to developing numeracy in the programme

In attempting to establish how numeracy could be planned for, descriptive analysis of the interviews were undertaken. For ease of analysis, the feedback was clustered according to the roles participants had at the institution. To this end, the feedback is presented from the perspectives of the managers, key informants and institutional module developers and the programme curriculum development teams or individuals.

5.3.1 Academic managers' views of conceptions on numeracy

There was consensus among managers about the importance of numeracy or quantitative reasoning in undergraduate programmes at the institution. Views included suggestions that every student could benefit from some development since numeracy in higher education included practices that were different to those students may have been exposed to previously. One participant said:

> *First of all, it's not about intelligence. Secondly, it's not about how qualified you are. Thirdly, I don't think people who got a PhD in real analysis – which is like proving that one plus one equals two – proving it – I don't think that they are necessarily numerate: it's a different skill*. (AM 1, L 430)

This viewpoint was further supported within the assertion that students studying mathematics-related degrees needed to be exposed to numeracy practices as well because that competence was not automatically derived from the study of mathematics:

> *For example, for our engineers, that should be a central part of their training, because when they design bridges they can't wait until the bridge is put up, they should be able to – in advance – predict, make judgements, et cetera.* (AM 1, L 191)

Although there was no prescriptive approach to how numeracy should be developed from academic managers, they did share how they felt it could have been approached. With respect to this, responses from the managers about how they envisaged developing the curricula to include numeracy reflected two broad categories. First, data was focussed on the curriculum process and, second, on the specifics of the phenomenon of numeracy development.

5.3.1.1 *Curriculum planning*

From the curriculum planning perspective, there was concern that the Curriculum Renewal Project should not become a technical exercise – one of compliance only:

> *We should be careful not to tick boxes: this should be new; this should really be innovative. I was beginning to get a bit irritated with some faculties who were just saying, "No, no, no - but we've got this already. We just need to change that" – leading to a 'reparcel'.* (AM1, L252)

It was important to managers that a supportive environment be created. The environment had to acknowledge that the planning for numeracy in undergraduate programmes, as with all aspects of curriculum design, was based on a dynamic process. One leader said:

> *The important thing is to just make sure that people understand what you want. . . . And then you have to set it free: let people kind of work away at it.* (AM1, L42)

According to this leader, one could not – and also should not – prescribe in detail what the process should be. It was only through working through it that it would improve.

Another key informant who was responsible for managing this process highlighted that curriculum design needed to work in an environment that acknowledges that:

> *curriculum is a dynamic thing and we need to treat it dynamically, because all these things are coming in afterwards and they are changing and will continue to change.* (AM3, L 994)

From these managers' perspectives, it can be seen that they valued curriculum design as process rather than as an act or a product. They did not expect a linear process but rather wanted programmes to "work at it" and come to positions that made sense to them. They expected that staff would be prepared to go through many cycles of planning for the curriculum of a programme. As will be seen later in the data, however, this approach left staff feeling anxious and underprepared.

5.3.1.2 *Numeracy planning*

Some managers appeared more engaged in terms of their ideas about approaches that would be effective for developing students' numeracy or quantitative reasoning, whilst others were comparatively less comfortable and less confident about whether they possessed the necessary experience and expertise to comment on this. One of these managers commented:

> *So to me it's an important – I don't know whether it's a skill or competence, for every human being to have – but because I am not a numeracy professional – if one has to put it that way – I will not be able to say to you, "This is how it should be done"; "It's done wrongly" when it's done; and that there are these many ways of doing it. I would be lying if I said I knew that: I don't know*. (AM2, L41)

Managers participating in the study presented different perspectives on how numeracy could have been included in the undergraduate programmes. One approach envisaged at the beginning of the Curriculum Renewal Process saw numeracy as being included in a module that was compulsory for all students. One manager describes this:

> *My thought, at the beginning, was that it would be part of the Cornerstone. I thought that what the Cornerstone was going to be. And then it was going to actually be able to – as a compulsory module – . . . ensure that the numeracy and quantitative reasoning part of it touches every student*. (AM2, L97)

Since every student could benefit from developing their numeracy practices during their higher education, this manager felt that a compulsory module would ensure that all students had the opportunity to develop their numeracy practices as they moved through the curriculum.

This view was consistent with that of another highly influential academic manager, but their opinion on how this could be achieved was slightly different. According to this manager, the design of new programmes aligned with the imperative to develop students' numeracy (quantitative reasoning), along with other imperatives, needed to be reimagined, reconceptualised and presented in new and innovative ways. He had felt that an approach should be developed that embedded numeracy development across the modules of each programme. He had felt that such a process needed an explicit planning process and should not happen in an ad hoc fashion:

> *My approach to numeracy was that it is something that needs to be built into the curriculum across the system – doesn't matter what you teaching and where you teaching. The same way as you want to teach young people how to write in health science, you also want them to be numerate*. (AM1, L304)

This manager believed that staff needed to build numeracy development into each module while they were being designed. Building on this embedded approach, another participant felt that this should be done incrementally, by increasing the level of difficulty over the three-year programme:

> *Let's build a certain level of numeracy at the first year level, another level at the second level…and that's why I was arguing very strongly towards the degree programme. And that gives you a little bit of extra space. It also gives you a little bit of extra room for depth. So if you talking about numeracy, it's not just about introductory numeracy: it's about numeracy at different levels*. (AM1, L189)

Another manager, sharing some of this perspective, spoke of introducing numeracy or quantitative reasoning in courses if and when it was needed:

> *I find that within higher education there should be, maybe, then 'just in time': so if you need to understand* ***this*** *we will teach you that* ***now****. So therefore, for me, I think the best way would be in the integration*. (AM3, L502)

Separate from these approaches to curriculum design generally and to including numeracy in the curriculum specifically, reference was made by the managers to the overemphasis by academics on the cognitive domain of numeracy and the neglect of the affective domain. One manager suggested that central to the task of developing students' numeracy practices is the need to deal with the anxiety or other attitudes or feelings students may have toward anything involving numbers or calculations as a result of their prior experiences with mathematics or related subjects. The manager felt that there is a need to include within the curriculum space opportunities for students to develop competence and confidence with numbers and their applications. The manager mentioned a project in the United States that was showing potential as something that they could draw on as they developed numeracy in the undergraduate curriculum that focussed on overcoming existing anxieties associated with numeracy.

In summary, the managers had varying ideas about how to best approach students' development of numeracy in undergraduate programmes should have been be approached. These included developing modules dealing specifically with numeracy; including numeracy in teaching using an ad hoc, 'just in time' approach in courses by relying on the pedagogical process; and integrating numeracy in modules across the curriculum using a carefully planned approach. Attention was also drawn to the need for the affective domain to be considered in the planning for numeracy, in order to build students' level of confidence and level of comfort with numbers. Interestingly, even the managers themselves demonstrated different levels of comfort and confidence in their ability to express what they understood numeracy to be and how they believed it could best be developed.

Next, I present the views of the two module developers (MD) who designed the generic institutional and faculty-level modules on numeracy (quantitative reasoning).

5.3.2 Module developers' views of numeracy development

The developers of two of the general numeracy/quantitative reasoning modules expressed the view that students' numeracy could not be developed adequately through just one dedicated module and there was a need to develop numeracy across all programmes, even those that included mathematics. One of the developers expressed this as follows:

> *I think there's no one module or one approach to developing a graduate attribute – even to develop numeracy or to develop it as an attribute of the graduate is not going to be done in one module.* (MD1, L450)

They asserted the viewpoint that numeracy development should not be addressed only in the first year of the curriculum but rather should continue through all years of each programme at increasing levels of complexity.

One of the module developers indicated that numeracy should be treated as a specialised area and that it should progress across the three years of the curriculum:

> *Numeracy should be developed as its own. . . . you can do a very basic module like this at first year but there needs to be some progression. If there's no numeracy in the curriculum it needs to be built in the curriculum throughout the three years*. (MD1, L 327)

The other module developer also supported including numeracy development across all three years of a programme:

> *I would certainly argue very strongly for numeracy-specific modules that extends over all three years . . . . Then it allows us the flexibility to almost develop these students through the programme and not like this this is just a once off shot . . . . if you do it in the first year, first semester, then it's forgotten.* (MD2, L509)

This approach enhances the chances that the graduate achieves the numeracy levels expected by industry. In fact, one of the developers felt strongly that the identification of numeracy requirements that need to be addressed by the institution should be driven by the industry the student would be entering post-qualification:

> *The people that should be driving the curriculum would be the people from industry within that discipline in what skills does this graduate need.* (MD2, L 439)

In contrast, the other module developer expressed the view that the numeracy module could be used to develop students' reasoning abilities. They indicated that programmes should adjust the contents of the module and use relevant sections of the module in their programme and then complement these in other discipline modules in the programme.

> *So, within the program, they have many different things going on. It's intended to compliment. So it's a kind of thing where you put all of it together and what emerges from that is an attribute of numeracy. (*MD1, L 455)

In essence, from the numeracy/quantitative reasoning module developers' perspective, numeracy could be developed through a series of levels of increasing difficulty over the duration of the programme.

While one of the developers felt that numeracy involved a certain level of generic reasoning that could be common across all programmes, both acknowledged that it needed to relate to the disciplines that students were studying and prepare students for the world of work. Also relevant is the fact that both module developers expressed the opinion that numeracy in higher education should be a specialised area that requires attention. Both the academic managers and the module developers provided valuable data and identified opportunities to include numeracy or quantitative reasoning in the institution's programmes.

Another important source used in this study to obtain data on the curriculum decisions made in the seven programmes selected were the programme curriculum developers. Their perspectives are presented next.

5.3.3 The perspectives of programme developers on numeracy development

All of the programme developers indicated that numeracy is an important issue that needed to be addressed in the curriculum. They held different views, however, on how this could be addressed and whose responsibility this should be.

The programme developers indicated that they realised that for student's numeracy to be developed a stronger approach was needed than to 'tick the box' by including numeracy in a module descriptor. One developer said:

> *Maybe there needs to be more. I mean, I know you tick on those columns – QR – but maybe one needs to be more specific with the outcomes and assessments.* (PG2, L 387)

The challenge identified with this by most of the developers was with articulating such outcomes or assessments. Some of the programme developers indicated that the process could have been enhanced by interrogating the expectations associated with the imperative to develop numeracy before beginning the planning process. One developer described how this process should have happened:

> *We sit down and make sure we understand what we mean, so that in the end we have a product where the students will understand what we mean and they then we will be able to assess that they understand what we mean*. (PG3, L 144)

This highlights the challenges involved with planning for numeracy if there is a lack of clarity about what numeracy is or what is expected to be achieved. The programme curriculum developers also highlighted the need for numeracy to permeate the curriculum and be relevant to the programme. Developers made the following statements in this regard:

> *Numeracy should be developed through the program incrementally: . . .it [numeracy] could be basic, intermediate and advanced.* (PG3, L 243)

> *It should be moulded into the program and sort of be in touch with what the program is about.* (PG5, L 197)

> *I strongly believe it should be embedded into the core modules that will go in line with it, so that students can see the relationship, instead of having a standalone.* (PG6, L 258)

The programme developers also articulated different positions regarding who should be responsible for developing numeracy in the programmes. Some programme developers indicated that they would benefit from input or guidance from 'numeracy experts' that were not necessarily mathematics specialists. They felt, though, that it was necessary that such a person have the conceptual and procedural understandings of the concepts needed to be dealt with at the very least. One developer said:

> *I'd rather have someone who was maths literate – like a maths tutor – tutoring our numeracy, rather than having someone who was course literate teaching numeracy.* (PG1, L33)

This developer expressed the concern that if the person responsible for numeracy development was not themselves competent and comfortable with numeracy, it would be detrimental to students' numeracy development. A disciplinary expert illustrated this as follows:

> *I don't know what that thing at the bottom of the fraction is called. And I can't teach someone numeracy when I say, "that thing at the bottom of the fraction", but I know the concept I'm a wanting.* (PG1, L37)

The point was also made that when students are taught numeracy incorrectly it can undermine their competence and confidence in future situations where numeracy is required. One developer stated:

> *I know that maths teaches you problem solving and everything else, but I also know that maths being taught incorrectly doesn't teach you anything. It actually confuses more people than it teaches them anything – apart from hating numbers.* (PG1, L 44)

On the other hand, some of programme developers stated that they, as disciplinary experts, were best suited to facilitating the development of students' numeracy since they could relate the concepts to their discipline. However, this approach required staff to have adequate experience, to have a desire to teach students holistically and to not limit their teaching to the content of the course.

> *I think if you are really someone who is concerned about that academic development of the students it will be implied for you, when you interpret the curriculum. And I think it does come with experience – but not just with experience. I also really think that it comes with that sense of "I need to holistically develop the student." It's not about my subject content. Within my subject content I need to look at needs of the student: I need to look at the numeracy, I need to look at reading, I need to look at writing – in that subject context.* (PG2, L 323)

They acknowledged that such an approach requires substantial staff development for this to be effective. The same developer stated:

> *Staff development: that's with you guys with your teaching and learning development.* (PG2, L557)

PG 2 further commented that staff development should include more experienced staff mentoring less experienced staff:

> *It has to be in every subject; it's mentoring – handing over to younger people. But not just handing over a file: it is mentoring, mentoring, mentoring. Going through with them, in this case, the numeracy demands and development*. (PG2, L 650)

There was an expectation that it would be beneficial to make explicit to the lecturers the numeracy demands of each module and the opportunities that the module provided for the development of students' numeracy.

Lastly, participants indicated that to ensure that numeracy is developed it should be included in outcomes and assessment criteria.

> *We have to go back to the module descriptor and include it as part of the outcomes. If it's part of the outcomes, then there is no way going around it: it has to be there.* (PG 7, L 393)

The explicit inclusion of numeracy in the module descriptor would help to ensure that staff remained aware of the need to engage with numeracy during their modules. Also, by including numeracy explicitly in the module outcomes, staff would need to ensure that it was properly addressed before students were assessed against the outcomes. As indicated previously, some were afraid that an informal approach to embedding numeracy could result in it being left out or given inadequate attention. In one of the curriculum team focus group interviews, participants raised the point that there needed to be a way to force staff to reflect on their assessments to ensure that practices around numeracy and other literacies were being addressed. If that happened, the assessment of numeracy practices would drive the developing of numeracy.

The programme developers identified particular strategies that they felt would have enhanced the planning for numeracy. They indicated that a process of engaging with the imperative to create a shared understanding of the importance of numeracy and of how to plan for its development would have been helpful, along with clearer direction from the institution's leadership about what was expected.

The programme developers held different views about the role of the disciplinary academics in the development of numeracy and which approaches would be most effective in developing students' numeracy. Some programme developers preferred a module-based approach; others thought that an embedded approach was better. The one thing that did seem consistent was the view around influence of staff preparedness within the programme to engage in numeracy development on curriculum planning and the need for staff development.

Before moving on to explore the approaches that were *actually* used to plan for numeracy, a summary of the approaches that participants felt *should* be used is provided.

5.3.4 Summary of planning approaches participants espoused

When reviewing the espoused approaches from the perspectives of the different key players in the planning for curriculum, the following points were raised:

- Numeracy/quantitative reasoning development is an important part of students' academic experience. All students should have the opportunity to develop their numeracy practices during their programme, including those enrolled in programmes with an emphasis on mathematics.
- A single module, or an intervention which is restricted to the first year of the programme, is not adequate to achieve this.
- Numeracy should be developed incrementally across the duration of the programme.
- Participants favoured different approaches to developing students' numeracy. One approach was to develop dedicated modules to develop students' numeracy. Another was to integrate numeracy development into core modules of the programme. A third approach was to deal with numeracy development as the need arose.
- Embedding numeracy within modules in the programmes appeared to be favoured by most stakeholders. A key consideration in adopting such an approach was the need for staff development.
- The issue of whose role it was to define numeracy or what it meant to be a 'numerate graduate' was highlighted. Leaders felt that programme staff needed to figure out for themselves what numeracy meant in their programme and how best they could approach its development, while programme staff felt that the process should be initiated by academic managers or other "experts" with clear guidelines on what was expected.

These observations add credence to the view that this lack of clarity could have arisen from the very nature of numeracy in higher education. While the planning that occurred indicates that the participants in the study had a tacit knowledge of what numeracy is, they found this difficult to articulate explicitly. As a phenomenon, numeracy is difficult to define and this means that a meaning-making process is needed as part of planning the curriculum. The different conceptions of numeracy that participants held are explored in greater detail in the next chapter.

The next section explores the actual plans that were put in place for developing students' numeracy as part of the Curriculum Renewal Process, as described by programme developers and evidenced in the curriculum documents.

5.4 Approaches actually used to plan the development of numeracy

Bennison (2015) identifies three ways in which numeracy can be developed in the curriculum in basic education: (i) by developing distinct courses or modules to address it; (ii) by integrating it into the modules of the particular programme; or (iii) by making it explicit and developing it across the curriculum in all subjects by finding numeracy moments within the subjects. This is equally applicable to higher education. These three broad approaches were considered when exploring how numeracy was developed at the institution in the study. The data sources used to explore the approaches that were taken to developing numeracy in the institution were curriculum documents, which included curriculum maps and module descriptors for each programme, and interviews with the study participants, which included module developers, programme developers, academic managers and other key informants.

Curriculum maps were analysed to identify if, and where, the departments prioritised quantitative reasoning or numeracy. This document analysis included a review of the purpose of each programme and its exit level outcomes and graduate attributes, and a similar review of each module in a programme. Further analysis was conducted of the module descriptors of the modules that indicated numeracy development as an outcome. In this analysis each programme formed a unit of analysis. The programme documents were analysed to establish which approach/approaches were adopted in the planning for numeracy in that particular programme.

The following approaches to the development of numeracy were identified.

5.4.1 Module-based approach

The Curriculum Renewal Project at the institution included the introduction of general education subjects, including numeracy. Many of the imperatives driving the curriculum renewal process were seen by some participants to be the responsibility of the General Education Task Team.

In the main, general education modules were developed by independent staff who were not attached to any department or programme. Three modules focussing on numeracy or quantitative reasoning were developed for use across the institution as part of the general education suite of offerings. These were not compulsory modules. The decision to register for these, or any other general education modules, was intended to be up to the students themselves, however, the study found that most programmes made these choices for the students. One of these institutional numeracy-specific general education modules was included as an elective in one of the seven programmes in this study.

This module-based approach was also adopted by one of the faculties of which two programmes were represented in this study. This faculty allocated general education modules to the first year of all of its programmes. One of the general education modules that was a numeracy module was developed by a group of staff in that faculty on the instruction of the dean. Programme curriculum developers from this faculty indicated that this approach was chosen to ensure that the numeracy imperative was properly addressed and did not get lost. One of the programme developers from this faculty explained the rationale:

> *because it was easy to show, "Here are my modules" . . . . That's why we have developed the modules as they are. . . . Where's the literacy? There's the literacy. Where's the numeracy? There's the numeracy. Then it's easy to audit.* (PG 7, L 57)

We thought we had taken care of it, in terms of the QUAMS[2]*,* (PG6, L 183)

In respect of a module-based approach to developing numeracy, then, 'generic' modules were made available as part of the general education suite of modules. Ultimately, two programmes within the same faculty made one of these numeracy specific modules compulsory. There was only one other programme from another faculty of the seven selected programmes for this study that included a numeracy-specific module as an elective. None of the other programmes included a numeracy-specific module on either a compulsory or elective basis in their programme design.

The second approach to developing students' numeracy was to integrate it into other modules.

5.4.2 Integrated approach

The integrated approach involved making numeracy development an explicit priority in respect of the purpose or outcomes of programmes or the outcomes of discipline-specific modules. A review of the curriculum maps generated a list of modules that were related to quantitative reasoning/numeracy. An analysis of the modules that claimed to introduce, reinforce and/or assess quantitative reasoning found that one of the seven programmes adopted this approach where a module included in the programme had an outcome for numeracy. In the programme documents the purpose of one of the modules stated:

Students will be expected to develop their skill in numeracy which is a fundamental necessity in this qualification. (PG1, CD1)

The following learning outcomes related to numeracy or quantitative reasoning in some modules in the programme:

[2] QUAMS is the name of the compulsory numeracy-specific module in one of the faculties.

(i) *Demonstrate competency in numerical skills covering all appropriate units of measurement (LO 3, Module 1);*

(ii) *Use and construct numerical data and formulae in calculations (LO 2, Module 2) and*

(iii) *Perform calculations relating to the cutting room and costing (LO 1, Module 3).*

The documents also made reference to the relationship between graduate attributes and quantitative reasoning/numeracy as follows:

> *Achieve graduate attributes through: Developing the application of quantitative reasoning to these processes, with particular reference to quality and productivity*. (PG1, CD1)

Lastly, there were examples of numeracy (quantitative reasoning) as part of the module content:

> *Quantitative reasoning is introduced with regard to the application of numerical and geometric concepts in measurement and technical specifications (Module content, Module 2).*

These examples demonstrate that numeracy (quantitative reasoning) was integrated into the purpose, outcomes and content of this programme. It also featured in specific module outcomes. This was not a popular approach, however. The most popular approach was to embed numeracy into the programme. This approach is explored next.

5.4.3 Embedded approach

The curriculum maps of all seven programmes in the study suggested that numeracy was introduced, reinforced or/and assessed in discipline modules in an embedded way (See Annexure G). While two programmes suggested that this was used in conjunction with the module-based approach and one programme integrated numeracy as an outcome in a discipline specific module, four of the seven programmes in this study used only the embedded approach. The interview data highlighted, however, that although there were many discipline modules that indicated that numeracy development was included, this was based on the pedagogical expectation by the curriculum developers and not necessarily a deliberate curriculum planning approach. During interviews, programme curriculum developers indicated that other module developers in the department felt that they had already been developing students' numeracy and this imperative was thus not something new. They indicated that they did not plan explicitly for numeracy development in their programmes but addressed it as needed. Two of these participants commented as follows:

> *I am going to honest with you: we are not like the Management faculty, where we see it as a core module or subject. It is probably embedded into other modules.* (PG5, L 8)

> *We didn't make a concerted effort.* (PG3, L247)

The participants did highlight, though, that because numeracy was not explicitly planned for it could be overlooked.

> *It's intertwined but you can completely ignore it and bypass it – but then you will not be a success in the workplace. But they can go through the system where it is bypassed. You can bypass it: there's no doubt.* (PG2, L 481)

The programmes which adopted this approach provided examples primarily of 'just in time' numeracy development – and only as much as was necessary for students to understand a disciplinary concept. This approach was very dependent on how teaching staff interpreted the curriculum and therefore was not consistent from year to year or cohort to cohort. In respect of the planning for numeracy, those programmes following this approach did not plan formally for numeracy development and rather expected that it would be addressed in the enactment of the curriculum.

In addition to these three approaches, the curriculum developers identified other approaches to developing numeracy outside of the formal curriculum of the programme. These are described briefly next.

5.4.4 Additional approaches to numeracy development outside of the formal curriculum

Besides the three approaches discussed above, during the interviews participants indicated that students' numeracy practices were sometimes developed outside of the formal planned curriculum through student support initiatives such as First Year Student Experience (FYSE) tutorials or other tutorials provided by support staff.

Participants also mentioned the role of the foundational modules of the Extended Curriculum Programme (ECP) in developing students' numeracy. The Extended Curriculum Programme provided students extended time to complete the programme with supporting modules. These programmes followed a similar approach to the module-based approach to numeracy development but targeted the small group of students who were part of this initiative. It was delivered by contract staff who worked for the ECP. One of the participants suggested that the ECP module was used to provide students with conceptual and procedural clarity:

> *We bring it in with ECP. We do lots: we really do lots. We go back to basics: how to calculate, how to convert from kilograms to grams and grams to kilograms...You know, those steps to understand those mathematical processes there*. (PG2, L95)

This approach to numeracy development in the ECP suggested that it was 'upskilling' students with practices they needed but had not mastered at school.

Other approaches to developing students' numeracy which participants mentioned were having students use established websites such as The Khan Academy or using quizzes to encourage students to revise computation skills they had been taught in basic education. Participants noted that, in some instances, tutorials were used to address gaps in the practices of students.

With the exception of the ECP module, all of these strategies were used informally; they were not included in plans but staff anticipated that they would be needed based on their previous teaching experience in the programme.

A summary of approaches used by the institution to plan for the development of students' numeracy is presented next.

5.4.5 Summary of planning approaches used

Varied approaches were taken to developing numeracy at the institution. These included numeracy-specific modules, an integrated approach and an embedded approach. While the embedded approach was most often taken, it included no explicit planning. Rather, it was expected that numeracy would be developed as needed during the teaching and assessing of the curriculum. The expectation that numeracy would be embedded in the enactment of the curriculum resulted in no explicit plans being considered during the curriculum design.

While the curriculum maps indicated that numeracy was allocated significant time across the curriculum, which was evident in the number of disciplinary modules in the programmes that claimed to be 'introducing, reinforcing and/or assessing' quantitative reasoning, interviews with the teams or individuals responsible for the planning of these modules revealed that in some instances there was no explicit plan even though the module indicated numeracy development in the curriculum map and module descriptor. Based on previous experience it was expected that it should be addressed as needed in the teaching. Programme developers ticked those boxes in the module descriptor if the module involved doing calculations or if it was assumed that numeracy practices were needed in other ways in the module, without explicit plans for numeracy development.

All categories of participants highlighted the need for numeracy to permeate the curriculum, increasing in difficulty as the programme progressed.

Although I present the factors and tensions influencing curricula decisions comprehensively in Chapter 7, it is helpful to the discussion to briefly mention the range of considerations here as well.

5.5 Influences in decision making with respect to approaches adopted

During the interviews, the programme curriculum developers identified several factors that influenced which approaches were chosen when planning for numeracy. As discussed earlier, in some cases there was no explicit plan to address the imperative regarding numeracy because there was an expectation that it would be addressed if and when the need arose. Some of the participants indicated that they felt this approach was more beneficial to students.

Some participants indicated that the way numeracy was addressed in the curriculum was based on input from their industries. One participant explained:

> *Dating back from the advisory board minutes and all of that, there was concern that our students were not good at numbers, so for everything they did they relied on computers and calculators.* (PG7, L21)

In other instances, the choice of approach was mandated by the management of the faculty and programme. One participant explained:

> *The decision to have a module approach rather than embed was driven by because we went with the decision taken by the faculty/dean that we will have a common first year with common modules. And then the decision was that that would be a standalone module.* (PG 6, L273)

A more detailed account of the factors impacting on curricula choices is provided in Chapter 7.

So far, this chapter has presented the different understandings within the institution of how best numeracy could be planned for and what should be considered before a plan could be conceptualised. The espoused practices and actual practices identified by participants have been discussed.

The next section presents a deductive analysis using the Autonomy dimension from the LCT toolkit. This analysis provides insight into the principles underlying the institution's practices for planning for numeracy in respect of *who* was valued in the planning and what their purpose in planning – whether undertaken implicitly or explicitly – revealed in this regard.

5.6 Analysis of planning practices using LCT Autonomy dimension

The data was examined using the LCT explanatory framework described in detail in Chapter 4 to make sense of the organising principles underpinning how numeracy was developed. For this aspect of the analysis, the Autonomy dimension of the LCT proved to be very useful in providing insights into the different approaches described in the data. Autonomy is premised on the idea that any "set of practices is based on constituents that are related together in particular ways" (Maton & Howard, 2018, p. 8). This dimension comprises two concepts: positional autonomy and relational autonomy. Positional autonomy (PA) refers to how insulated constituents in a particular context are from constituents in other contexts. Relational autonomy refers to the relationships of constituents within a context or category to other constituents in different contexts or categories.

This study focussed on establishing how numeracy activities were planned and who drove this process (Positional Autonomy, PA) for the explicit purpose of developing numeracy practices (Relational Autonomy, RA). As described in Chapter 4, for each LCT analysis translation devices were created to connect the data to the theory. The concepts within each LCT dimension and related definitions needed to be reconfigured to provide a device that talked to the data. Through a process of abstraction, as discussed in Chapter 4, a translation device was developed for the purposes of this analysis. The translation device for the LCT dimension Autonomy is shown in Table 5-1.

Table 5-1 Translation device for Autonomy dimension: practices used to plan for numeracy

Autonomy		Description of concepts in relation to study
Strong Positional Autonomy	**PA +**	numeracy-specific modules planned by numeracy/independent professional
Weak Positional Autonomy	**PA-**	activities that include some numeracy practices planned by disciplinary staff or others not considered independent numeracy professionals
Strong Relational Autonomy	**RA +**	target is for the intention of developing numeracy practices
Weak Relational Autonomy	**RA -**	for any other purpose, such as understanding disciplinary concepts

Figure 5-1 illustrates how these concepts were used together to generate the autonomy codes.

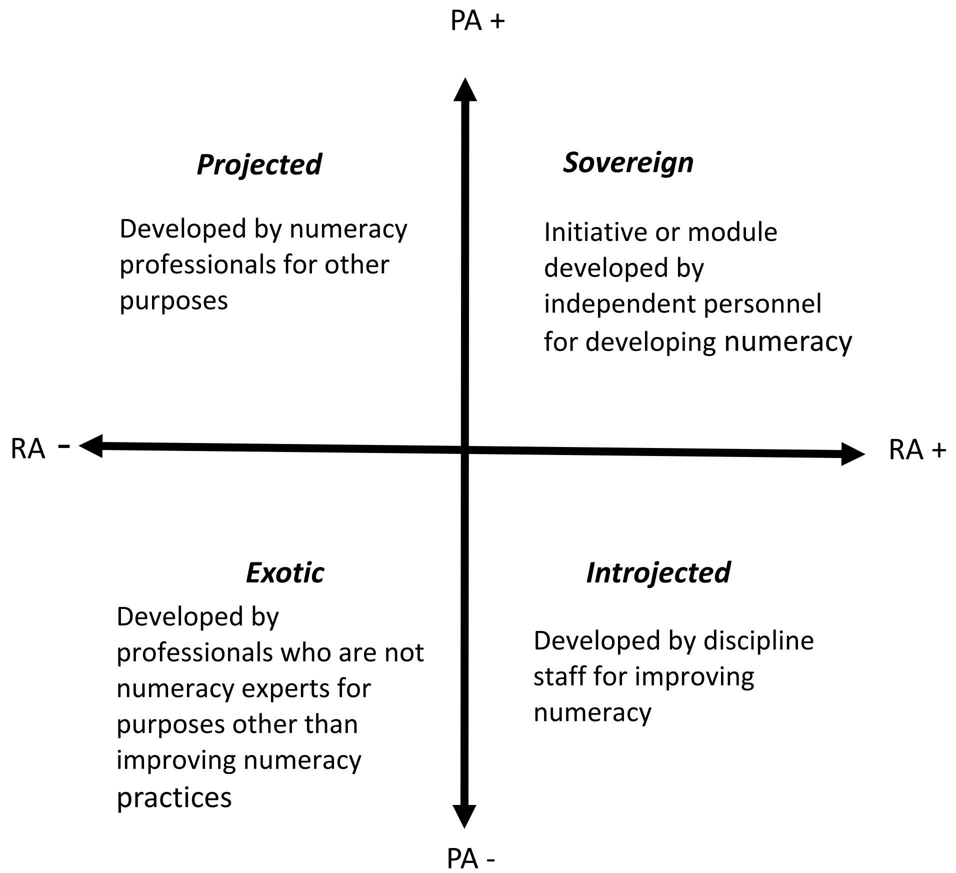


Figure 5-1 Criteria for Autonomy plane for the practices used to plan numeracy

The different approaches were analysed using Figure 5-1 as a guide.

Figure 5-2 illustrates the principles underlying the different approaches.

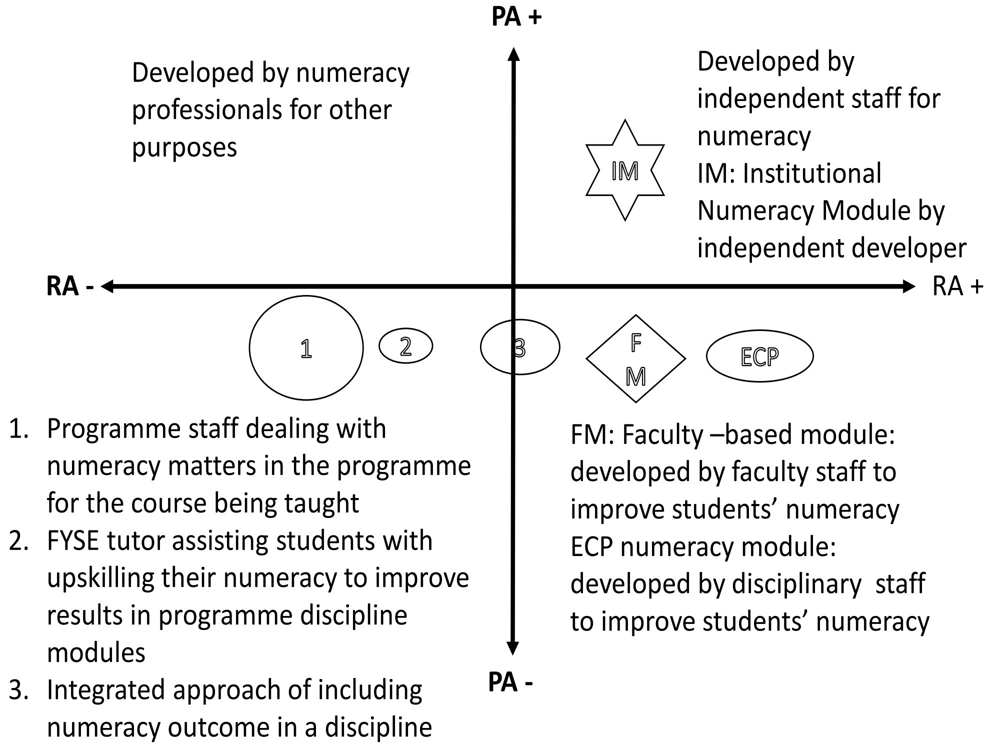


Figure 5-2 Analysis of the practices used to plan for numeracy using LCT Autonomy codes
(Note: The size of the figures does not represent how many programmes adopted the approach. The different shapes indicate different initiatives, and the size is based on being able to fit a label).

Application of the Autonomy dimension of LCT confirmed that a variety of approaches were followed to develop numeracy. In this case study, all these approaches were considered acceptable and legitimate practices at the institution.

The institutional quantitative reasoning module was developed by someone who was viewed as having stronger positional autonomy for the purpose of developing numeracy and whose planning of the module was not really influenced by the expectations of other constituents. Their planning was thus more insulated from other influences than those of other approaches. With an explicit target of developing numeracy, this module was also characterised by stronger relational autonomy. The module was thus coded as 'sovereign' (PA+, RA+), reflecting its stronger positional and relational Autonomy.

In contrast, the generic faculty-specific numeracy module was designed in response to a directive from the dean. The purpose of the module was to develop numeracy that was specific to faculty needs. In this respect, the disciplinary expert here had weaker positional autonomy with regard to numeracy education and designing how the module should be approached. It was a collaborative approach that had input from different disciplines – suggesting a weaker PA and stronger RA. This approach was thus coded as 'Introjected' (PA-RA+).

In terms of the two generic modules, interestingly, while both were approached with the explicit target of developing students' numeracy, the one legitimated an independent numeracy professional and the other a disciplinary expert.

In other cases, as with the integrated approach, there were one or two disciplinary modules within the programme in which numeracy practices were included explicitly in the outcomes. These, too, were designed by programme disciplinary experts. However, in this case the programme department did indicate in the interviews that they felt that they were not best suited to addressing these due to their perceived weaker positional autonomy in respect of numeracy. The relational autonomy was also slightly weaker than in modules dedicated to numeracy but not as weak as, for example, in cases where an embedded approach had been taken with no explicit target of developing numeracy. These approaches, when analysed, fell between the 'exotic' and 'introjected' codes, both of which correspond to weaker positional autonomy (PA-).

The two generic modules and the integrated approach found in one programme were the only examples of truly explicit planning of numeracy by programme developers within the mainstream undergraduate programmes. The other most dominant approach that was identified was the embedded approach. In this approach, however, the staff teaching these disciplinary modules were expected to embed numeracy development and engage with the practice as needed in the context of the module. This approach legitimated a weaker positional autonomy (PA-) of those responsible. The development of numeracy as a target also appeared to be weaker with this approach, thus corresponding to weaker relational autonomy (RA-). This approach was thus coded 'exotic' (PA-RA-).

Although these were not part of the mainstream curricular planning for the undergraduate programme, I considered it worth exploring what principles might underlie the ECP and FYSE approaches. ECPs often included numeracy modules designed by programme staff in their foundational offering. This was thus coded as 'introjected'. The FYSE tutorials were described as an initiative within which numeracy could also be included. This initiative however was also not planned in advance and was mainly used to respond to gaps identified in students' numeracy practices during numeracy-related activities in the programme.

The LCT Autonomy analysis of the varying approaches highlights that there were different organising principles underpinning the different approaches. Even so, all of the approaches were valued and legitimated. This could raise the question of whether it really did not matter which underlying principles were operating as they generated the same outcome. However, as the discussion has shown, each approach was found to enable and constrain the development of numeracy in different ways.

A deeper analysis of the intentions and espoused planning suggests that participants found that using these approaches in combination in different ways at different stages in the curriculum plan was most effective. For example, there was an indication that dedicated modules would be beneficial to students early in the curriculum to address students' confidence and conceptual depth (sovereign) but that these should be developed by disciplinary experts (introjected); however, because some disciplinary experts lacked confidence they could benefit from interaction with numeracy professionals (combination of

PA+ and PA-). However, all discipline academics needed to be competent to identify opportunities to facilitate students' development of numeracy practices for personal, social and professional growth (projected). This suggests that endless possibilities exist if there is movement between the codes and within the codes. This was not evident, or did not manifest though, in any explicit plans for developing numeracy.

5.7 Conclusion

This chapter has presented and analysed the first set of findings related to the research question: 'How was numeracy planned for in the undergraduate programme at an UoT?'

Analysis revealed that the institution in this case study did not follow a single approach to planning for the inclusion of numeracy development in the undergraduate academic experience. Different participants had different expectations regarding which approach should be used. Interestingly, the analysis revealed that the academic managers had expected that their programme staff, in their capacity as curriculum developers, should have engaged in a process of scholarly exploration of the phenomenon to find their own way to engage the directive to develop numeracy grounded in their academic expertise. The programme staff, on the other hand, felt that the process would have been more effectively facilitated if the academic managers had given them a clearer directive in terms of how they understood the task and what their expectations were.

The LCT Autonomy analysis showed that the approaches adopted to develop numeracy had different organising principles. While certain module-based approaches valued explicit development of numeracy, there was more support among participants for the embedded approach in which numeracy was developed incidentally and as the need arose – responding to the context rather than determining an explicit agenda for the development of numeracy by programmes. The acceptance of the different approaches as relevant and appropriate could be indicative of a lack of a common understanding of the imperative to include numeracy in the design of new programmes at the institution; however, it could also reflect the complexity of numeracy and that it is not understood in a single way within higher education.

The LCT analysis also showed that most numeracy activities were planned for or were expected to be carried out by disciplinary experts – academics who were seen to have lower positional autonomy in respect of the numeracy imperative at the institution. While some programme developers or development teams indicated that numeracy is best learnt in the discipline there was a strong indication that this may sometimes not occur due to a variety of reasons.

To gain further insight into the curricular choices made at the institution, and to understand why these approaches were used in the ways that they were, it is necessary to explore the factors influencing the choices that were made. One broad influence is internal: the ambiguity around the nature of numeracy in higher education. This is explored in Chapter 6. The other is external: the contextual and situational factors which had bearing on the planning of numeracy. This is explored in Chapter 7.

Chapter 6
Conceptions of Numeracy

6.1 Introduction

The previous chapter presented the institution's approaches to planning for developing students' numeracy and analysed the principles underpinning these practices. A range of approaches to developing numeracy were identified and perspectives on which approach should be followed and which approaches were actually followed were explored.

The reasons for these variations can be divided into two broad categories that influence curricula choices around planning for numeracy development: firstly, the influence of conceptual understandings of the phenomenon of numeracy in higher education and, secondly, as the influence of contextual factors that are external to the phenomenon but influence curriculum planning in general and planning for numeracy in particular. These two broad categories are intricately connected and influence each other and the bigger picture of the practices aspired to or adopted in the planning for numeracy in an undergraduate curriculum. The first of these is addressed in this chapter and the second is the focus of the next chapter.

Secondary to exploring the practices of how numeracy is developed, participants were asked to offer insights into the conceptions of numeracy in higher education. This chapter is dedicated to gaining a nuanced understanding of the conceptions of numeracy in higher education and to understanding the underlying organizing principles of legitimation of this phenomenon in the context of the study. To achieve this, a descriptive and thematic analysis of the conceptions of numeracy at the institution in the study was conducted. This was followed with an exploration of participants' conceptions of numeracy using the LCT dimensions to make the organizing principles underlying the varying conceptions of numeracy explicit and to offer insights on the legitimation of the phenomenon of numeracy in higher education.

An analysis of the data using the LCT Specialization and Semantics dimensions was presented in an attempt to provide insights into what is valued as legitimate numeracy practices in higher education. This forces us to acknowledge that numeracy involves multiple practices that are dependent on context. The complexity of these practices was found to vary at different points. This led to an exploration of the cognitive demand associated with numeracy practices at different points in the curriculum.

The chapter ends with a discussion of the different numeracy practices evident or expected and the varying levels of complexity. This is done through an examination of the knowledge and knower practices; the specificities and complexities related to contexts and conceptual understanding; and the levels of cognitive demand of numeracy practices in higher education.

6.2 Conceptions of numeracy: thematic data-driven insights

Participants across all categories in the study found it challenging to articulate their understanding of numeracy, even though they expressed that they had an implicit sense of knowing what it is. One participant commented on the confusion created by the varied understandings of numeracy that exist:

> *It means a lot of different things. . . . Quite a few people are saying that numeracy is purely about calculation of numbers and understanding how to manipulate them – numeracy is knowing what to do with these numbers. There will be another group of people that will say, well they can apply that to the real world, we can apply numeracy and still have a problem with numeracy. Another person said that if we let numbers be represented by x, that's still numeracy. So I think we need to nail down what is numeracy,* (K2, L 256)

Participants found it easier to provide examples that illustrated numeracy than to define what it is. At a basic level, the general consensus was that there was an expectation of competence in respect of mathematical concepts and processes that related to being numerate. Participants' descriptions of numeracy or being numerate included the following:

I think numeracy is just counting. (PG4, L 8)

I am thinking basic addition, subtraction, multiplication and division. If you know those you are numerate. (PG1, L22)

I can say [numeracy is] to be literate with numbers. (AM3, L 28)

Numeracy is about clinical judgment. You might know your numbers or how to calculate right but if you don't use it clinically then you will lose the plot completely. Numeracy is about making and justifying your judgement. (PG 4, L 90)

Participants' descriptions of numeracy ranged from extremely simple activities such as counting or being able to perform the four basic operations in mathematics to complex numeracy practices informing decision making. Other descriptions focused on numeracy being an implicit or intuitive 'knowing' if something was right or wrong or performing whatever numeracy practices were needed mentally in the process of completing their professional responsibilities.

While attempting to describe numeracy, participants tended towards deficiency-based descriptions of 'innumeracy or 'being innumerate'. This data suggested that participants tended to have an 'internalized' dichotomy where they labelled someone as either being numerate or innumerate, even though they found it difficult to articulate what numeracy was. A response below by one of the participants on their understanding of what is numeracy was surprising

It's something that our students don't have (PG6, L 74)

Numeracy was described in respect of student competence rather than the concept or phenomena. This perception of "innumeracy" of students was expressed by most participants and related to students across all years of the programme.

Table 6-1 presents the range of expectations of numerate students mapped against what would be considered innumerate.

Table 6-1 Numerate and Innumerate dichotomy

Numerate	Innumerate
trying to understand, if somebody says the temperature outside is 40^0 people should be able to say that's ridiculous	Does not know what a specific temperature feels like
understanding how the number 10 relates to the number a million	No conceptual understanding of the relation of numbers
able to read graphs and make assessments and judgements	Cannot read graphs, cannot make judgements
Able to infer from what you are seeing (L1)	Cannot draw inferences
not necessary to be able to add or calculate, should be able to see where something is wrong and is not making sense (L2)	Cannot assess whether something makes sense
Business skills, we gear our students more towards self-employment, they need to know basic bookkeeping, how to keep a cash book cash flow, they need to know that - most important (P3)	Does not know basic accounting skills and procedures
They call it quantitative reasoning and we like to call it critical thinking, so I think it's bordering along the same lines (P3)	Not a critical thinker
the application of any kind of mathematical processes or steps within your subject felid (P2)	Cannot perform calculations related to the discipline
Can visualise difference in quantity measurements	*Cannot conceptualize how much is 3 kilograms of salt and how much is 1 gram of salt (P2)*
Can read mathematical instruments like a ruler	*students couldn't even read a measure ruler*
Perform basic percentage calculations	*they can't even calculate the percentage of their test*
Students are comfortable and confident with numbers	*the students are not comfortable with numbers, they just blank out when they need to work with numbers*

The implications of such either/or positions creating binaries or dichotomies, is that in being either numerate on not, students are likely to be seen to have all the characteristics of any one side of the dichotomy. So, for example, if you are unable to intuitively know that something is incorrect that makes you innumerate which then can be understood and assumed that you are unable to calculate or count or read measuring tools etc. In this way students will continue to be considered to be innumerate because the characteristics of being numerate vary widely in respect of purpose, content, context and cognitive demand.

Interestingly, during a notable number of interviews, especially with programme curriculum developers or teams, the participant's initial description of numeracy focused on the mathematical aspects of basic operations of numbers. However, as they described examples and expectations their conceptions of numeracy practices or being numerate broadened to include conceptual understandings, applications of mathematical concepts and processes to particular contexts, and then to areas not directly related to mathematics as well, such as critical thinking and particular dispositions.

From participants' general descriptions of numeracy, a number of themes emerged from the data about their conceptions of numeracy.

6.3 Conceptions of numeracy: themes

An analysis of participants' conceptions of numeracy identified several interrelated dimensions within the conceptions articulated by participants or document sources: the knowledge domain, the contextual domain, the cognitive domain, the practice domain and the affective domain. Each of these is discussed in this section.

6.3.1 The knowledge domain

Numeracy does not exist as a distinct discipline. It has been described as a multidisciplinary space. However, it is linked to the specific disciplines or fields on which it draws. The most dominant discipline related to numeracy is mathematics.

6.3.1.1 *Numeracy and mathematics*

Some participants viewed numeracy and mathematics as being the same, or very similar. One participant said:

> *To me, [(maths and numeracy are] one and the same – because, for one, in order to understand how numeracy works, and all of that, you need to have a basic understanding of what mathematics is.* (PG 7, L 214)

In fact, every description of numeracy or quantitative reasoning included mathematical skills, concepts and processes. Mostly, however, numeracy was described as being connected very closely to mathematics but not necessarily being the same.

The data also revealed that participants' conceptions of numeracy shared certain concepts and processes. These included an expectation of procedural fluency and conceptual understanding of mathematical concepts and processes. One participant described evidence of being numerate as being

> *able to demonstrate that they are numerate, in a list of all of those fancy words – percentage increase, decrease, ratio, proportion – that deal with basic addition, subtraction, multiplication and division and hard-core fractions; how to add them, subtract them, multiply them.* (KI 1, L149)

The data suggested that numeracy was seen by the participants as a subset of mathematics. Notably, in the beginning of some of the interviews participants made reference to numeracy as the application of basic mathematics, which related to doing basic calculations. The mathematical concepts that were consistently considered important in the development of numeracy were based on concepts introduced initially early in school education - such us fractions, percentages and ratios.

Further concepts articulated by participants included 'graphical representation', 'number sense', including calculations and interpretations, measurements and conversions, application and manipulation of formula and mathematical equations. The dominant concepts evident were those associated with 'number sense'. These included the concepts and procedures associated with whole numbers, fractions (common and decimal), ratios and percentages. In each of these cases there were variations and extensions of the concept like percentage increase and decrease etc. For some participants, the fact that these concepts have been previously encountered led them to expect that the related numeracy demands of programmes in higher education will be met by students. Others were more aware that although the concepts may be familiar and repetitive to school, the numeracy or quantitative reasoning practices that were relevant to higher education were different. One participant asserted that:

> *to design a course on fractions for a 6-year-old, for a 10-year-old is totally different from designing it for a 19-year or 18-year-old. I mean, the whole thinking process, logic, the interpretation – all of that – is very different.*(AM1, L110)

At university, there is an expectation then that higher order reasoning with the concepts were required. The same participant added:

> *A point worth noting, though, was that some of the numeracy practices alluded to moving between concepts and different representations of those concepts which expected a level of combining, or unpacking, of mathematical concepts in contexts*. (AM1, L110)

This highlighted the multiple processes that were inherent in numeracy practices. Situations that required numeracy did not manifest as simple activities.

Although participants focussed on numeracy relating to basic mathematical concepts. Some, however, took this further, understanding numeracy as involving the use of different mathematical procedures (including more complex, and less 'everyday' processes) to make meaning of numbers in a particular context and know implicitly whether they were correct or not. One participant explained this:

> *When I was doing my PhD I had a supervisor. . . . I had these long calculations – like really complicated – and now I'm feeling quite good about it, because I've got some numbers which make sense, and so on. He just took one look at it. [He says, "Sorry man. It's wrong." So I said, "What? Why?" But his level of*

> *numeracy in that field was at such a level that he could tell just by looking at some of the numbers that, actually, it didn't make sense*. (AM1, L 194)

In this example, numeracy was seen as not being limited to basic concepts of mathematics but rather was used with complex and higher levels of mathematics as well.

Notably, participants made a very strong connection between mathematics and numeracy. However, as the interviews progressed they identified other aspects of numeracy that were unrelated to mathematics as a discipline. One participant said:

> *It suddenly occurred to me . . . when I was thinking about my presentation at Numeracy Symposium that's there a difference between mathematics and numeracy. Like, you can ask somebody who's a mathematician – done mathematics up to Grade 12, or first year or second year – but is still innumerate. Like there are different skills involved.* (AM1, L 143)

Two points surfaces from this response. Firstly, the suggestion that the difference between numeracy and mathematics was not something known explicitly and secondly that success in Mathematics may not imply that the person is numerate. Participants' examples of numeracy suggested contextual knowledge and higher order reasoning as being necessary.

In some instances, participants mentioned that direct application of mathematics operations could yield an inappropriate numeracy response, since the mathematical solution may not make sense in that context. One of the managers in the study provided this example in respect of the concept of scaling:

> *It's so easy to show that if you take a rat and you see a rat, you going to create a giant rat simply by scaling it up. But that would be [a] nonsensical thing to do, because the rat won't survive. So although you can just do the scales – because it's very easy to, mathematically, do the scaling, because scaling is very easy – it may be technically correct but nonsensical*. (AM, L 148)

In respect of numeracy or quantitative reasoning, these perspectives emphasized that contextual sense-making is as important, if not more important, than mathematical competence. This is an important domain that emerged in the data that will be discussed later in this chapter.

A related 'field' which is now also a formal secondary school subject in South Africa Mathematical literacy is arguably more aligned to numeracy or quantitative reasoning than to mathematics because of its focus on the application of mathematical concepts to solve problems within real life contexts.

6.3.1.2 *Numeracy and statistics*

Initially, statistics was seen as a 'strand' of mathematics. Over the years it has evolved into its own academic field. The specialized knowledge, vocabulary, procedures and processes related to statistics are included in numeracy in higher education. When describing numeracy in higher education participants mentioned the importance of concepts such as probability, permutations and combinations, and descriptive representation and interpretation of data – including frequency distributions, tables, charts and graphs, calculation of central tendency (mean, median, and mode) and variations, at the undergraduate level.

Some of the participants who supervised students' research described numeracy in respect of statistical analysis and interpretation in research. Numeracy/Quantitative Reasoning was described by them as being able to understand and make sense of the complex calculations done by a statistician or a computer application analysing the research data. One participant drew attention to the lack of this type of numeracy among post graduate students:

> *Because even if you speak to some supervisors they indicate that students will get a result and they will include it – and then supervisors will say, "But it doesn't make sense!" and the student how no idea why* (AM2, L 499).

Another shared similar response of numeracy in higher education being about the need for students to have adequate knowledge of statistics to be able to analyse their research data accurately and meaningfully:

> *I think there has been less emphasis, for instance, in terms of statistical analysis – that is where the student battles the most – and in terms of being able to interpret or decide what stats to use. . . . Do I use frequency or do I use probability? . . . And when SPSS has thrown it out for them, they don't know what it means, how to interpret it and why.* (AM2, L 131).

In respect of the numeracy practices associated with statistics, participants appeared to give greater emphasis to recognizing the correct statistical processes, interpretation of analysis, and inferring from the data and less priority to procedural fluency suggesting an alignment to statistical literacy rather than abstract statistics that need to be as studied by statisticians.

6.3.1.3 *Numeracy and finance, accounting or business*

Participants across most of the programmes included in the study alluded to the need for students to achieve competence or mastery of finance and business-related knowledge and skills as part of 'being numerate'. Among the seven programmes in the study, at least six programmes resulted in qualifications where graduates could have their own practices/businesses such as health science professionals.

So in essence, the numeracy referred to by the participants in these programmes included calculations pertinent to businesses: for example, calculating profits, surplus, break even, or inflation. This could have been described as typical disciplinary-specific expectations had the programmes been from commerce faculties. However, only two of the seven programmes had some link to business-related industries. In fact, one of the programme curriculum leaders made the point that they do not use accounting practices, such as creating profit and loss statements, but rather use business or finance-related numerical calculations, which she described as numeracy.

> *Although it sounds like accounting, it's more based on physically doing – as opposed to just writing it on a spreadsheet like an accountant would do. We have to apply the accounting, as opposed to being a bookkeeper*. (PG 5, L 50).

This quote highlights that being numerate implies not only being able to perform financial calculations but also to make judgements and informed decisions based on those calculations appropriate to the context.

6.3.1.4 *Numeracy and discipline knowledge*

Almost all participants referred to numeracy or quantitative reasoning in undergraduate programmes as being specific to their disciplines. Whilst there is an obvious rationale for understanding the varying conceptions of numeracy as a result of the varying disciplinary and professional contexts, there are also forms of knowledge in numeracy or quantitative reasoning that are particular to the programme. In one of the programmes they introduce the concept of breaking time into decimal minutes, for example.

> *In your approach and breakdown, it takes 0.35 of a minute to actually close two shoulders and ten you add up your entire operation breakdown. So your centi-minutes are always in decimal units. Anything in terms of working on the whole side is in the whole minute – the sixty-second minute. Thereafter, it's broken down into the decimal or the metric minute. We can't work in 60 second because it's too difficult [for] you work with that: even our stop watches are in metric time.* (PG1, L 63)

In this quote it can be seen that the concept of metric time is introduced which is not understood in the same way as decimal is normally used. This illustrates how mathematical concepts are interpreted and used in different ways in different disciplines.

In summary, then, the knowledge domain of numeracy is seen to draw on knowledge from different disciplines and fields. In this study, numeracy is shown to be connected to concepts and procedures from mathematics mainly and then also extended to statistics, business, accounting and finance. While some of the concepts are familiar, engagement with them in higher education expects different understandings than what students have previously been exposed to. Although participants linked numeracy to the different disciplines and fields mentioned above, they also suggested that numeracy is not limited to any one of these fields and actually refers to skills, practices and attributes that go beyond those engaged with in the disciplines mentioned. Lastly, there is knowledge in numeracy or quantitative reasoning that is specific to the profession and therefore is part of the programme.

While particular conceptual understanding and procedural fluency is core to numeracy development, numeracy cannot exist on its own as an abstract discipline. It has to relate to a purpose within a context. The next section draws out another crucial theme that emerged from the data and is also central to participants' understanding of numeracy. This relates to the contextual domain.

6.3.2 The contextual domain

As demonstrated in the previous section, participants' conceptions of numeracy ranged from a focus on mathematical calculations to greater tacit contextual numeracy practices. Being numerate expected that there is an understanding of a concept as it related to particular contexts. One participant explained:

> *That's what numeracy is about: [it's] understanding that a number as it stands there is a symbolic representation of something. It gives meaning to something and we need to understand what that meaning is – and, also, not only where it comes from but what that meaning is for*. (AM3, L 37)

This notion that in numeracy even numbers cannot exist without a context to give them meaning is aligned to the NLS perspectives on numeracy or quantitative reasoning that suggests that numeracy practices are contextually bound and can change based on the specificities of the context.

In the data, references were made to various contexts. The contexts in the data spoke to individuals' numeracy practices in relation to their personal existence and development, professional growth and societal responsibilities. Participants described these while providing examples of everyday, academic/scholarly, disciplinary and professional contexts.

Initially, participants made reference to what they called 'everyday or 'common sense' practices. Participants provided examples such as:

> *Money: that basic simple thing. If you are not sure of your change then it can be very easy for people to give you the wrong change. That's the simplest thing that we are talking about.* (PG5, L102)

> . . . *buying washing powder you need to know which gives more value for money, or following a recipe, you know put 10 ml or baking powder, put so many ml and so many grams. If you don't know that – I mean I am just thinking a lot of products say put 15 ml or 50 ml when they're diluting the disinfectant.* (PG 5, L134)

Examples were mostly provided around household management and personal finance planning. At this level participants' conceptions of numeracy suggested that these practices are tacit. The everyday contexts predominantly related to the numeracy demands of personal life. In these situations, there were very little formal calculations, or very basic calculations if needed at all. These were also generally mental calculations. The notion of estimating or having a 'rough idea' of the correctness of the solutions was important.

There were, however, a few descriptions of numeracy practices in everyday contexts that required higher levels of cognitive engagement such as decision-making. One participant provided the example:

Take a student for example, looking at something as food, is it cheaper to buy your food daily or is it cheaper to actually cook? We could argue that – because if you cooking for one person and you using electricity, you are paying for all of those things. It actually affects your quality of life and your lifestyle. (PG 5, L 99)

In the everyday contexts, it did appear as if number-sense, money-sense and measurements dominated the knowledge described as being expected of a numerate person. All examples provided by participants of numeracy in 'everyday' contexts involved performing a task/an 'act' such as diluting disinfectants, choosing to cook or collecting the correct change.

Another distinct context participants referred to was academic. This included numeracy practices learnt at school, generic numeracy or quantitative reasoning modules taken at university or numeracy practices related to the programmes or the demands of the professions. The contexts mentioned varied and degrees of complexity of the contexts increased over the years of study. In the higher education context, Galligan (2011), Frith and Prince (2006) and others differentiate this as 'academic' numeracy practices. Academic numeracy practices expect that one can read and understand the context, recognize what needs to be done and act accordingly to communicate the results or implications. Within this context students experience, or are exposed to, numeracy demands in written texts as well. The evidence of performing appropriate numeracy practices is often in the form of written or practical assessments.

Most programmes prepared students to practice their profession as an employee of an organisation or to run their own practice. Therefore, the numeracy expectations within the programme were also in relation to two broad categories: the business/finance/entrepreneurial contexts, on one hand, and the more professional aspects of the discipline and programmes, on the other hand. Speaking about the professional/disciplinary context, one participant said:

They will use it in applied photography techniques and also in visual communication. Because once you have taken these photographs you have to resize them for the report and portfolio. The resizing will impact on quality, so

> *you have to make sure you not compromising quality with the dimensions used and also you have to know the level of clarity expected in different set-ups, for example the quality in the report it is slightly less important that the quality for the applied which goes into your portfolio.* (PG 3, L 368)

Equally important to some programmes is the development of numeracy or quantitative reasoning as it relates to the business context. What was evident, though, even in these contexts was that numeracy practices were implicit and often happened unconsciously. The focus of the activities was part of other courses in the programme or practical professional practice.

The examples offered by the participants also included the context of being a numerate graduate. The same broad contexts of disciplinary specific and business related areas prevailed in this space. However, here the focus was to a greater degree on the 'practices of the profession'. As an example, there were numerous numeracy practices that graduates were expected to be able to do in their heads as part of professional decisions such as administering a particular drug or choosing to buy products. In this context, numeracy was directly related to professional judgement. One manager said:

> *It has caused a lot of problems, to be honest. A lot has happened. For instance, even being able to know the drips – how many of those drips are appropriate at what time interval for a one month old baby. Those kind of things. We don't call it numeracy – we just call it nursing*. (AM2, L 290)

Another participant said:

> *If you talk about quantitative reasoning, I would imagine that is more in line with what we also do. Because you are using numbers to justify your clinical judgment or assess with your clinical reasoning, as well*. (PG 5, L 52)

Interestingly, in one example provided, the participant combined the numeracy of the professional/disciplinary part of the programme with the business/financial management part of the programme. The example highlighted the role of numeracy, where the graduate is expected to make a decision between their role and responsibility as a therapist against the financial benefits. There is a need to know which numbers are of greater importance in terms of the context:

> *The other one for calculations is your peels. When you doing alpha hydroxic peels, you got to know your pH balances and understand that if you go below the pH from a therapy position it's probably gonna be sitting between 2 and 5. But if it's going from a pH of 3 it doesn't matter how high the pH is. So if you getting a discount, you can buy these ones and – say it's a 20% discount – if the pH is 3 and above then it will be effective. So if I don't know about pH and numbers then it will be silly. I have to know that my pH is going to be 3 and then 20% is gonna sound like it's important to me. And if the doctor is doing it, he will do it at 2 or 2 and a half. So I have to know that a pH is more valuable to me as a therapist than trying to sell me a higher of 10 to 20% discount.* (PG 5, 698)

This example suggests that while something may sound like a lucrative deal, it defeats the purpose if it cannot be used by the therapist in their practice.

Beyond the understanding of the numeracy of a graduate as integral to the practice of their profession, specific numeracy development was expected for further academic qualifications. Here the context of research became an important consideration as well. In this space making sense of texts in the form of journal articles, performing statistical calculations and interpreting these in the contexts of the study were important. Another key practice was to write about, and with, numbers in a context. These practices seem to be different to those expected in the 'everyday' contexts described previously. In the case of quantitative research these practices were more explicit, however there were elements of the quantitative text sense-making – especially in post-positivist research – that appeared implicit.

Contextual sense-making was thus as important as conceptual understanding in participants' conceptions of numeracy. While each context brought with it contextually-bound specificities, it was possible to look at some commonalities. These distinctions were in respect of what participants described as everyday contexts, higher education programme and discipline contexts and graduate preparedness contexts, which included personal and professional contexts. What seemed prevalent in this case study was that in the higher education programmes, and in preparing students to graduate with the knowledge and practices they needed for their profession, the contexts of the discipline and the future workplace were dominant. Another key feature of numeracy in higher education and in the future workplace was to engage with numeracy through written texts. Across all contexts the numeracy practices appeared predominantly to be implicit – manifested in the 'solution' to the problem being addressed. While implicit, these practices were used in contexts with varying degrees of complexity and levels of conceptual understanding, possibly involving varying levels of cognitive demand.

6.3.3 The cognitive domain

The data revealed different levels of cognitive demand required for numeracy in the examples provided by participants, depending on the complexity of the contexts and the concepts involved. While in some instances reference was made to procedural mastery of learnt processes, these were expanded on during the interview.

Most often, numeracy was described as requiring conceptual understanding of the specialised knowledge in the context and of contextual sense making. While procedural knowledge in the form of arithmetic procedures was sometimes seen as numeracy or being numerate, in most instances a higher level of cognitive engagement was seen to be necessary, expecting a deep understanding of the concepts that informed calculations. One participant said:

> *I think it has to do a lot with understanding the concept behind each and every arithmetic calculation. This is the thing that I always stress with them in class: it's not a matter of getting the right numbers, it's a matter of understanding what is it that you are calculating*. (PG 1, L142)

During the course of some interviews there were shifts towards an underplaying of procedural knowledge and an expectation that being numerate implied being able to apply their conceptual understandings in particular contexts at a higher level than mastery of procedural knowledge. One participant said:

> *Numeracy is important in that people have to be able to understand what numbers mean – not necessary be able to add, but to be able to see where something is wrong and is not making sense. And to me that is what is important*. (AM2, L 34)

Another participant said:

> *I think that numeracy for me would include QR, for which it will have to have some maths literacy so for me. It's not just maths, it's about that interpretation of the numbers: applying that to your work situation, using that to analyse situations to reason about what you see in front of you*. (PG 2, L 90)

Within the cognitive domain there appeared to be a hierarchy of cognitive levels in respect of what was described as numeracy or being numerate. It became apparent that numeracy in higher education was not simple or basic or foundational only, but involved a range of cognitive levels. Also, the data suggested that there was a notion of intuitiveness, or common-sense or tacit mental practices, expected even though cognitive demands were high in certain instances. Numeracy practices were often immersed in, and masked by, other practices.

6.3.4 The practice domain

Numeracy was often seen by participants as being intrinsically purpose driven. It appeared to be an inherent part of broader practices such as clinical judgement. So there appeared to be a "life preparedness orientation" (Venkat, 2010, p. 55) that was valued in certain descriptions of numeracy. The examples used to describe numeracy often associated it with an action or task, whether in an everyday, academic or professional setting. Everyday contexts included managing household budgets, diluting a detergent or choosing the most appropriate cell phone contract, where the numeracy practices that were required are generally not dependent on having a formal education in mathematics or numeracy but are acquired through life experience and exposure to the practice of others. These numeracy practices were usually not linked to a particular language either.

In the higher education context, the numeracy practices that were required were also intertwined with other literacies, such as engaging with academic texts (both reading and writing) or critical thinking.

In some instances, numeracy was seen as a specific type of literacy. In other cases, the relationship between numeracy and mathematics was equated with the relationship of literacy to language. One of the key informants used the term ‘numeracies’, saying that as with literacies there are multiple forms of numeracy. From the quote below, one can identify multiple numeracy practices. One participant said:

> *There is a difference in terms of a numerate graduate compared to other numerate persons, because one, for you to be able to interpret exactly what the stats mean, you have to be able to write exactly and make the reader understand what you had done with that and the decision you are taking based on those figures to a degree. I think there is a difference in terms of what the normal person will be able to understand and someone who has been to higher education and the manner in which they present the figures and interpret them.* (PG 7, L 321)

This comment firstly highlighted the notion of different numeracies and demonstrated a concept of numeracy in higher education as inclusive of the following practices of other literacies as well such as:

- reading quantitative texts
- story telling through and with numbers
- communicating through writing and
- critical thinking

In fact, two programme developers equated numeracy and quantitative reasoning with critical thinking. Viewing literacies as practices suggests that there could be both a skills/competence requirement and an affective domain associated with numeracy. These include certain dispositions/habits of mind that are expected of 'numerate' students or graduates which, again, are specific to the contexts in which they are used.

6.3.5 The affective domain

Typically, scholarly engagement is seen to be strongly related to the cognitive domain. Also, as a phenomenon closely related to mathematics, numeracy is often seen to have similar properties to mathematics, which is focused mostly on cognitive areas. However, in the data 'being numerate' was also described in relation to affective attributes such as attitude towards numeracy concepts and practices. One participant said:

> *For me, it's that mind-set they have towards numbers, so for me it is something above the calculations*. (PG 5, L 422)

As discussed earlier, numeracy is associated with expectations of both conceptual understanding and of contextual sense-making. Particularly when making sense of contexts, one would need to recognize and focus specifically on numeracy situations or moments without ignoring the parts of the context that require numeracy engagement. Some participants spoke of students' dislike and anxiety associated with numeracy which resulted in them avoiding anything involving numbers or linked to mathematics. They described 'being numerate’ as being comfortable and confident with numerical concepts, procedures and applications.

One of the academic managers shared details of a special project in the United States of America on the development of numeracy, to make the point that numeracy development requires the development of the affective domain as well.

> *Generally, numeracy development focusses on working with the cognitive domain, - can you do these things logically- But actually what they are finding there in these programmes called pathways – QuantWay, StatWay and MathWay – is that there is a huge component of the affective domain that needs to be negotiated. These pathway initiatives ‘unblock’ students mind and encourage them to engage in numeracy, which makes the cognitive development easier.* (AM3, L 204)

Together with the dispositions and habits of mind of being confident and comfortable, participants noted that numeracy also involves making judgements and taking decisions. These actions are value laden. So, while it is possible to mathematically perform the calculations that justify a decision, the decision itself is based on values. This suggests that numeracy is value-based.

The affective domain therefore can be seen to focus on two broad areas. Firstly, the confidence and ease that stem from having a strong conceptual understanding of the specialized knowledges and procedures which make it possible to negotiate between concepts; also, the confidence and ease with exploring information requiring numeracy that contributes to understanding a context. Secondly, being able to question and be critical of the values that decisions are made on and reflect on the fairness of the consequences of those decisions.

In summary, then, the thematic analysis of the data revealed that conceptions of numeracy highlight an integration of knowledge, context, cognitive, practice and affective dimensions. In the next section, further insights are derived by analysing participants’ conceptions of numeracy using the Specialization and Semantics dimensions from the LCT toolkit. This allows for an exploration of how the different components of numeracy that have been discussed talk to each other in terms of knowledge, knowers and context. This is complemented with an analysis of the cognitive demand associated with numeracy practices.

6.4 Conceptions of numeracy: an exploration using Legitimation Code Theory (LCT)

Having thematically identified the multiple domains of numeracy, a deductive analysis was undertaken to explore the organizing principles of legitimation of numeracy in higher education. The data was analysed using two of the five dimensions from LCT: The Specialization and Semantic dimensions, which were discussed in depth in Chapter 3.

6.4.1 Conceptions of numeracy: Analysis using LCT Specialisation dimension

Specialization is a dimension of the LCT toolkit that is made up of two concepts: Epistemic Relation and Social Relation. Epistemic relations refer to the relationship to specialized knowledge and can either be stronger (ER+) or weaker (ER-). Social relations, on the other hand, refers to the relationship to the actor or subject and can also be either stronger (SR+) or weaker (SR-). It is important to remember that SR- or ER- does not necessarily imply that social relations or epistemic relations do not exist, but rather indicate that these relations play a minor role. When both these concepts are presented on a Cartesian plane, four quadrants are generated which can be used to represent four interactions between the two concepts, which are termed ‘codes’. The four codes generated from the intersection of epistemic relation and social relation dimension are the knowledge code, which has a stronger epistemic relation; the knower code, which has a stronger social relation; the elite code, which has both stronger epistemic and social relations; and the relativist code, which has both weak epistemic and social relations. The Specialization codes are represented in Figure 6-1.

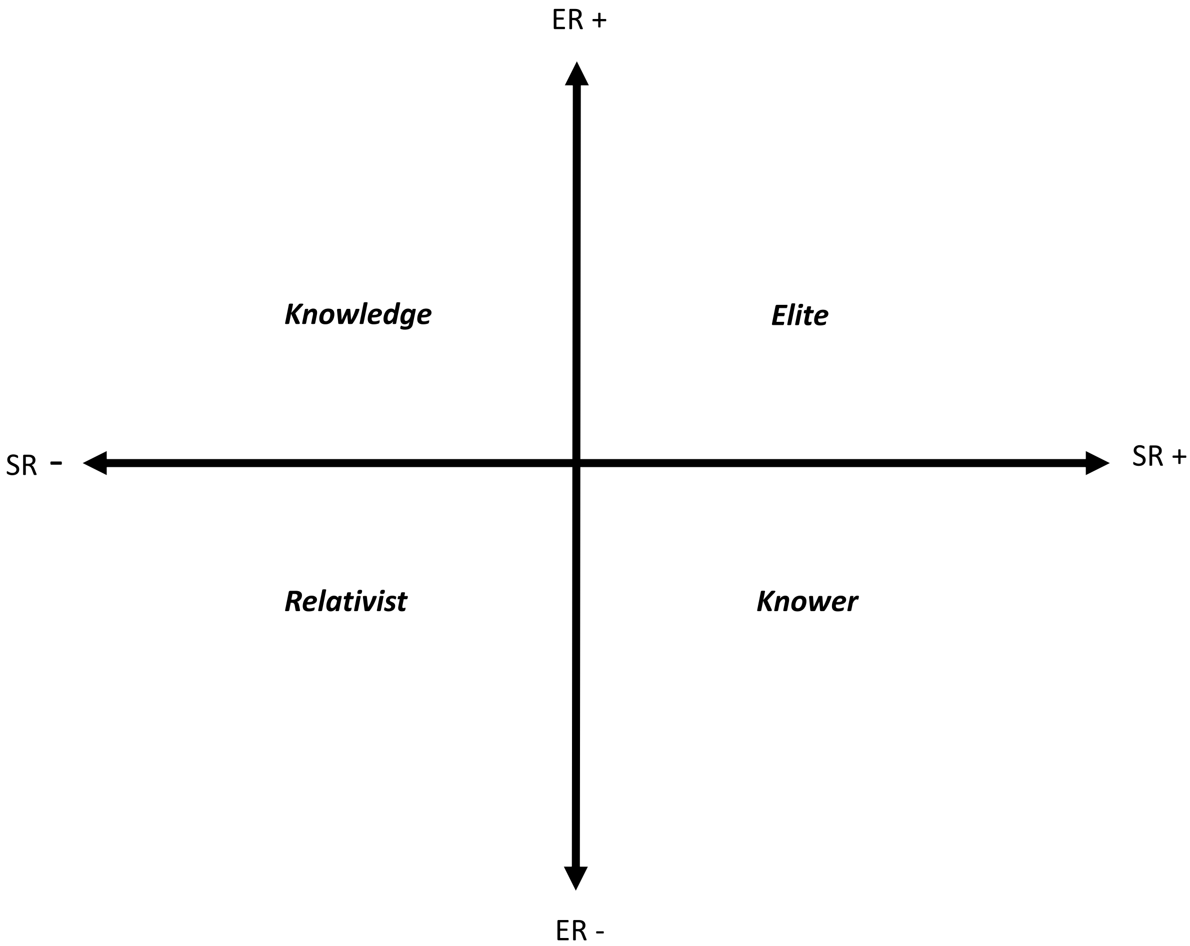


Figure 6-1 Specialization Plane

In order to undertake this analysis, it was important to be able to connect the data to the theory and the theory back to the data. A translation device was created to ensure that the coding and mapping of the data was consistent. Table 6-2 shows the translation device used for this analysis.

Table 6-2 Translation Device: Specialization analysis of the institutions conception of numeracy

Aspect	Concept	Description of concept	How concept can be manifested in the study	Examples from data
Epistemic relation	**ER+**	Knowledge, skills and procedures that are strongly bound and controlled	Emphasis is on specialized knowledge: for example, mathematical concepts and procedures	This requires ratio and proportion background. A percentage increase and decrease where the student has to be able to apply these and perform the calculations. . . . so the mass of an object is kind of proportional to its volume, right? So you know, the bigger the volume of something the bigger the mass – this is assuming that the density doesn't change. Volume: it's length – cubed, right? So if you calculate the volume of a box, it's length times length times length: length cubed, right?.
	ER-	Knowledge, skills and procedures that are weakly bound and controlled	The specialised concepts and procedures are underplayed and there is some degree of overlap with other disciplines or contexts	For us it will be like to the ability to reason clinically, so that you can base some judgments on whether you proceed with a certain action on your treatment plan, quantify things – for instance, things like blood pressure, that is similar to things like your glucose level: that is all quantity. Taking all of these qualities in account, now you have to clinically use your physiology and bring it together. So, for me, it can't be separate.
Social relation	**SR+**	The subject as the author is emphasised	Emphasis is placed on dispositions and habits of mind	there is a logical brain, confidence, everything, the men, 10 time better with machinery At what point are you numerate? To me it's more than just "Can you do ABC at this level?" It's more an issue of culture. It will be critical thinking in everyday sort of situation.
	SR-	The subject of the author is downplayed	Dispositions and attributes are downplayed	Follow the correct procedures and perform the four operations.

Using this translation device, the various definitions of numeracy or characteristics of 'being numerate' and the examples of numeracy provided were analysed. This is presented as scatter points on the Specialization plane in Figure 6-2.

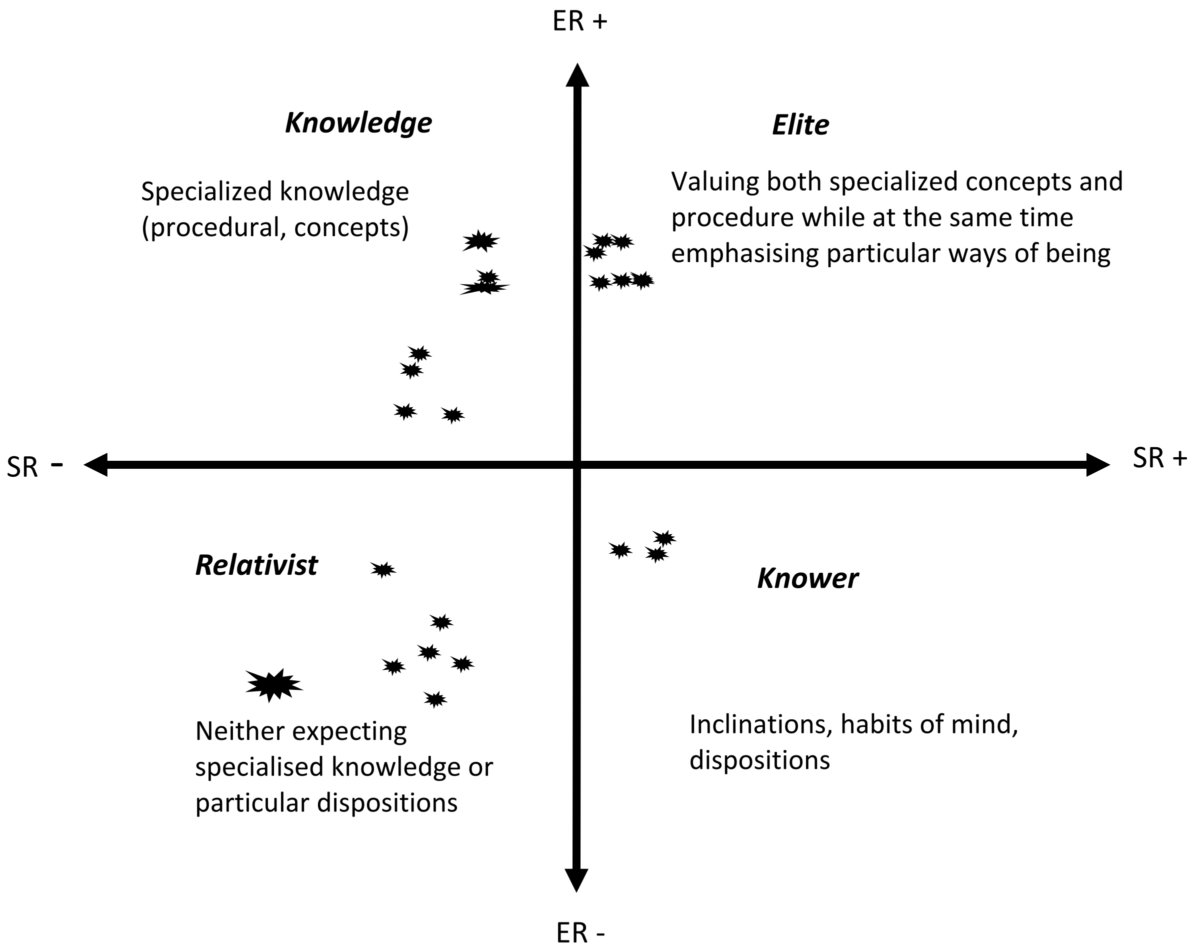


Figure 6-2 Specialization analysis scatterplot of conceptions of numeracy

As can be seen in Figure 6-2, the data was scattered across all quadrants. This suggested that the legitimating principles of what was described as numeracy or being numerate varied across varying legitimation of social relations and epistemic relations. These results imply that there was valuing of knowledge dominant practices, knower dominant practices, of a combination of both simultaneously in some instances and practices that could be acted on without any explicit specialized knowledge or dispositions. At a surface level this could be interpreted as suggesting that numeracy actually did not have legitimating principles. However, on deeper analysis, this indicates that the legitimating principles of numeracy varied. It is important to note that this variation existed across the different data sources but also within the examples or definitions given by a particular source as well, suggesting that participants' conceptions of numeracy spanned across the different combinations of varying strengths of epistemic and social relations.

To delve deeper, the data that was coded in each of these quadrants were clustered together and examined to establish if there were any patterns or trends that differentiated them. What became evident was that it was possible to map these clusters to the curriculum time line. Figure 6-3 represents the dominant codes at different points during the undergraduate programme. I must highlight that this does not mean that there was not mention of strong procedural and conceptual knowledge at graduation but these were not the dominant numeracy practices identified. Also, note that what was the knower code above has become less distinct in Figure 6-3 because it did not show any distinct dominance in relation to the curriculum timeline but rather was present more subtly at each phase. In other words, aspects such as dispositions or attitudes were present at entrance and first year but to a lesser extent.

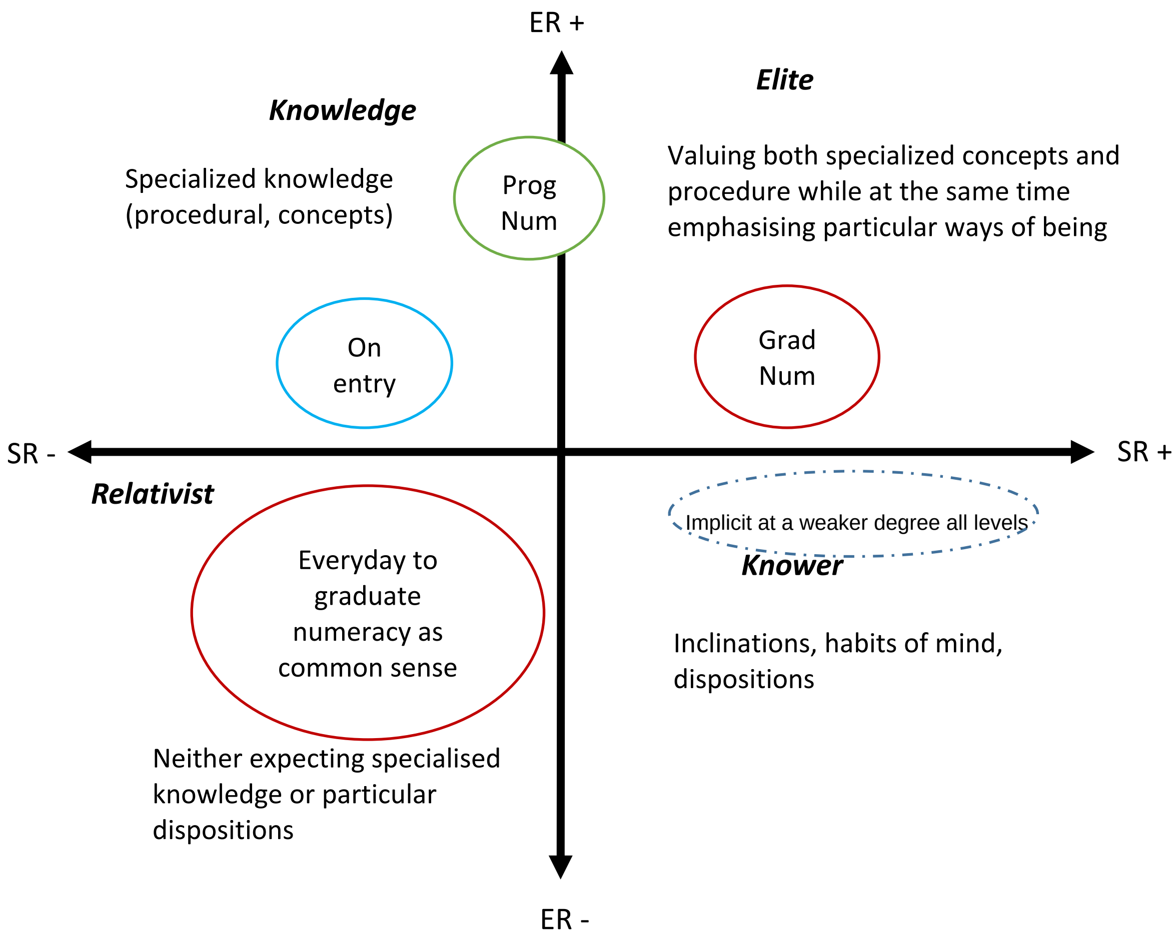


Figure 6-3 Clustered Specialization analysis of conceptions of numeracy

It was found that the data in the knowledge code could be split between those that referred to knowledge of simple concepts, symbols, calculations, procedures and those that that referred to conceptual understanding in greater depth that was necessary to deal with the numeracy demands of discipline modules within the programme – for example, such as rates of change. In the knowledge code (ER+SR-), that included procedures, symbols and vocabulary, this was mainly described with examples in the interviews and documents of being on entry expectations (denoted by the blue circle) such as students should be able to calculate percentage, perform basic operations or first year necessary development. The clustering around conceptual depth, which is slightly higher in the knowledge code and overlaps the elite code, was mainly in reference to programme demands of numeracy (denoted as 'prog num' in figure) implicit in other course modules. The data in the elite code (ER+SR+) was mainly in reference to the numeracy expected of a graduate in their profession or in society (denoted as 'grad num' in figure 6-3). Within the knower code there was slight differentiation in respect of developing confidence with numbers at first year and more critical dispositions at graduate level. At graduation level the strength in the social relation and epistemic relation suggested combined legitimation of particular knowledge and particular knowers

The relativist space (ER-SR-) was commonly described as 'common sense'. However, the data suggested different types of common sense: that based on prior everyday experiences and others based on some level of scholarly experience. Most examples used to describe numeracy or being numerate at a graduate level also fell within the relativist code. In fact, there was dominance of numeracy ranging from everyday practices to everyday professional practices that were described as intuitive and as falling within other practices, such as clinical judgement in the context of treatment. It may seem strange that what is described as application of complex concepts within complicated contexts is coded as relativist. Remember that relativist implies that there is more than one form of specialised knowledge that can be used in performing a practice. The interpretation of this important finding is discussed in greater detail in Chapter 8.

The LCT analysis presented in Figure 6-3 highlights that the organizing principles of what was described as numeracy appeared to be different on entrance and exit of the undergraduate programme. It was noted that this is aligned to the New Literacy Studies (NLS) perspective of multiple numeracies. Within this perspective, as discussed in Chapter 2, there is no real reference to innumeracy, but rather to different numeracies. These numeracies are ideological in nature and influenced by socio, cultural historical contextual factors. Analysis of the data suggested that it could be expected that how numeracy is conceptualised will be influenced by the existing numeracy practices – or perceived lack thereof – on entry to the programme and the numeracy practices that are anticipated to be required during the programme and, later, in the profession.

The Specialization analysis makes explicit the legitimating principles of numeracy in relation to strength of particular knowledge and knower attributes.

Another core dimension of numeracy evident in the data and noted in the literature is the contextual domain. The Semantics Dimension of LCT provided the tools and language to engage with the conceptual and contextual relations within numeracy. This is discussed in the next section.

6.4.2 Conceptions of numeracy: Analysis using LCT Semantics dimension

The semantics dimension of LCT comprises two concepts: semantic density and semantic gravity. Semantic density is used to unpack the level of abstraction and complexity of a phenomenon. Semantic gravity is concerned with the strength of context-dependence or independence. The combination of these two concepts generate four different codes on the semantic plane, as presented in Figure 6-4.

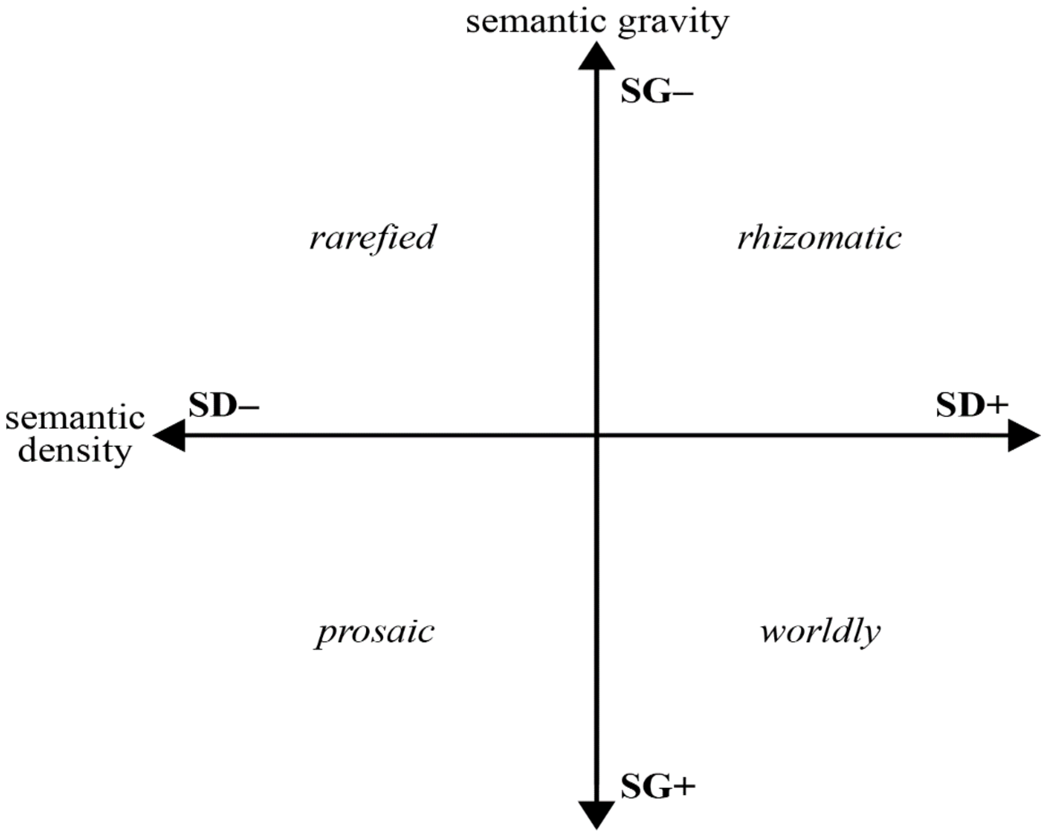


Figure 6-4 LCT Semantic Plane

As alerted to previously the representation of the LCT dimensions do not follow the principles of a mathematics cartesian plane. In the case of the Semantics, represented in Figure 6-4, it can be seen that SG+ is at the bottom of the vertical axis. This is because it represents a strengthening of semantic gravity implying stronger context dependence. The prosaic code represents strong semantic gravity and weaker semantic density. The rarefied code is indicative of weak semantic gravity and weak semantic density. The rhizomatic code indicates a weak semantic gravity and strong semantic density and lastly the worldly code is indicative of both strong semantic gravity and strong semantic density.

Figure 6-5 describes the relation of these codes to the study.

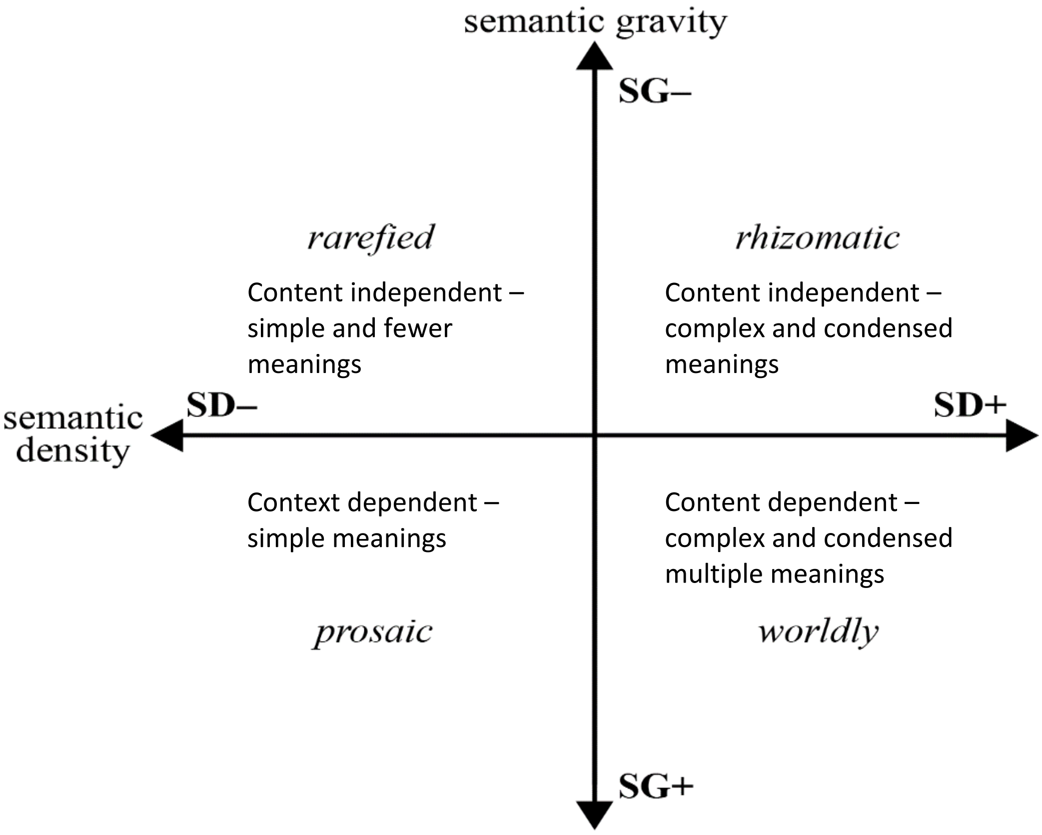


Figure 6-5 Description of Semantic Codes on Semantic Plane

The semantic codes in Figure 6-6 highlights the relation between contextual dependence and conceptual depth within each code. A semantic translation device was created to connect the data to the theory and theory to the data, as shown in Table 6-3.

Table 6-3 Translation device for Semantic analysis of conceptions of numeracy

Aspect	Concept	Description of Concept	How concept is manifested in the study	Examples from data
Semantic Gravity	**SG+**	Contextually dependent	Problem is based on particular context	What is our current unemployment rate? So, ok, the official rate is 27.7. And what does this mean and how many people in South Africa are in the 60 age group; how many people are working and how many are not working? What is the unofficial unemployment rate? What does it mean to have the official unemployment rate for youth?
	SG-	Contextually independent	Technical/abstract concept	To actually read a trend graph or develop a trend graph Perform operations of addition, subtraction, multiplication and division
Semantic Density	**SD+**	Complex concept: High condensation of meaning	Condensation of meaning	A higher level of numeracy that is very important would include, optimization: for example if I give you a sheet of metal and I want you to give me the most cost-effective way of producing a coke can from this.
	SD-	Simple everyday concepts	The concepts are everyday and non-technical	It's working with quantities – for example, diluting detergents

Using the translation device to map conceptions of numeracy that were expressed by participants as definitions of numeracy or being numerate and through examples of numeracy practices on the Semantic plane is represented below.

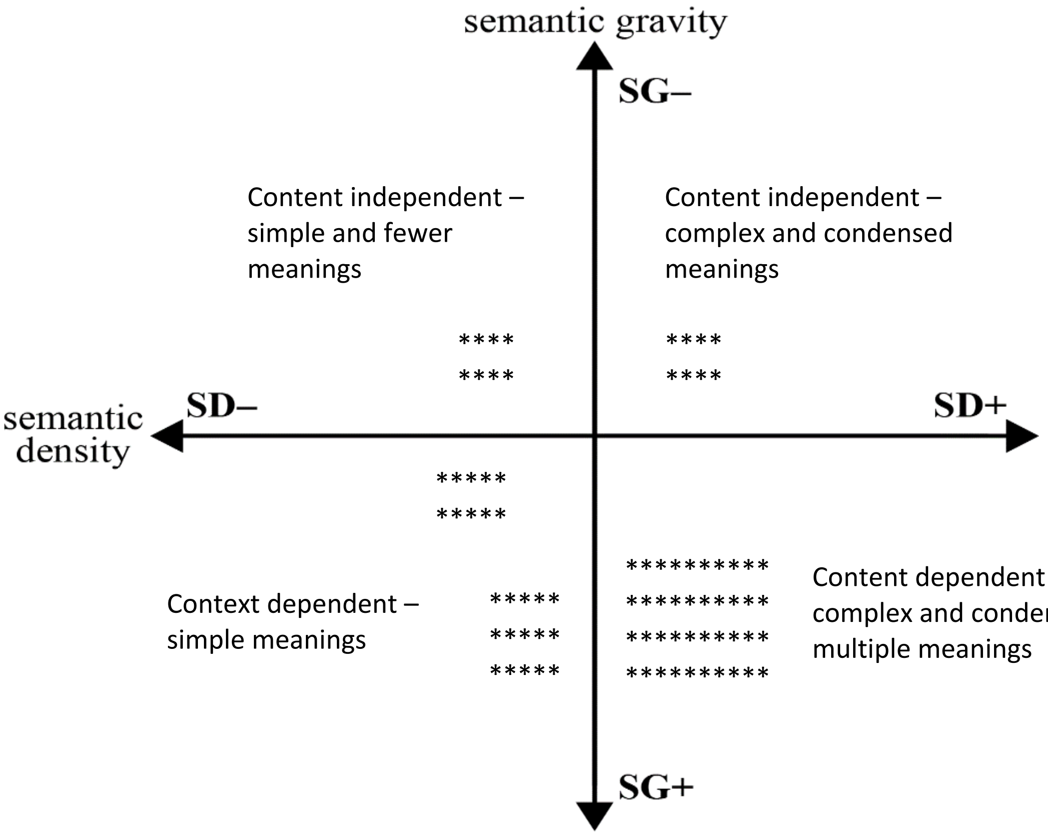


Figure 6-6 Analysis of conceptions of numeracy using Semantic dimension

Figure 6-6 highlights that the data around the conceptions of numeracy also appears to be scattered across the four quadrants. However, there is stronger concentration in the prosaic code (SG+SD-) and the strongest concentration in the worldly code (SG+SD+). The common definition of numeracy as being about use of simple concepts in simple, everyday situations was legitimated. However, the analysis also highlighted that numeracy was not limited to simple concepts or simple contexts but rather there was greater dominance of stronger condensation of concepts and numeracy practices being needed in rather complex contexts as well. What was evident, also, was the limited legitimation of the conceptions of numeracy being about mathematical concepts and procedures only: although it was present in the upper quadrants, it was not dominant. This was in direct conflict with the common perception of numeracy as basic arithmetic or the four basic operations of mathematics, which was found in some of the data. What was expected, in terms of numeracy practices or 'being numerate', required much more than basic knowledge of concepts and procedures.

A similar approach was taken to analyse the data using the Semantics dimension as was used with the Specialization dimension. The data in each cluster were re-examined to identify any particular patterns and trends. As was found in the Specialization analysis, clusters were found to correlate with different points along the timeline of the curriculum. Figure 6--7 shows the clusters on the Semantics quadrant correlated to points on the timeline of the curriculum.

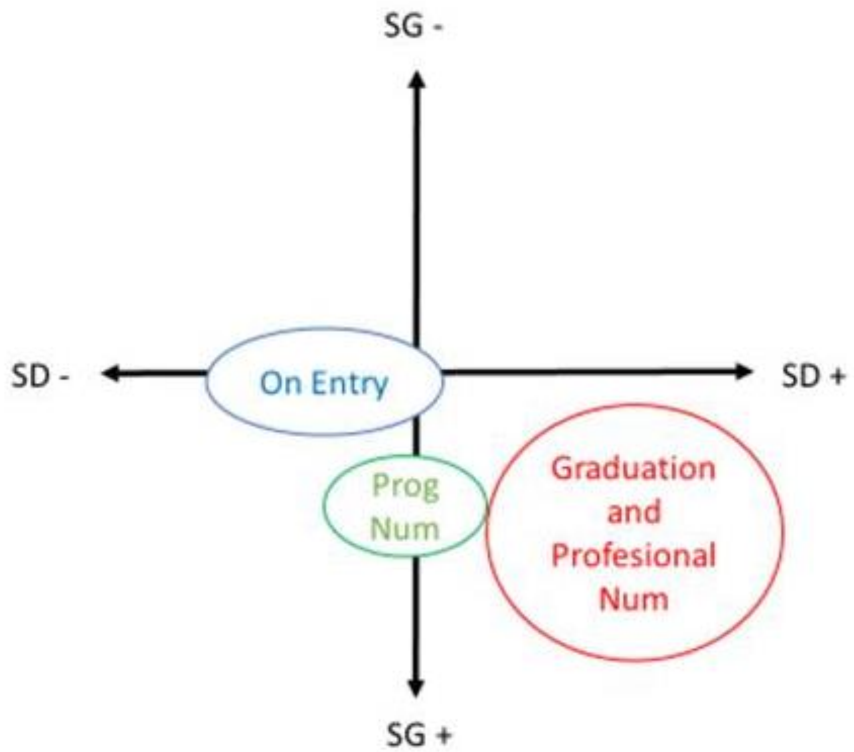


Figure 6-7 Clustered Semantics analysis of conceptions of numeracy

Descriptions of numeracy the *beginning of the programme* was found to prioritise concepts and some simple applications, such as calculations using operations with numbers in simple contexts. *During the programme* there are more instances of calculations required specifically for the courses in the programme. The data appeared to be split in this phase between the prosaic code and the worldly code but with dominance in the worldly code. In the prosaic code, numeracy referred to the application of concepts in simpler contexts and could take the form of word problems – for example, instances where you need to calculate how much of an ingredient needs to be added to another.

Mostly, however, there is dominance of numeracy in the worldly code. A numerate graduate featured mainly in this quadrant where there is expectation of the graduate, but also within the study of the programme, for students to engage with concepts that had a stronger condensation of meaning in more complex contexts.

Again, there was indication in both these dimensions of LCT analysis that there were different legitimating principles that may have been dominant in different understandings of what was meant by numeracy at different phases in the curriculum. The differences here seem to suggest the move from simple to complex contextual sense-making and from simple concepts to combined concepts that were more complex. As was found in the Specialization analysis, the ‘on entry’ numeracy expected evident in examples provided in respect of students entering the programme and ‘graduate’ numeracy expected in examples of numeracy practices expected on graduation phases were prominent, suggesting that curricula could provide opportunities for movement from the legitimating principles of numeracy that were prevalent on entry to those expected at graduate levels across the dimensions. The increase in semantic density also is aligned to the increase in difficulty along the epistemic axis of the Specialization plane.

During the analysis using the Specialization and Semantics dimension, I became aware of another construct which could not be captured within this analytical framework. This also featured as one of the thematic domains. The cognitive demand varied across different conceptions of numeracy and examples of numeracy practices. To present a more nuanced exploration of conceptions of numeracy within the institution, I conducted an analysis of cognitive demand. This is presented in the next section.

6.5 Conceptions of numeracy: analysis of cognitive demand

I found it was not possible to assess levels of cognitive demands from the programme curriculum documents. However, this was more explicit in the documents relating to the institutional modules and in the interviews.

Although, the LCT Semantics dimension allows for an exploration of levels of difficulty to some degree. In other studies this was often seen in terms of moving between concrete contexts to abstract concepts as discussed in the use of semantic waves by for example Clarence (2014) or Hartnett & McNamara (2020). This case did not offer the similar combinations of strong semantic gravity and weaker semantic density or weak semantic gravity and strong semantic density only but there were also instances of cognitively demanding practices of numeracy that required both conceptual depth and contextual clarity. I found that I could not relate the different cognitive levels articulated in the data to the cognitive levels of Blooms Revised Taxonomy of Cognitive Objectives (Pohl, 2000).

Instead I found the work of Porter (2006), who distinguished different levels of cognitive demands in the context of demands of mathematics, easier to adapt and create a framework to code the different levels of cognitive demands evident in the data around the conceptions of numeracy. Porter (2006) used the following levels basic level memorizing and performing routine procedures, communicating problems and solutions, solving complex problems and conjecturing and proving. The adaptation of these constructs in respect of conceptions of numeracy generated the levels of cognitive demand of numeracy practices, as shown in Table 6-4.

Table 6-4 Levels of Cognitive Demands Expected

Levels	Description of Level	Examples from data
Level 1	Memorization Known algorithmic calculations Procedural calculations: no connection	. . . the numeracy part of it that the student doesn't understand; certain things have to be kind or rote learning and those things they have to entrench . . . (PG3, L 226) I am thinking basic addition, subtract, multiplication and division. (PG 1, L21)
Level 2	Conceptual understanding of specific concepts Connecting concepts Application to routine contexts	It's someone who would have a knowledge of numbers, who is a quick thinker in terms of making decisions and if you saying you have to have a 20% marked down, a person would be able to know what that is. (PG 7, L 149) I think it has to do with a lot of understanding the concept behind each and every arithmetic calculate. This is the thing that I always stress with them in class: it's not a matter of getting the right numbers, it's a matter of understanding what is it that you are calculating. Because once you understand the concept behind calculation you will be able to see that there is no way I can get to this answer with this calculation. (PG1, L 142)
Level 3	Conceptual understanding of new concepts Making meaning of contexts Making informed judgments drawing on multiple knowledges, skills and process	. . . the ability to work with numbers, to recognize numbers, maybe identify a pattern. (PG 6, L 73) It also depends on how one interprets it: like we say students should be able to have that numerical analysis and be able to just justify whatever they doing. (PG 7, L 121)

Level 4	Meaning-making in complex unfamiliar contexts Tacit application of numerical processes and procedures Professional Judgements that balance mathematical accuracy with contextual sense	In our program, students have to administer drugs and there are times that they will need to – particularly when they are administering to paediatrics, because the dosages are less than what is required for an adult. So they have to calculate how to administer those drugs, because most of them are weight-based. So you have to work out what is the patient's weight and then how much do you give them. And also, when you give infusions, infusions are in milligrams per kilograms per hour. So you need to know: if this is the patient's weight how many kilograms do you give per hour. And then the infusion devices: although it is per milligram per kilogram per hour, it works on your administering quantity of medication per minute. (PG 4, L 9)

The data was reviewed using the framework described in Table 6-4. Numeracy practices were identified in the data in all four levels of cognitive demand. Some participants described lower-level cognitive demand in some of the numeracy practices which can be undertaken mechanistically, such as being able to count or perform basic mathematical calculations. On the other extreme, participants noted that the professions for which students were studying expected graduates to be able to perform calculations mentally, assess the contextual implications of calculations, make decisions and act on those decisions. In essence, numeracy practices ranged from basic and simpler levels to very complex, higher levels of cognitive demand. This is illustrated in Figure 6-8.

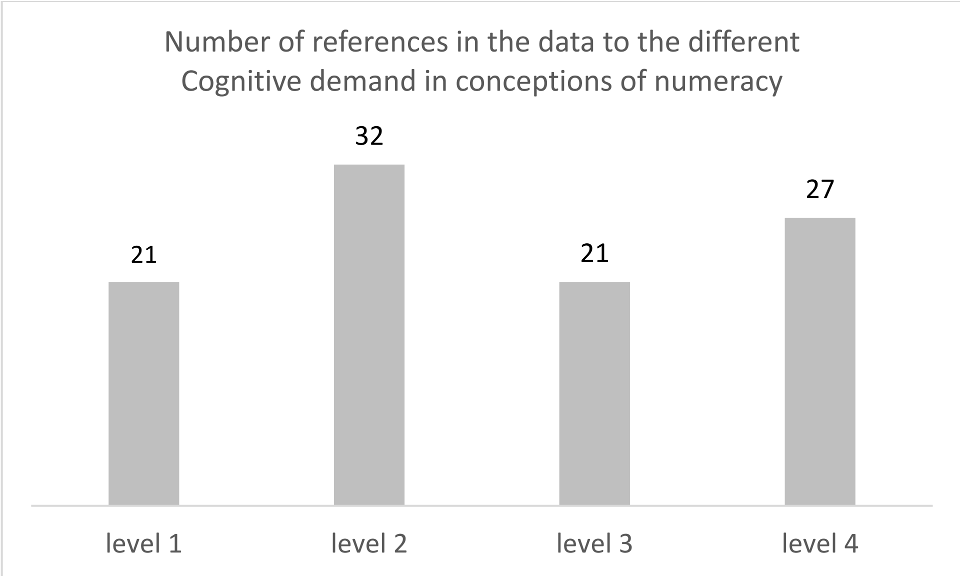


Figure 6-8 Levels of cognitive demand identified in participant's conceptions of numeracy

This graph highlights that what was described as numeracy varied in respect of the levels of cognitive demand. A review of the data at the different cognitive levels again suggested the dominance of particular cognitive demand levels at different stages of the curriculum. For example, it was found that initially participants described numeracy as being common sense knowledge of temperature or counting or arithmetic calculations and this they described in respect of what they expected students to know already on entrance to the programme. At graduation, however, there were more descriptions of numeracy requiring engagement with more complex concepts, sometimes in different contexts. This does not imply that this is the only levels at these stages but rather that there were more instances of what participants described as numeracy at these times. What actually was more fascinating though was that the different levels of cognitive demands were also evident in practices coded with similar epistemic and social relations so for example in terms of applying processes to contexts. These ranged from simple to complex concepts and simple to complex contexts, creating a range of cognitive expectations. Another variation that was fascinating was the description of what participants considered common sense in everyday, personal contexts across to specialized, professional contexts. Thereafter, I conducted an analysis combining the LCT Specialization analysis with the cognitive demand analysis to offer a more nuanced understanding of the principles of legitimation underpinning conceptions of numeracy within the institution. The next section presents the combined analysis, highlighting the underlying principles of numeracy practices in respect of epistemic relations, social relations, semantic gravity, semantic density and cognitive demand.

6.6 Combining cognitive demand with LCT Specialization analysis

The data plotted in each code from the LCT Specialization analysis was analysed again to identify the levels of cognitive demand expected, as shown in Figure 6-9.

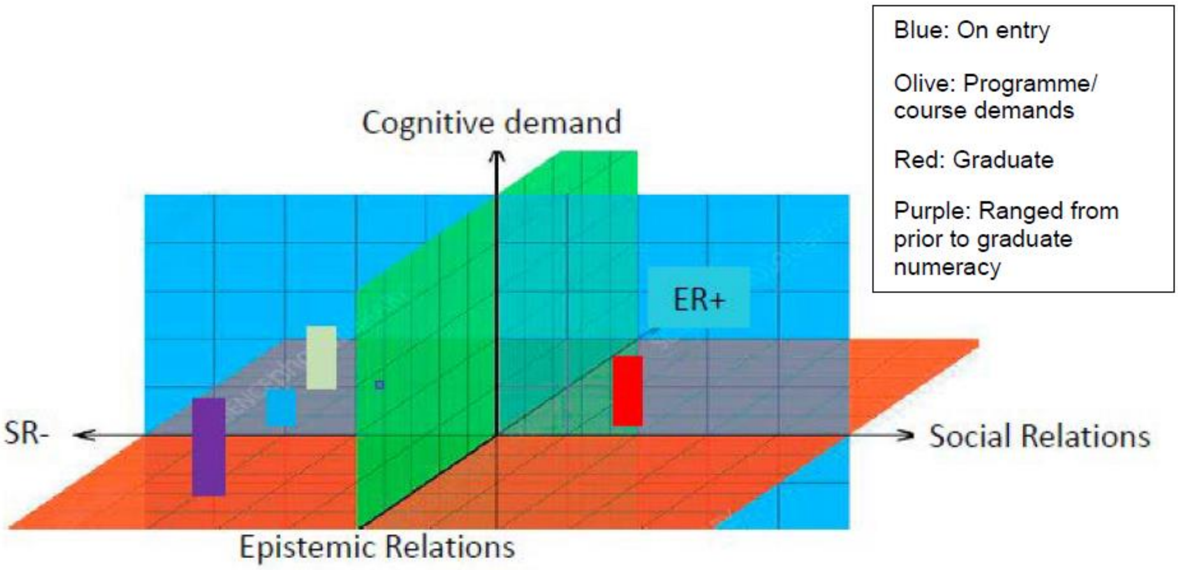


Figure 6-9 Cognitive demand in the Specialization analysis of conceptions of numeracy

Figure 6-9 represents the different Specialization codes created through the intersection of the epistemic relation (ER) and the social relation (SR) (on the red plane) with the level of cognitive demands (blue/green plane) dominant at different times in the curriculum. There is evidence of ‘common sense’, or intuitive, understanding of concepts at very basic cognitive levels that does not necessarily involve scholarly engagement with formal concepts; where both social relation and epistemic relation is weak (ER-SR-).

In this space there are also examples of numeracy practice such as those expected in professional practice that require high levels of cognitive demand, denoted by the purple band.

It can be seen for example that the numeracy spoken about in the initial part of the undergraduate programme which could be procedural calculations relying on stronger epistemic relation and weaker social relation (ER+SR-), which is known as the knowledge code. The data suggests that numeracy at this stage is less cognitively demanding since the focus seems to be on familiar procedures and knowledge that could be achieved through memorization represented by the blue band. This includes concepts from secondary education that are expected to be understood and applied in simple contexts within the discipline.

During the course of the programme itself students are more likely to engage in academic numeracy practices that relate to the new context of their discipline and also require a deeper conceptual understanding that goes beyond memorization or applying routine procedures. There is an expectation that known concepts can be combined and understood in relation to others and used appropriately to make sense of and act in situations. This suggests that greater cognitive demand is expected of the specialised knowledge as denote by the olive band.

At final year and/or graduation, the numeracy practices are valued through particular gazes and habits of mind such as being confident and at ease with numbers and having the conceptual depth to apply, synthesize and engage critically with numeracy practices to solve problems denoted by the red band in the elite code (ER+SR+). However, at graduation, numeracy also is described by the use of a variety of knowledges from different disciplines in varying contexts. It is in this space (the relativist code) that the expectation of 'common sense' numeracy corresponding higher levels of cognitive demand engagement appears as a contradiction.

The interpretation of this analysis is revisited in more depth in Chapter 8.

6.7 Conclusion

This chapter has demonstrated that numeracy is a highly complex phenomenon which seems to be legitimated by a range of organizing principles. This could contribute to the tensions and difficulties that arise when planning for numeracy in undergraduate programmes. A thematic analysis of the data relating to conceptions of numeracy within the institution identified multiple interrelated domains of numeracy. These included the knowledge, context, affective, practice and cognitive domains. Each of these domains highlights particular complexities in the conceptions of numeracy and brings to light common assumptions. For example, within the knowledge domain it could be seen that numeracy, in the context of this case study, brought together multiple disciplines and fields, highlighting the fact that the knowledge associated with numeracy is not limited to basic mathematics. Planning for numeracy by emphasising mathematics in the curriculum is thus unlikely to enable students to develop all of the numeracy practices they will be expected to have by the time they graduate. In addition, within each domain there was a range of attributes from the other domains. For example, within the knowledge domain, numeracy could involve simple or complex concepts used in a range of contextual settings and requiring varying levels of cognitive demand and personal dispositions.

Using the LCT Specialization and Semantics dimensions to analyse the data made the organizing principles around the prioritization of specialized knowledge or specialized knower, and the interplay between contextual dependence and conceptual condensation, explicit. The analysis showed that the principles of legitimation span varying strengths of epistemic and social relations and semantic density and semantic gravity. Within each of these domains, though, it was found that the descriptions of numeracy or examples of numeracy practices corresponded to a range of different levels of cognitive demand. For example, one could prioritise stronger relation to knowledge and weaker relation to the subjective nature of the knower such as being able to calculate percentage mark up. In the same space of stronger epistemic and weaker social relations, the practice could expect high cognitive engagement such as being able to extract data from multiple data representations and perform complicated calculations. This was true in all the different codes.

However, importantly, when the analysis was related to the phases of the programmes particular dominating principles became evident. These could be clustered around the stages of students' entry into the programme, the demands arising throughout the programme and students' completion of the programme at graduation. So, for example, when students entered the programme the knowledge and prosaic codes were dominant as students were expected to know concepts and be able to apply procedures to simple contexts based on what they had learnt from Mathematics or Mathematical Literacy at school. In contrast, by the time students graduated the numeracy they needed was integrated into professional practice and therefore was seen as implicit. However, if these were separated it could be seen that there was an expectation of conceptual understanding of specialized knowledge across different fields, of adopting particular dispositions, understanding complex contexts and higher cognitive engagement. In essence, there was indication of shifts in terms of knowledge, knower, context and cognitive engagement throughout the programme which could suggest that programmes could benefit from planning curriculum that moved across the different codes with the LCT dimensions.

One challenge to the planning for numeracy could lie in the possible dichotomy between numeracy and innumeracy mentioned at the beginning of the analysis. What the thematic and theoretical analysis made explicit was that numeracy has varying principles of legitimation and the numerate/ innumerate binary may suggest particular valuing principles only, while it can be seen that their numeracy involves all these dimensions in different configurations. This complexity in the very nature of the phenomena of numeracy and the understanding of this complexity is likely to impact on curricula choices in terms of the planning for numeracy. This discussion is picked up again in Chapter 8.

Beyond the nature of the phenomenon itself, there were also other contextual and situational forces that needed to be negotiated in the planning of the undergraduate curriculum generally and the planning for numeracy in the curriculum more specifically. The next chapter of the analysis, Chapter 7, focusses on the presentation of data, thematic analysis and theoretical analysis of external contextual factors and their impact on why numeracy was planned for in particular ways.

Chapter 7
External contextual and situational factors

7.1 Introduction

This chapter focusses on the third main theme in this study. Chapter 5 explored the different approaches used by the institution to plan for numeracy development in its undergraduate programmes and the different organizing principles which underpinned these approaches. Two key factors were found to drive the institution's selection of approaches. The first was internal: the varying conceptions of numeracy that staff held. These conceptions, and the underlying principles which legitimated them, were explored in Chapter 6. The second was external: the contextual and situational forces that influenced planning for numeracy in the curriculum. These forces are explored in this chapter.

To ensure an informed and well-considered exploration, the findings on this theme are presented beginning with descriptive and emerging themes and followed by a theoretical exploration of the data using the LCT dimensions of Density and Temporality.

7.2 Insights from the data: What drove the choice of approaches to numeracy planning?

The interviews offered opportunities to identify factors which influenced the decisions related to numeracy from the perspectives of leaders, curriculum programme developers and specific module developers. Academic managers were influenced by their personal interpretations of the need for numeracy development in higher education. One of the academic managers who was responsible for initiating the curriculum renewal project, indicated that the drive to include numeracy or quantitative reasoning as one of the imperatives within the curriculum renewal process was motivated by two considerations.

Firstly, it was seen as necessary practice for graduates who were entering the workplace in the 4th Industrial revolution. This was explained as follows:

> *Let's put it this way. If we move into – not if we move into, when we move into – this 4th industrial revolution, if are we still producing graduates that are not numerate and we don't have a solution in mathematics and we don't know how to deal with big data, we are in trouble: we're in desperate trouble. And by the way, we're seeing that already. And so, from my point of view, it's not simply about saying these are things that will be good for students to have because it makes them to be better citizens. That's true, but what will be doubly true – and triply true is – if you want those people to be effective in the new economy that's coming, my God they better have these skills! Otherwise we will be in trouble*. (AM 1, L 469)

According to this manager, 'being numerate' was not negotiable and therefore university programmes needed to develop students' numeracy practices.

Secondly, numeracy was viewed by some as a social justice initiative. The unequitable educational experiences in the former South African secondary education resulted in particular races being excluded from the study of mathematics. Many decades later the limited exposure to good mathematics education persists. The imperative within the curriculum renewal project at the institution aimed to provide opportunity for all students to be exposed to mathematics or quantitative reasoning. The response from the same manager exemplified this view:

> *I think people need to be numerate. It's also about being a political project: it's about saying our students need to be confident that they can do this.* (AM 1, L 138)

This manager also identified the dissatisfaction of employers with graduates' ability to engage in appropriate numeracy practices in the work place as a factor in prioritising numeracy in the curriculum:

> *Employers are actually telling us that technical training is fine, but they're really complaining about the fact that students can't write reports, **are not numerate**, can't manage time or communicate effectively . . .* (AM1, L 235, emphasis added)

According to the academic manager, in previous conversation he had with the Deans, they reported similar feedback from employers of their graduates. In that respect, the inclusion of graduate attributes that went beyond the technical knowledge of the discipline – of which being numerate was one – was a key influencing factor that informed the imperatives of the curriculum renewal project.

Other contextual factors were also identified by the academic managers as having possibly hindered formal planning for numeracy by the institution.

Firstly, all of the managers made the point that they did not see themselves as experts in the area of numeracy. Examples of their comments are as follows:

> And *to be honest, I am not an expert on this area at all. (*AM1, L 144)

> *But because I am not a numeracy professional – if one has to put it that way – I am not sure I can say how it should be developed.* (AM2, L 39)

> *I realized and recognized that I did not have the expertise, number one. And number two, I was more interested in looking at the overall movement of work.* (AM3, L 166)

Some of these participants indicated that they themselves became more aware of the complexity of the phenomenon as they engaged in related activities or delegated the conceptualising of this process to others. There were no recognised numeracy experts at the institution and managers made the point that there was an implicit expectation that curriculum developers would address the imperative by working through the process of curriculum design and the related imperatives of the curriculum renewal project. One of the academic managers engaged with the Mathematics department to discuss possibilities of addressing the inclusion of numeracy/quantitative reasoning in the programmes and reported that those conversations did not yield the expected results of the mathematics department performing this initiative. In other instances, curriculum developers' data suggested that this would be undertaken by colleagues from the General Education Task Team.

Another issue that was raised was whether programme staff – including the Head of Deapartments who provided academic leadership in curriculum planning and the staff who were involved with developing the curriculum – had the necessary qualifications and expertise to be able to engage in curriculum planning, generally, and in planning for numeracy in the curriculum, specifically. One manager said:

> *As a university of technology, historically black university, there were some departments where the head of department was like somebody with a BTech. How're expecting this person to lead an enterprise – curriculum reform, and so on? It's just not fair. So, having stronger academic leadership would have helped.* (AM 1, L 402)

This statement raised the issue of whether the institution's past as a technikon was also a factor influencing the level of the staff's expertise with regard to engaging with this process. A factor compounding this was the institution's lack of resources, which one manager noted:

> *The lack of resources is always a constraint. I would have loved to have said, "Well, for each faculty lets hire one or two people who can help with the curriculum".* (AM1, L 382)

The intention of the institution was to build staff capacity through exposure to universities abroad and/or by employing a curriculum co-ordinator to guide the programmes. But the lack of resources limited capacity development initiatives as well, leaving staff inadequately prepared to deal with the curriculum renewal process and its associated imperatives.

Participants also mentioned that financial consideration at the institution also posed a challenge to the initiative to include numeracy in the curriculum or impacted on the approach adopted. Firstly, because the costs and benefits of initiatives such as staff development were evaluated in monetary terms by some stakeholders at the university and therefore necessary staff development initiatives were limited. Secondly, the choice of approaches was sometimes influenced by financial consideration such as whether the department could employ somebody or was easier to adopt an institutional module that is serviced by another academic department. Another consideration was that numeracy as modules could generate funds through government subsidy, but embedded approaches could not be quantified in ways that was aligned to the funding framework.

> *The constant fight with the finance people about the FTEs [Full time Equivalent] – we had our fights on this but of course I constantly had to tell them that this is not about money, this is about the education project.* (AM1, L 282)

> *The question is: what should go in and how it should be taught and do we have the capacity? And, of course, the finance people are complaining because they are saying that if you removing a technical course and you putting in a non-technical course it has an impact on the subsidy and all of that.* (AM1, L49)

In summary, the managers indicated that the inclusion of numeracy or quantitative reasoning was a necessary imperative to respond to the concerns raised by the employers around the under-preparedness of graduates in respect to numeracy and other 'non-technical' practices. However, as well intended as this was, they collectively identified the following factors as constraints to the potential transformation of the curriculum:

- Lack of generalised expertise in curriculum planning. This was identified both from the perspective of staff responsible for curriculum design and those responsible for academic leadership around curriculum design generally and in response to planning for numeracy in higher education.
- Lack of resources to create spaces and support initiatives for staff capacity development to address the gaps identified

- Impact on subsidies from government for related initiatives
- History and culture of the institution as a previous technikon and now a very young UoT, which is an evolving identity
- Lack of conceptual understanding of numeracy in higher education and absence of numeracy professionals who could guide the process and provide ways of quality assuring that these imperatives were addressed in depth

Analysis of the interviews with programme curriculum developers and programme development team also suggested that there were external contextual factors that influenced their choice of approaches to the planning for numeracy.

As mentioned previously, in some programmes participants indicated that there was no intentional plan to include numeracy even though it was one of the imperatives driving the curriculum renewal process. One of the programme developers demonstrated how little attention was paid in their programme design to these imperatives when they said,

> *Do people read that thing? [curriculum renewal imperatives]* (PG 6, L 215)

Although this response may appear complacent, the data suggests that it may rather reflect the confusion that arose over expectations during the complex and challenging process of planning for numeracy. In some instances, although programme curriculum developers did not address the imperative to address numeracy explicitly, they indicated that it featured as part of the programme in an embedded way and will be addressed in the enactment of the curriculum as needed.

In respect of influencing contextual factors, some curriculum developers indicated that the decision about what to include in the curriculum was driven by input from the industries: work preparedness was a priority. One curriculum developer said:

> *Dating back from the advisory board minutes and all of that there was concern that our students were not good at numbers, so for everything they did they relied on computers and all of that – and the calculators.* (PG 1, L133)

In that respect, numeracy planning was a response to industry's dissatisfaction with the numeracy practices of the institution's graduates. Participants expressed the view that the industries, and professionals in those industries, were best positioned to determine what numeracy needed to be developed in the programme because numeracy was seen as specific to the profession. One of the module developers explained:

> *Look, for me it would be people that come from industry – from particular disciplines – because every single discipline will have its own numeracy needs. In other words, what is required for me will be totally different from what is required for HR or marketing or hotel management. In other words, industry professionals' input influenced the numeracy that needs to be included*. (MD2, L 429)

So in the minds of some curriculum developers the expectations of industry represented a key factor in the curriculum planning process.

Another important consideration raised by the curriculum developers was the perceived inadequate numeracy practices of students entering higher education. Participants made the following comments in this regard:

> *We use the SATAP (numeracy) testing and we know most people fail that quite dismally.* (PG 1, L398)

> *They battle horribly you wonder how they passed matric. . . You know, for example, they cannot adjust a recipe – and this is numeracy.* (PG2, L 157)

> *They haven't been taught properly at school, surely. I really think that it's the basic mathematical processes – that basic maths – that they find very difficult to learn, anyway.* (PG 2, L 186)

Besides students' inadequate numeracy practices on entrance to the university, curriculum developers also indicated that students' attitude towards numeracy was not always positive.

In the cases of programmes that opted for an embedded approach, curriculum developers indicated that this was because students would resist an explicit focus on numeracy as a standalone subject.

> *If you took our students and you put them in a classroom with a lot of others and do numeracy, forget it. If you teaching them adding and subtracting and all those kinds of things, no. But because you are getting it in an area that they are interested in – they are passionate about – it's a totally different ball game because you hide it in the interesting things. We use to have a game – and there was calculations and watch time and how much you need and money and all those things – and if you actually hide it in a field or topic it's a different ball game.* (PG 1, L 554)

Numeracy development within a programme was also influenced by who the staff were and what expertise they brought to the department. In one programme, for example, because a young lecturer who was considered strong in numeracy-related practices had recently been employed, the department opted to design numeracy strong modules in house rather than having this done by other departments as it would have done previously. In another department it was indicated that the staff member responsible for numeracy development was "not so numerate" so it was unlikely that numeracy development featured in the modules for which this participant was responsible.

In summary then, staff expertise and the expectations of industry were important contextual factors in the view of programme curriculum developers as well as managers. Programme developers also included programme numeracy demands, students' existing numeracy practices and their attitude towards studying numeracy as factors that influenced the approaches taken to developing numeracy in the curriculum.

What is evident is that there were multiple contextual factors arising both from within the institution and from the external contextual situation which influenced the choices made by curriculum developers at the same time. The curriculum choices that were made were thus strongly impacted on by the capacity of the curriculum developers to negotiate tensions created by the combination of these influences.

7.3 Factors to be negotiated: Emerging themes

As has been demonstrated, curriculum planning is a dynamic process that is influenced by a variety of factors. In respect of the planning for numeracy, this could be attributed to the personal conceptual understandings and preparedness of the curriculum developers or development teams to deal with curriculum planning, generally, and with numeracy planning, specifically. Similarly, planners' perceptions of other contextual factors and how these needed to be negotiated influenced the curriculum choices they made.

7.3.1 Curriculum developers' perceptions of their preparedness

Each programme team or programme curriculum champion found themselves in a space when there were multiple forces acting on them. These included their own understandings of their competence, knowledge and attributes in curriculum design and their competence and ease with numeracy or quantitative reasoning.

Some of the curriculum developers felt underprepared in respect of their own numeracy practices; in other cases, they felt confident practicing numeracy but did not feel comfortable in respect of developing numeracy in an educational context.

As discussed in the findings presented in Chapter 5, planning for numeracy happened in various forms but essentially the staff responsible for this planning could be described as having weak positional autonomy in terms of numeracy; the relational autonomy was also low in some initiatives. This will be discussed again in Chapter 8.

This could be due to the varying conceptions of numeracy and because it is so strongly contextually bound it could mean different things in different situations. Since the 'field' of numeracy is weakly insulated it is subject to influence from other fields. As a result, it is difficult to reach consensus of what numeracy is so that it can be addressed in a consistent way. The lower positional autonomy of those involved in the conceptualizing and planning could be as a result of the process of curriculum design adopted in this case study. As indicated above, there was a challenge at the institution in respect of who could guide the process. The managers themselves did not feel that they could provide expert direction in this regard and while the programme staff working on curriculum were experts in their disciplinary domains some were uncomfortable with identifying and the developing the numeracy expected or their own numeracy practices were so tacit that they found it difficult to articulate and therefore difficult to plan for.

This was also coupled with the curriculum developers' experience – or lack thereof – with dealing with curriculum design. In some programmes, there were a group of individuals who worked on this (one programme), in others it was the HODs (2 programmes) and in others it was left to one (1) or two individuals to complete (4 programmes). This was in respect of conceptualizing the entire programme and completing the necessary processes. In most cases, the module descriptors for the different modules in the programme were written by the lecturers who taught those modules.

The curriculum developers' freedom to make choices was constrained by situational factors external to their own level of experience and expertise for developing the curriculum. These programme and institutional factors are discussed in the sections that follow.

7.3.2 Programme and Departmental Factors

7.3.2.1 *Academic staff in the programme department*

In some cases, the programme curriculum developers indicated that they considered the experience and qualifications of the programme staff in the choices they made. In fact, one programme developer indicated that when planning the curriculum, he was hopeful that experienced staff will be able to mentor younger staff in enacting the curriculum in ways that support what numeracy needs to be developed and where in the curriculum this could be done. He said:

> *I wrote the programme with the intention that the remaining staff would still be around over, they still have to keep someone who will be able to explain to new staff. "Look, this is what you've got to do: you've got to provide them with teaching materials and things like that. These are the basic calculation part of it and here's the basic Photoshop*. (PG 3, L210)

If the experience of staff in a department was considered to be weak in numeracy, this could have resulted in non-numeracy specific modules, or in the decision to have numeracy-specific modules provided externally if the programme staff were not equipped to teach numeracy. In some cases, programme staff were reluctant to engage with numeracy because they felt they lacked competence with numeracy and, as a result, lacked confidence to engage in developing this in their discipline modules.

As indicated previously, the programmes selected for this study were not strongly mathematics-based. Staff in these programmes were not always comfortable with teaching numeracy or quantitative reasoning. One said:

> *I'd rather have someone who was maths literate – like a maths tutor – tutoring our numeracy, rather than having someone who was course literate teaching numeracy. And this was the argument that we had in our last discussion, when you said, "No it must be somebody who is course literate," and I said, "But I don't know what that thing at the bottom of the fraction is called" and I can't teach someone numeracy when I say 'that thing at the bottom of the fraction,' But I know the concept I am wanting.* (PG1, L 33).

This participant was a very experienced and dedicated lecturer. This indicates that it is possible for a lecturer to feel incompetent to teach the specialised conceptual language and processes that are associated with numeracy although they know they are competent to perform the numeracy-dependent task within the context of the discipline they do not feel competent to teach this.

Confusion arises when staff articulate that numeracy is important to their professions and to the programme in which they are a successful lecturer and professional and yet they are uncomfortable with teaching these crucial practices explicitly. This suggests that their numeracy practices are tacit. This presents the curriculum design and pedagogical challenge of making their tacit knowledge explicit so that they can facilitate the development of their students' numeracy – a different challenge than if they had not actually possessed the required numeracy practices themselves. Also, the common perception of numeracy practices as grounded in mathematics knowledge could be a reason staff who do not feel confident in mathematics lack confidence when faced with the prospect of embedding numeracy in their curriculum and teaching explicitly.

The prior experience and qualifications of staff were also considered in respect of their capacity for teaching numeracy. Firstly, the issue of staff qualifications at the institution was raised by participants a few times. Secondly, some participants expressed concern that if young, inexperienced lecturers who had inadequate post graduate qualifications were lecturing, they may not be able to facilitate the development of students' numeracy within the course of their discipline module adequately. One programme developer said:

> *The problem . . . in whether or not [integration of numeracy] is done successfully, it comes down to the quality and experience of the lecturer – or experience that the lecture has. They see the need to include and keep building it into their curriculum or their subject area. Because it often worries me in the institution like this, as they get more inexperienced, younger, BTech students to do a bit of lecturing, or whatever, they don't have that experience. What then goes to the students is incomparable to that from a lecturer who is experienced in the subject matter. So, the delivery kept varying: although it might be embedded and you might know it, the delivery of that totally depends on the experience of the lecturer*. (PG2, L 255)

This concern with the challenges that some staff in departments will have with embedding numeracy development in their discipline sometimes influenced curriculum choices. In some programmes, concern that informal planning for developing numeracy through an embedded approach could result in it being neglected led to the choice to adopt a module-based approach which would guarantee that students received some exposure to numeracy and where this could be more easily monitored.

As the curriculum developers planned the curriculum, they did acknowledge that there was no way to guarantee that the planned curriculum would be enacted as intended, particularly where an embedded approach was used. According to one participant, the development of numeracy through an embedded approach expected that staff should be able to assist students through appropriate questioning. The developer commented:

> *Students need to be taken from the lack of numeracy into the numeracy and if the staff aren't asking the questions and separating – teasing it out – and everything else, how do we expect our students to come along to the party? (*PG 1, L 732)

This suggests that there is a need to move students from their current numeracy practices to those that are more appropriate or relevant to the discipline, profession and is expected of a graduate in a highly quantified society. The curriculum team's perceptions of the capacity of lecturing staff to identify the numeracy practices of students and then make these explicit thus impacts on how the curriculum is planned. There was a common perception that students lack numeracy practices (which is discussed further in the next section). The developers' conceptions about what that lack is impact on how they plan for students' numeracy development throughout the programme. So, for example, in instances where they perceive students as lacking the procedural knowledge associated with mathematics, this may motivate them taking the approach of building numeracy-specific modules that focus on procedural knowledge into the early stages of the programme.

Some participants also suggested numeracy should be facilitated using creative and enjoyable activities, which implies an expectation that lecturers have the capacity to be innovative in their teaching. The expectation however, is that the lecturing staff know the programme and profession in sufficient depth that they are able to anticipate the numeracy moments and plan for these in their teaching and assessment. Curriculum planning expects that teaching staff will be able to plan teaching and assessments that value numeracy or quantitative reasoning. The perceptions of curriculum developers of the capacity of staff to identify and make explicit the application of numeracy within the disciplines was one of the considerations during curriculum planning and may have impacted how they planned for the development of numeracy in the programme.

> *I think it's easier to do numeracy kind of thing where you are in a class or in a course that you like and you are dealing with patterns, or you have cut fabric in the sewing lab, and you remember you cut a marker that is so long and this wide and then for that piece you do a costing and then there is this whole relationship, with the understanding behind all the numbers it becomes clearer",* (PG1, L 161)

In some instances, curriculum developers or programme teams reported that they found lecturers resistant to including numeracy development in their teaching and this presented a challenge. One said:

> *Some of the guys have been naughty: they haven't been including that in the syllabus and they haven't been teaching them – like basic bookkeeping, which is an important part of it which will show them how to add and subtract and multiply. And they actually struggle with that. . . . and staff willingness to adopt the changes...you get a younger staff member – the person will be able to do it. If you look at our organogram, you got everyone here over fifty. Are they willing to change? You know, that's a question.* (PG 3, L 76)

In these instances, departmental programme developers were likely to repackage their existing programme curriculums to meet the new criteria. This could have influenced the approach adopted.

The characteristics of teaching staff – including their experience, qualifications, pedagogical approaches, understanding of numeracy, and confidence and willingness to teach it – represent an important consideration in curriculum planning.

7.3.2.2 *Addressing perceived student lack of numeracy on entry with expected numeracy at graduation*

Participants reported that students frequently lacked the numeracy practices expected in higher education when they entered a programme, as evidenced by their entrance test results and their performance in first year courses that required numeracy. At the same time, professionals in industry had reported that graduates' levels of numeracy when exiting the programme were inadequate. This was a potentially serious issue because of the possibility that a graduate entering a practice without the appropriate numeracy practices could make poor decisions which could have serious consequences.

Curriculum developers thus needed to consider the actual level of students' numeracy practices on entrance to their programmes and level of numeracy required on entrance to their profession as graduates, and ensure the curriculum closed this gap by taking them from their actual level on entrance to the university to the level required in industry. Within the duration of an undergraduate curriculum this presented a challenge to programme developers who were in a position of needing to negotiate paying attention in the curriculum to addressing gaps in prior numeracy practices while also developing new numeracy practices expected by the disciplinary courses in the programme and the profession.

One of the programme curriculum developers indicated:

> it was a toss-up hey. (PG 3, L 206)

These forces involved negotiating how "low" could one go in terms of "upskilling" students with a repeat of what was done at school given that the programme needed also to meet the expectations of industry within the structured nature of the curriculum and the fixed timeframes of the programme. Curriculum developers whose conception of numeracy focused on the procedural application of foundational mathematics might favour placing more emphasis on dealing with the perceived under preparedness of students on entry to higher education. However, the examples provided in terms of the expectations of graduates suggested different numeracy practices. So essentially the dichotomy of numerate and innumerate as described in Chapter 6, presents a problem because it could lead to an assumption that if the under preparedness in numeracy is addressed students are now numerate and should be able to deal with other numeracy expectations in the programme and in the profession. The challenge of course is that curriculum developers did not explicitly understand that these involved different sets of legitimating principles, as can be seen from the chapter on the "Conceptions of Numeracy". Therefore, curriculum decisions on what Industry meant by lack of numeracy practices of graduates, how these were similar to or different from the numeracy practices students were seen to be lacking on entry to higher education and what then needed to be included in the curricula was mainly engaged with in respect of broad and simplistic conceptions of what is numeracy. There was no real evidence in the data that suggested that participants saw that the principles underlying each set of numeracy practices as being significantly different.

7.3.2.3 *Prior programme structure*

The programmes that were offered prior to the curriculum renewal process were very structured. Students were allocated a timetable with prescribed modules. (See programme handbooks prior to 2012). There was very little flexibility, and all subjects were directly related to a specific vocation. Each of the modules was allocated credits and the time allocated to each module corresponded to its credit allocation.

The programmes offered previously were all diploma programmes which were common across all South African Technikons. In the case of one of the programmes, the national consortium of professionals for that qualification still discussed and agreed on a curriculum for the different institutions. The programme developed described the process as follows:

> *Four UOTs and one comprehensive university, UJ, and we would meet and set the general exit level outcomes collectively* (PG 5, L 165).

The participant went out to suggest that being part of a group of institutions working on the curriculum together resulted in this particular department choosing approaches to general education and numeracy that would not create tensions with other UoTs. This was evident in the statement by one participant:

> *We couldn't cheat and take from our core module coz the other UOTs wouldn't be happy if we said we doing body at 16 and they all doing it at 24, I'm just giving you an example because we stole 8 for Gen Ed somewhere along the line. . . . in most cases then we were okay like with numeracy which was embedded, in others we added credits, so our diploma has more credits than the normal 360.* (PG 5, L 192)

One of the factors in this programme for choosing an embedded approach could have been that they did not want to increase their already high credit value. Opting for a module base approach would have done so.

Six of the seven programmes in the study worked on curriculum planning independently from other UoTs. During interviews with programme curriculum developers it became evident that they were resistant to deviate too much from the old programmes that were designed by the national body previously or else experienced the programme staff to be so. Curriculum choices were also influenced on factors that were broader than the programme/departmental specific conditions.

7.3.3 Institutional Specific Factors

Curriculum planning was impacted on by institutional factors. Some of these were as a history of being an old Technikon and others were related to the change initiated by the Curriculum renewal project such as the compulsory inclusion of general education in all undergraduate programmes.

7.3.3.1 *Large scale reform*

Many participants indicated that curriculum planning was a challenge and they focused primarily on meeting the imperative to include 30% general education in their programmes. As a result, in some cases not much attention was given to the explicit planning for numeracy or quantitative reasoning in the programme. An interpretation of why the 30% of all programmes to comprise of general imperative carried more importance in the curriculum planning processes could be attributed to:

- This being the overarching imperative, and therefore was the first non-negotiable of the curriculum renewal project and sometimes only consideration curriculum developers could explicitly focus on because of the magnitude of the change
- The 30% of programmes dedicated to general education imperative further specified allocations to be distributed as follows: 10% had to be adopted from institutional generic general education modules, 10% based on general education that focussed on faculty specific needs, and 10% was in respect of offerings decided upon by departments as important general education for their professions. (DUT, 2015), Senate guidelines Document). The quantification made it easier to track and monitor. Departments typically claimed that their 10% was embedded or else they repackaged courses from their old offerings as general education offerings.
- A General Education Task Team was established to explore the phenomenon and to guide its implementation. Although numeracy development was introduced in the Curriculum Renewal Project as one the imperatives whether this was acted on as part of general education or specific discipline initiatives was not specified. This task team did not/could not provide detailed guidance on numeracy development as it did with other aspects of general education.
- Adherence to the 30% of programmes comprising of general education was monitored through validating the credits in the programme allocated to general education being 30% of total programme credits. In respect of the presence of numeracy development or QR intensive (see module descriptors templates) modules within the programme the ‘ticking’ of the block on the module descriptor indicating QR was seen as sufficient to monitor that the imperative was addressed.

- There was no explicit guidance on the criteria to indicate that a module was developing QR. Curriculum developers therefore "ticked" this block in the module descriptor if the module had calculations or used "numbers."
- For many, numeracy development was not seen as something new to the programme. Programme staff indicated that they were always forced to address numeracy due to the perceived "lack of numeracy" of students in the programme.

The fact that numeracy/quantitative reasoning was included only as one aspect of the imperative for large scale change brought with it the risk that curriculum developers could overlook it. The prioritising of the 30% general education imperative by the curriculum developers could suggest that as they engaged with the imperative the curriculum developers reached to imperatives of the curriculum renewal project that could be quantified and shown explicitly and to aspects of the change for which they were given more explicit leadership and guidance.

In the next section, the institutional factors in terms of its structure and cultures that influenced curriculum planning are presented.

7.3.3.2 *Institutional academic structure*

In this institution, specifically but also typical to most higher education institutions, universities are structured in ways that are either professionally influenced or academically influenced. For example, the university in this study comprises six academic faculties: Engineering and the Built Environment, Applied Sciences, Arts and Design, Management Sciences, Accounting and Informatics and Health Sciences. Each faculty comprises academic departments that offer academic programmes. These programmes are mainly developed and facilitated by professional staff in the department such as engineers, or accountants, for example. A few modules of the programme may be developed and facilitated by other academic departments. These could be service departments, such as Mathematics and Statistics, or academic programme departments, such as Financial Accounting, which might facilitate a module on accounting for another programme, for example. Support units also offer support programmes outside of the formal curriculum of the programmes. For example, there is a Writing Centre that supports students with their writing and also engages with staff on how to integrate academic writing development throughout the programme.

The institutional structure at this institution did not include a department, or professional staff, dedicated to numeracy that could be called upon to guide programmes in their task of planning for the development of numeracy in the curriculum. Because of the obvious link between numeracy and mathematics there was initially an expectation by the academic managers that the Mathematics department could support the process of planning for numeracy. However, as the process unfolded there was unanimous agreement by participants including those from the mathematics department that it would not be ideal to have the Mathematics department guide the planning for numeracy. One participant said:

> *I certainly don't think mathematicians should be driving this in the curriculum because mathematicians are going to give you formulae: they're going to want to test logic rather than real-life application*. (MD2, L436)

Another said:

> *You give the module to a mathematician and they will say to you that this is a useless module because there is nowhere where this module deals with trigonometry, quadratic equations – and it doesn't give you the meat of mathematics.* (AM3, L 416)

The mathematics department was seen as skewing the numeracy development to including a revision of the mathematical concepts and procedures or using the application to real life context as problems to create understanding of the mathematics rather than focusing on the real life or professional contexts.

On the other hand, curriculum developers indicated that some of the programme departments were not ideally equipped to develop numeracy, either, because they did not have staff with the required mathematical competence. The institution therefore found itself in a position where no established department/discipline could adequately address all the different domains of numeracy.

7.3.3.3 *Resources*

Participants noted that resources were a problem at this institution. A tension existed between ensuring that the institution was financially viable and sustainable and maintaining the academic standard of the programmes. From academic managers to curriculum developers, all participants found themselves in debates with the finance department around financial viability and budgetary matters.

From at least two academic managers' perspectives, it would have been helpful to make contact with institutions abroad which had been through a similar process and could provide mentorship to staff involved in the curriculum renewal process. One said:

> *I would have loved to have sent people, to go to universities abroad and just experience other universities who have engaged with this as part of capacity development, but also for them to see that it's not something that's beyond us.* (AM1, L 390)

Managers also felt that the process could have been enhanced through staff development programmes or community of practice initiatives to improve practice, or by hiring consultants to help staff engage with the imperative, disrupt the previous approach and generate new possibilities for curriculum planning. One manager said:

> *I was really anxious for us to try and to bring in as many external people from outside as possible just so that we could inject some new experiences. (AM1, L 264)*

However, this was not possible to the extent to which it was required and therefore curriculum developers had to negotiate how they use funds available so as to be most productive and complete the process timeously. This limited the resources that were at their disposable to engage in benchmarking or sourcing the expertise of "numeracy" scholars to unpack what it meant and how it could be implemented.

In essence, conflict of interest between the academic project and the business operations of the institution impacted the planning of numeracy.

7.3.3.4 *Workload*

Curriculum developers indicated that it would have been useful to critically review the previous curriculum and reflect critically on whether their choices were justifiable academically. They noted that their workload at the university was a constraining factor as it did not allow for them to take the time to do this. One developer said:

> *If I didn't have such a hectic workload I think I could be a better lecturer and also had more time to reflect on that in the planning of the curriculum. I could help the students more. I think I could help reach those graduate attributes better. But yesterday, for example, I went from a 9 a.m. meeting with the whole task team to 10:30 to advisory board meeting to 1 o'clock when my students were writing a test, to them going on to do part-time class. Where do I have time? Where do I have time to think about how I can improve what I am doing? I don't. So if I had time to be a person, then you would have time to interrogate what I am doing*. (PG 6, L 884).

The challenge to find time to reflect and interrogate the possibilities restricted the opportunities for curriculum developers within the programmes to engage with the curriculum planning needs more deeply. Programme developers were so keen for this to happen that one programme used the interview as a place for programme staff to critically interrogate their practices. The HoD of the programme said:

> *I wanted everyone here during this interview because I felt by you asking us questions that we interrogate our own thoughts and try to clear up what you really thinking about it and everything. We did not really do this and I think that this is possibly a very big problem across education . . . that there is not enough of this kind of discussion with lectures across the board.* (PG 1, L 727)

These discussions were described by most participants as necessary staff development initiatives that developed and enhanced communities of practice to improve the offering of programmes.

One of the participants reiterated the point around community of practices but again workload worked against that:

> *I think there were things, like subject meetings, where anybody that was interested in nutrition, or was part of nutrition, sat; they have to talk and have a meeting for one hour and that translated to development within your field. But things like that need to be built in . . . people need to be given time, you can't run around on a normal time table.* (PG2, L 667)

Staff development and engagement were hampered by the heavy workloads staff had at the institution. Without dedicated time and engagement with peers, the curriculum developers often negotiated many of these complex factors on their own or with the support of only one or two other staff members.

7.3.3.5 *Excessive reliance on part-time or contractual staff*

Curriculum developers noted that there was constant turnover among staff and many worked on a part-time basis. This lack of continuity impacted curriculum planning because the developers did not know what the capacities of the staff would be in the future and if the new staff would interpret the curriculum plan in the way it was intended. One developer said:

At this institution there's a lot of part-time lectures: [they] come in for six months; disappear. Find a new lecturer for the next year, possibly no handover from the previous lecturer – just here's a file, maybe here's some notes. Continue, carry on. And they don't find their feet. And then the following year another lecturer coming in. So our continuity with a lecturer developing themselves – I think for part-timers, being thrown in and just doing a six month or eight month stint, with the next year a different part-time; the quality is going to be compromised. (PG 2, L 338)

Turnover among staff and the presence of permanent staff could influence how the curriculum is interpreted and enacted, and the curriculum planners' awareness of this could be a factor in how they decide to plan to develop numeracy. For example, they could opt for a module-based approach to ensure numeracy will be covered, or choose an embedded approach based on the current staffs' capacity to implement this.

The factors within the institution impacting on curriculum planning was in some way influenced by national policy and funding frameworks.

7.3.4 National Policy and Structure including Funding Framework

Although a considerable number of programmes at the university changed from offering diplomas to degrees as a result of the curriculum renewal project, most programmes (5 out of 7) in the study opted to continue offering diplomas. A three-year diploma is likely to have a maximum of 360 credits. This translates to 3600 notional hours, which refers to the expected number of hours that students will need to spend, on average, including both formal instruction and self-study, to have a fair chance to succeed.

The modules within the diplomas are pitched at certain levels that are regulated by the National Qualifications Framework (NQF). In the South African education system, the school leaving examination is at NQF Level 4. The programmes in higher education are at higher levels: 6 for a diploma and 7 for a degree. The modules within the programme start at Level

5. In some cases, participants felt that numeracy should not be offered in higher education because its demands were perceived as being below NQF Level 5 and thus appropriate to basic education and higher education remedial support programmes. One manager mentioned:

> *There was this big debate with [name omitted] about what can be done at Level 1 and Level 2 and Level 3 and why are we doing fractions at first year level that should have been done at Grade 6 at school*. (AM1, L103)

This manager indicated that initially he had had numerous debates with the staff he had thought would be responsible for the numeracy planning around what belonged in a numeracy course in higher education. This issue was also mentioned by one of the institutional module developers who indicated that the module they had developed was viewed by other academic departments at the institution as not belonging at a university as it was too easy:

> *At that stage we didn't really know what we wanted to do – how low could we go without putting our qualification at risk. You know: if somebody audited us and said, "This is Grade 5 maths: why are you teaching it at higher education?" That was the sense that we were working around. And then we did share our module descriptor with colleagues in other faculties and they were highly critical of it, because they said the level is not right*. (MD 2, L284)

A review of the content of that numeracy specific module showed that the content of mathematics in the module was mostly content that students were likely to have experienced in previous schooling. This could be the reason other departments felt that the module was too easy and were critical of the module.

Participants noted that some staff were resistant to the 'loss' of credits from valuable technical content to general education areas. Numeracy was also considered one such area. This implied that fewer than necessary credits were allocated to the numeracy specific module in programmes were such an approach was used. So, in this case, an 8 credit module translated to 80 notional hours. This needed to be made up of contact time (lecturers, tutorials, etc.) and self-study. Generally, contact time at the institution in the study was allocated as being at most 40%, which converted to 32 hours over a six-month semester which resulted in programmes allocating one double period per week for the module. Although implementation of the curriculum is outside the scope of the study it was mentioned that, as anticipated during the planning, an 80-hour allocation did not do justice to the development of numeracy. One participant said:

> *There's not much you can achieve in an 8 credit module. In fact, there should not be an 8 credit modules in higher education: that's my personal view. You should at least have 16 credit modules – you know you can do justice.* (MD2, L 114)

In some instances, due to the perceived level of numeracy to be developed or due to the importance of the technical content that was difficult to sacrifice, it made more sense for curriculum developers to choose an embedded approach. This approach did not require the same explicit evidence of what numeracy is, how it should be facilitated and when in the curriculum it should be placed that was expected of a module-based approach to numeracy.

Another factor that curriculum developers had to deal with which arose at the national level was funding. Where there were modules that met the criteria set by national frameworks, this generated income through government subsidies (FTEs). The funding was allocated to the departments that offered these modules. As discussed previously, this resulted in tension between the priorities of departmental financial viability and maintaining the academic quality of the programmes. In fact, one of the leaders made the point that one of the reasons a particular department was actually unhappy with the introduction of the 'modules' for numeracy was because it impacted on a previous offering that was facilitated by the service department and therefore the service department received the subsidy previously. One manager said:

> *I just didn't buy the [name omitted] department arguments and I just I had a long on going conversation with them. And, you know, they were clearly kind*

> *of unhappy about – partly I think they were worried about the fact that it was other people are going to do the maths.* (AM1, L114)

The same manager went on to say:

> *. . . because all we were doing was really just dealing with insecurities around the funding model, nothing else. You know, it was like how the FTEs were going to be divided.* (AM1, L119)

On the other hand, participants from the service department reported that numeracy was conceptualised in ways that were influenced by funding rather than by who was best equipped to work with this.

> *You have statistics teaching something to the management sciences and in the name of Gen Ed and also FTEs. So it is the neoliberal design. You have a course called QR that has been taught here to the management sciences by the management sciences and I suppose you can get away with it because that is how you conceptualize it. I think that they are chasing money because there is a Department of Statistics with less work to do and there are people who don't know as much about statistics to teach what they are offering – called Quantitative Analysis or something like that.* (KI 2, L411)

The module referred to here was one of the institutional modules designed to develop numeracy or quantitative reasoning. Although I am not sure that the FTEs were the most influential consideration, finances played a significant role in conversations leading to the planning of curriculum. So even in the case of the modules that were dedicated to developing numeracy or quantitative reasoning, decisions had to be made around whether these should be offered by the programme department or be facilitated by a service department like the Mathematics and Statistics department or through general education modules offered by the General Education Unit which was still not constituted at the time of planning. Each of these decisions skewed what numeracy was valued and legitimated in varying ways. What became evident was that the current allocations of funding against specific modules could force departments to create programmes that were an accumulation of modules that are created as silos. Yet what was seen in the section on conceptions of numeracy is that numeracy cuts across disciplines and modules. The existing structure did not allow for allocation of resources for such offerings.

Programmes that adopted embedded approaches were able to maintain the funding of the programme specific module and address numeracy within those modules. This however expected that staff were comfortable and competent to identify the numeracy moments and act on these appropriately. Again this approach prioritises particular numeracy practices that were strong in the department.

7.3.5 Summary

In summary, it can be seen that the curriculum planning was impacted on by many factors that were actually external to the phenomenon of numeracy in higher education. These factors included the curriculum developers' preparedness in terms of their understanding of numeracy and their capacity to negotiate the tensions created by the multiple contextual factors influencing the choices in planning for numeracy. The insights from the data that have been presented make explicit the complexity of making choices in curriculum planning because of the interrelated factors that influence curriculum planning for numeracy in the programme, as well as in general. In this case study these could broadly be clustered as departmental, institutional and national considerations.

7.4 Insights from LCT analysis

As indicated previously, LCT is a multidimensional toolkit that facilitates an understanding of the organizing principles that underpin the legitimation of practices. There are five dimensions which serve as tools in the LCT toolkit. I used the Autonomy dimension to explain the diversity in the approaches adopted to the planning for numeracy and the Specialization and Semantics dimension to analyse the conceptions of numeracy that were prevalent among the participants of the study. All three of these dimensions have been used extensively in research and revised since they were first introduced by Maton in 2005. The other two dimensions have not been used as extensively or a newer revised interpretation is not available. Nonetheless, I do think that the original presentation and description of these dimensions by Maton (2005) adds value to this study. In the next section, I present an analysis using the Density dimension. (Note: Density here is a dimension in its own right and should not be confused with semantic density which is a concept within the Semantics dimension).

7.4.1 Analysis using LCT Density dimension

Density has been described in greater detail in Chapters 3 and 4, which addressed the theoretical orientations and methodology of the study. Density is concerned with the degree of diversity within the field (Arbee et al., 2014). The Density dimension comprises two concepts: material density and moral density. The mapping of these two concepts on the Cartesian plane generates four quadrants which can be assigned codes, as shown in Figure 7-1.

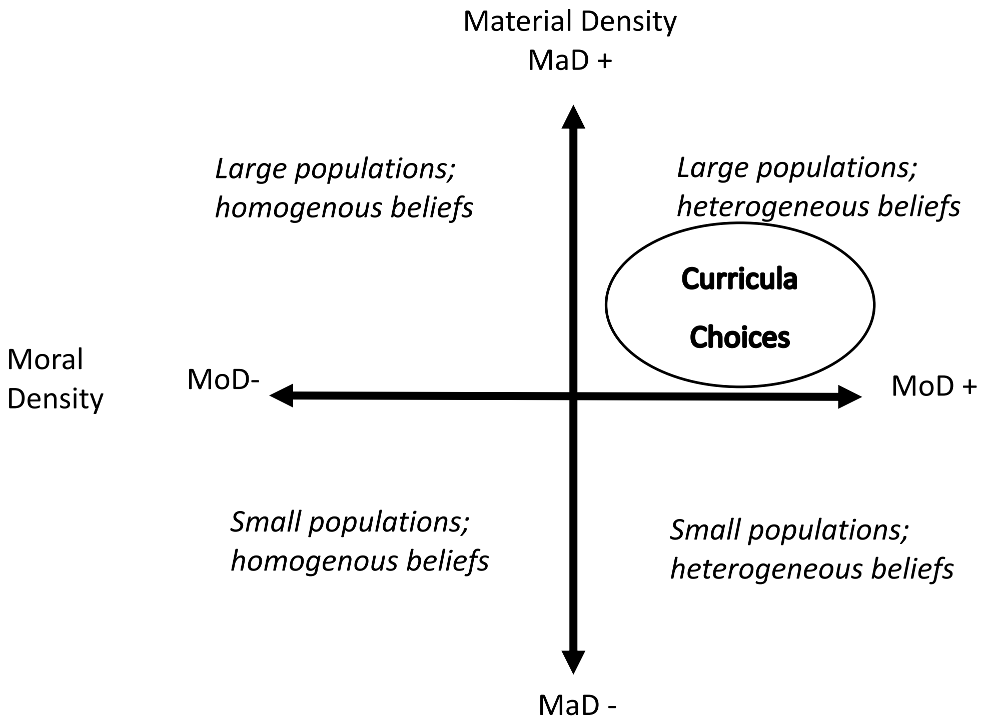


Figure 7-1 LCT Density plane (adapted from Maton, 2005, p.90)

In this particular case study, every programme had the liberty to act on the imperative to include the development of numeracy or quantitative reasoning in whichever way they chose. There was no quality assurance of the new programme application that addressed the compulsory inclusion of numeracy development or programmes that chose not to explicitly plan for numeracy. Therefore, it could be described as a large population that were considered legitimate 'players' in the planning for numeracy development.

This large population was subjected to multiple contextual forces that acted on their decisions. These factors were also different for each of the programmes. They negotiated in very different ways the contextual factors they faced. This was indicative of stronger material density.

What was evident from the exploration of the conceptions of numeracy in Chapter 6 is that there were varying conceptions of numeracy and varied ways in which participants felt numeracy could be developed in the programmes, suggesting stronger moral density as well. In this space of heterogeneous beliefs of what is numeracy among a large population responsible for curriculum planning. Without clear guidance from the institution on how to engage with the planning for numeracy in the programme curriculum developers had to negotiate a number of competing pressures which potentially influenced their planning choices in different ways. These many factors may have resulted in even more diverse conceptions of numeracy and approaches to planning for numeracy development within the undergraduate curriculum.

Further insights into the complexities of planning for numeracy in the undergraduate curriculum were derived by analysing the data using the LCT dimension of Temporality.

7.4.2 Analysis using LCT Temporality dimension

The fifth LCT dimension, Temporality, is concerned with the rate of change within a field (Arbee et al., 2014). It comprises two concepts: temporal position (TP) and temporal orientation (TO). Temporal position refers to the 'age' of the field while temporal orientation refers to whether the field/practice is forward-looking or backward-looking. When these concepts are combined four temporality codes can be generated, as presented in Figure 7-2.

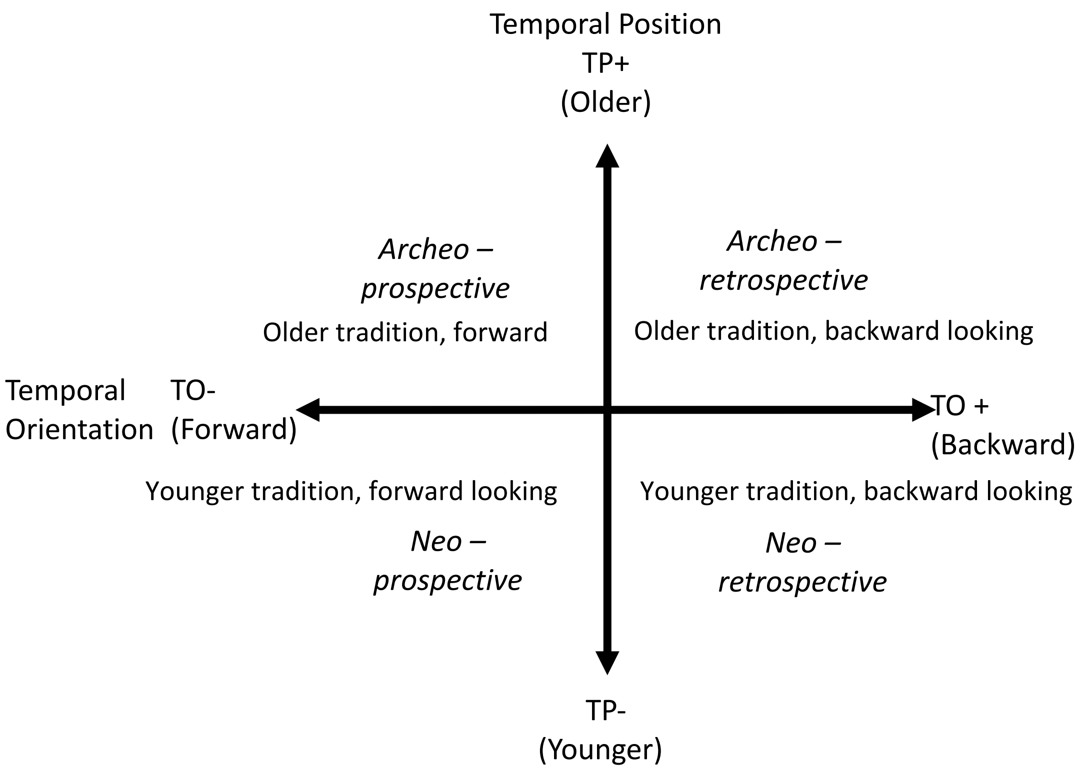


Figure 7-2 LCT Temporality plane (Adapted from Maton, 2005)

The research data revealed that most participants lacked conceptual clarity on the concepts of 'numeracy' or 'being numerate', suggesting that curriculum developers were uncertain of which disciplines traditions they could draw from.

All of the participants' initial descriptions of numeracy related to mathematical procedures and application of concepts. As interviews progressed and participants provided examples of expected numeracy practices, however, these descriptions showed numeracy to be influenced by multiple disciplines with varying degrees of established traditions. Mathematics was one of the more established disciplines with deeply entrenched traditions and the academic managers and some curriculum developers initially looked to the

Mathematics department to support numeracy development, suggesting their legitimation of numeracy to be based on older traditions of mathematics.

The examples provided also showed that the numeracy that was expected in different programmes was discipline-specific and needed to be developed in different ways. Participants also shared examples where the numeracy practices sometimes had to underplay the outcomes of mathematical skills and processes because these were sometimes not valid in the context of the discipline problem. This then suggests that numeracy is more likely a field that is based on newer traditions or certainly is not limited to the older traditions of mathematics only.

The data indicated that curriculum planning for numeracy had to be both backward looking – focus on upskilling students who were considered underprepared in respect of numeracy that should have been addressed in school education – and forward looking – ensuring graduates were equipped with the numeracy practices needed to engage with numeracy with confidence and ease in their future personal, professional and civic lives.

What becomes evident when analysing the data using the Temporality dimension is that engaging in a space such as numeracy that is not well-established and is forward looking is challenging; the attempt to integrate the principles of multiple disciplines could result in one discipline taking dominance in terms of the principles valued.

7.5 Conclusion

This chapter has discussed the findings of the study related to the specific research objective of exploring the factors that impacted curriculum developers' choices in their planning for numeracy as part of the curriculum renewal project at the institution. The thematic analysis explored the multiple situational and contextual factors that could have impacted on programme decisions to adopt particular approaches to numeracy development. These factors ranged from the perceptions of curriculum developers that students lacked the required numeracy practices, their perceptions of the expertise and capacity of academic staff to enact the curriculum, the structure of the programme, funding and budgetary aspects, resources and the massive change brought about to the curriculum by the introduction of general education.

The findings show that the curriculum developers and curriculum teams were required to negotiate a number of influencing forces resulting from situational contextual factors.

Analysis using the LCT Density dimension highlighted the large population (as in all) programme developers who had varying understandings of the imperative to include numeracy or quantitative reasoning, as well as varying conceptions of numeracy (as the curriculum planning project did not include a process of conceptual clarification), which may have resulted in the legitimation of multiple approaches to planning for students' numeracy development.

The Temporality analysis highlighted the challenges curriculum developers faced as they planned for numeracy – an emerging field that is still under-researched – in negotiating the influence of a number of contextual and situational factors. Each of the factors could be seen as 'forcing' different orientations for example the development of a numerate graduate in a profession which could favour a forward-looking or lack of student numeracy on entry which could favour backward-looking orientation. As an interdisciplinary 'field' that is still establishing new traditions particular to numeracy a subscription to established traditions of older known disciplines could be considered easier.

The findings, and the analysis of these findings, have been presented according to specific research objectives in Chapters 5, 6 and 7. Chapter 8 integrates these analysis and discusses comprehensively the generative principles that may have underpinned curriculum developers' choices as they planned for the development of numeracy in the undergraduate programmes within higher education context.

Chapter 8
Discussion

8.1 Introduction

In the previous three chapters (Chapters 5, 6 and 7), the results of the analysis were presented and discussed, with each chapter addressing one of the main themes of the study corresponding to the objectives. This began with an exploration of practices of planning for numeracy which provided insights into how numeracy development was planned for in the undergraduate programmes of the institution in this study. The thematic analysis revealed that varying approaches were adopted to planning for numeracy. These approaches included offering numeracy or quantitative reasoning by including generic numeracy specific modules within the programme not developed by the programme department; integrating the numeracy development into specific modules within programmes; or using an embedded approach where no explicit planning for numeracy development was undertaken because of the assumptions that these would be addressed during teaching and learning as needed. Other initiatives were also identified to support students as needed. The thematic analysis was followed by an analysis using the Autonomy dimension of LCT which revealed the varying organising principles underpinning the approaches taken to planning for numeracy. This analysis made explicit that most of the plans were created by academics who had weaker positional autonomy in respect to numeracy and stronger disciplinary autonomy. In other words, programme developers did not feel confident or consider themselves qualified to address numeracy. The numeracy plans ranged from being intentional, being subtle or completely non-existent.

In order to understand why these varied approaches were valued in the ways that they were, an exploration of the conceptions of numeracy and the contextual factors resulting in the adopted practices was undertaken both inductively and deductively. Thematic analysis revealed the different domains of numeracy and the factors influencing curricula choices. The dimensions of Specialization and Semantics from the LCT toolkit were used to explore principles of legitimation of the conceptions of numeracy which provided insights on the value placed on specialized knowledge and knower attributes. The dimension of Semantics was used to explore the interplay between contextual dependence and conceptual understanding. A dimension of cognitive demand was placed on the LCT specialization analysis and revealed interesting understandings of the complexities of numeracy.

The third phase of the analysis also revealed the different external contextual and situational factors influencing numeracy planning decisions. Although multiple factors surfaced from the analysis of the data, one major factor influencing the planning was actually the field of numeracy in higher education.

In this chapter the intention is to abstract the findings from the previous three chapters. To this end, this chapter is structured, firstly, to provide an integrated account of the analysis engaging with the objectives of the study and, secondly, to discuss the insights from the findings in respect to how the complexity of numeracy in higher education leads to other factors having greater impact on curriculum planning.

This chapter furthers the discussion of the findings with an engagement with the epistemic pedagogic device that explores the influences on curriculum planning from the perspective of the influence of the site where knowledge is produced and the site of teaching and learning to offer plausible understandings of the impact of the combination of underlying forces giving rise to the actual plans for numeracy in higher education. Together with making explicit the generative mechanisms giving rise to the planning of numeracy, the chapter engages with implications for planning for numeracy within higher education.

8.2 Integrating the analysis of the three key themes

The discussion that follows is based on an integration of the insights offered through the LCT analysis. The LCT exploration highlighted many tacit principles of conceptions of numeracy, the planning for numeracy and the impact of other forces due to the nature of the field of numeracy. This moves beyond the 'technicalities' of the LCT analysis and language towards a comprehensive explanation of the complexities of planning for a curriculum that includes an emphasis on numeracy development.

8.2.1 Practices of planning for numeracy revisited

Figure 8-1, which was shown in Chapter 5 plots the various approaches to planning for numeracy identified by participants, highlighting that the principles which gave these approaches legitimacy also varied.

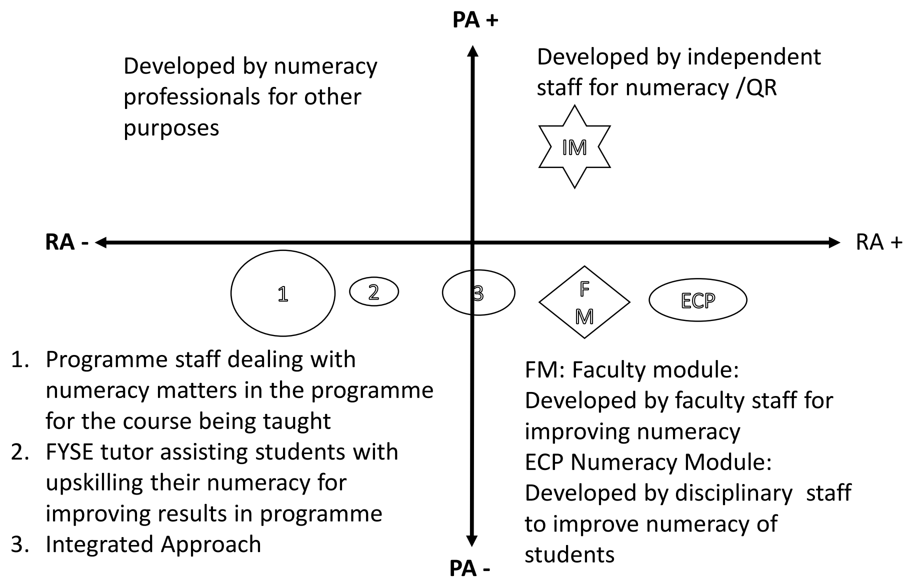


Figure 8-1 Autonomy Analysis of the Practices of Planning for Numeracy Replicated

(Note: The size of the figures does not represent how many programmes adopted the approach. The different shapes indicate different initiatives and the size is based on being able to fit a label).

According to the curriculum maps of each programme, there were plans across all programmes to address numeracy development. However, interview data suggested that some approaches were more explicitly planned like the inclusion of numeracy specific modules or the inclusion of numeracy specific outcomes in an integrated approach and others like the embedded approach that included numeracy in the curriculum maps but relied heavily on the teaching to embed numeracy in the modules. Almost all of the initiatives that were explicitly planned for or were embedded were implemented by disciplinary staff.

Programme developers also made reference to the use of support programmes from support services to provide students with additional interventions to improve numeracy. The data suggests that most of the staff implementing initiatives did not have a strong numeracy identity. In some instances, the programme plans included more deliberate interventions which were focused on developing numeracy as the programme developers understood it. These were initiatives designed by disciplinary staff but targeting developing numeracy outcomes within the programme modules. In most instances, though, although numeracy development was suggested by curriculum overviews, interview data revealed that explicit plans were not drafted and there was no explicit agenda to develop numeracy practices. The development of students' numeracy was seen as important but incidental: lecturers were expected to address it as the need arose during teaching and learning.

The parallel use of multiple approaches may have arisen due to a number of reasons. One possible explanation is that the curriculum planning progress was not monitored to ensure that numeracy, specifically, was adequately addressed. As long as programmes included an indication that numeracy or quantitative reasoning with a 'tick' against the relevant block in the module descriptors and that the curriculum maps which were an accumulation of programme modules had a spread of modules that claimed the development of numeracy (see Annexures F and G) this was considered adequate.

Secondly, the expectation of the staff to be provided with explicit guidance, on the one hand, and the expectation of managers that staff should work out for themselves how to address numeracy, on the other, left the task of addressing numeracy in the curriculum planning process up to staff generally. This could be as a result of many discipline experts and managers finding it difficult to articulate explicitly what they believed needed to be included and therefore were looking to the other to resolve. It also highlights the position of numeracy as straddling many disciplines and thus having no clearly designated 'home' and therefore no place that could be used as a resource in making sense of numeracy and how it could be developed.

If we return to the arguments made by the New Literacy Studies perspective that were discussed in Chapters 2 and 3 it is clear that, in principle, an approach of addressing numeracy within the programme and throughout the duration of the programme by disciplinary experts is favoured. Galligan (2011), Prince and Archer (2008) and Frith and Prince (2009), among others, argue using the NLS approach that numeracy practices are ideological in nature and therefore politically, culturally, historically and socially influenced. These scholars also advocate that numeracy development should permeate the curriculum and that this is best supported by disciplinary staff since they understand the numeracy practices required within the context of their disciplines.

However, throughout the interviews with programme teams and other participants there was concern expressed that most disciplinary staff lacked the necessary confidence and agency to be able to explicitly plan to embed numeracy during the curriculum planning process without mentoring. Similar concern was expressed by participants in respect of the enactment of the embedded numeracy by staff in the teaching. The programmes included in the study sample were selected specifically because they did not have a strong mathematical component. Some of the staff in these programmes did not have a strong grounding and were uncomfortable with mathematics and this translated into discomfort with numeracy.

This analysis raised two possible tensions. Firstly, in the planning of the numeracy development within the programme there is the tension of whether to rely on disciplinary experts or someone with specific expertise in numeracy to drive the process. Exploring this tension further, we have on the one hand the experience and specialized knowledge of the disciplinary expert which is invaluable to understanding numeracy as it is contextually situated within the profession and is one context in which graduates will be expected to practice numeracy. On the other hand, curriculum developers saw someone with specific numeracy expertise as potentially being able to bring in specialized concepts in greater depth and apply them across contexts – possibly also including societal and personal contexts. This surfaced a possible dichotomy around whether the responsibility for numeracy planning legitimates the expertise of the disciplinary expert or whether someone with specialised expertise in numeracy could bring in an approach which could be effective across multiple contexts.

In some instances, programme curriculum developers indicated that they had looked to those they considered experts to lead this process of numeracy development – staff in the mathematics department. The mathematics staff, however, did not see themselves as experts with regard to numeracy. Some curriculum developers also expressed the view that mathematics lecturers would not be best suited to lead this process. The planning process highlighted that there was no real 'home' for numeracy development. It was moved from one discipline space to another, while the staff in one discipline criticised the ways it was handled by the staff in other disciplines. This draws attention to another tension within the debate around to which discipline numeracy belongs: the relationship of mathematics and the role of mathematicians in the development of numeracy in higher education.

A second tension highlighted in the study was whether numeracy development within an undergraduate curriculum is best served by an explicit and intentional agenda to develop numeracy – such as is evident in a module-based approach; an integrated approach that includes numeracy development in the outcomes of other modules; or through an embedded approach, where no plan is identified explicitly but staff are expected to develop students' numeracy in the course of teaching and learning as opportunities present themselves. Each of these alternatives came with its own potential drawbacks. For example, with the module-based approach there were questions about the relevance and transferability of the numeracy students would learn to their specific disciplinary contexts. Another example is that the embedded approach raised concerns about its reliance on the expertise and commitment of programme staff to identify and engage with opportunities to develop students' numeracy practices during teaching and learning: without requirements spelled out explicitly in curriculum documents lecturers could easily overlook this task. In addition, by addressing numeracy only as the need arose the students' understanding of the underlying principles of the processes and knowledge involved in the numeracy practices might not be adequately developed.

In summary, the 'non specialization' of numeracy implied that the responsibility and accountability for planning for its development was dispersed across the institution, including the mathematics department, disciplinary staff who were also professional practitioners, and staff who were involved with developing numeracy specific modules that could be used across different programmes. The absence of a dedicated centre or staff to spearhead and manage this and the ambiguity around how numeracy was understood resulted in a diverse range of initiatives based on very different organizing principles.

The question of why this range of different approaches to planning for numeracy was adopted was explored from two perspectives: firstly, in terms of the factors internal to the phenomena – the various conceptions of numeracy and, secondly, in terms of the contextual and situational factors external to the phenomenon.

The following section discusses how the organizing principles that determine what is valued as numeracy in higher education can impact on the curricula choices that are made. This allows for a 'below the surface' explanation of plausible generative mechanisms that have configured numeracy development at this institution, specifically. It also raises considerations for the planning for numeracy in higher education generally.

8.2.2 Conceptions of numeracy revisited

Both the inductive and deductive analysis generated findings that described the different domains of numeracy and the underlying principles which determined what numeracy was legitimated. The thematic analysis revealed that numeracy drew on multiple disciplinary knowledges and highlighted that numeracy practices went beyond cognitive engagement and brought together the affective, cognitive and contextual domains as well.

The analysis of the data using the LCT Specialization dimension in Chapter 6 highlighted that numeracy legitimated at the institution have a range of underlying organizing principles, spanning varying degrees of valuing of specialized knowledge and specialized knowers. At times the valuing of specialized knowledge is dominant, as well as the dispositions and habits of mind indicative of a particular knower. It is interesting and, in some ways, consistent with definitions of numeracy – that numeracy is often described as involving "mental processes", "common sense" practices that are part of professional or everyday practices that are based on the intuition. There was no particular dominance by a particular specialized field or process.

Further differentiation using the lens of cognitive demand, however, highlighted that cognitive expectations are different for different numeracy practices even where the principles of legitimation were the same – for example, where specialized knowledge was prioritized, this spanned different cognitive levels, from simple recall to conceptual understanding to application and synthesizing. Interestingly, even the common sense practice showed different levels of cognitive demand, suggesting that common sense, appears to be a relative term.

As Davis (2006) points out, common sense is an “elusive concept” (p. 6). Davis contrasts common sense with mathematics and describes common sense as “unarticulated and not formalized or given abstract structure, contrary to mathematics” (Davis, 2006, p. 7). Davis (2006) also describes common sense as being characterised by the implicit practices of mathematics that involve being aware of the real world problem and real world practice.

Gramsci (1971), in his prison notes, described common sense as the "diffuse, unco-ordinated features of a general form of thought common to a particular period and a particular popular environment"(p. 330). This brings attention to the situated nature of common sense. Gramsci (1971) characterised common sense as being ambiguous and contradictory as well.

Most numeracy practices in the examples provided in this study, especially in the professional practice, legitimated numeracy where there was a weakening of specialist knowledge and specialist attributes, the relativist code in Specialization often described as a space of common sense. This could be misinterpreted to imply that specialised knowledge or particular dispositions are not important. However, the examples participants used to describe numeracy required certain levels of engagement with specialised knowledge and particular habits of mind and dispositions. The point is thus that a particular specialised knowledge is not prioritised, but rather that an amalgamation of various knowledges and dispositions are expected to engage in the numeracy practice.

Coben (2006) discusses the use of the concepts 'common sense' and 'good sense' as proposed by Gramsci to explore adult mathematics education. Gramsci describes good sense as:

> a philosophy which already enjoys, or could enjoy, a certain diffusion, because it is connected to and implicit in practical life, and elaborating it so that it becomes a renewed common sense possessing the coherence and sinew of individual philosophies. But this can only happen if the demands of cultural contact with the "simple" are continually felt (Gramsci 1971:330n cited in Coben 2006, para. good sense).

This portrays good sense as a hierarchical extension of common sense and the referral to a renewed common sense again alerts us to the dynamic nature of common sense. One of the concerns raised in Chapter 1 is that numeracy is often described as common sense and thus it is often assumed that everyone should be able to be appropriately numerate intuitively. This study verified the conception of numeracy as a commonsense phenomenon – something I had not initially expected, but also highlighted the nuanced nature and the levels of sophistication required of the commonsense practices that were valued in the different numeracy practices identified.

This is shown in the Figure 8-2 below replicated from the analysis in Chapter 6.

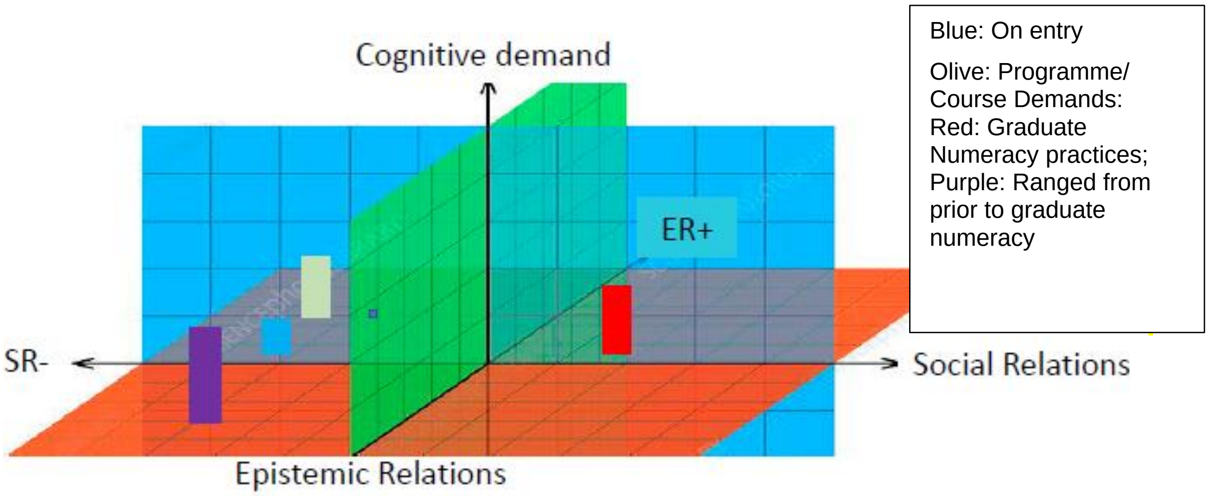


Figure 8-2 Combined Specialization Analysis and Cognitive Demand of the Conceptions of Numeracy Replicated

As can be seen in figure 8-2 above and as discussed in Chapter 6, there was weakening of relations to particular specialized knowledge or ways of being as evident in the purple band above in certain examples of numeracy practices provided by participants. This was most dominant in the descriptions of a numerate graduate, where the practicing of numeracy was viewed as a mental process or something students should know and do inherently.

Reflecting on the discussion of Bernstein's vertical and horizontal discourses in Chapter 3, it was argued that numeracy as an everyday practice is best described as a horizontal discourse. Research in workplace numeracy and adult numeracy has also described numeracy as a horizontal discourse (FitzSimons, 2006).

However, while the findings of this study show the non-prioritizing of a particular specialised knowledge and processes mostly as a professional, there are other indicators of numeracy that are associated with particular knowledges and particular dispositions. The analysis represented in Figure 8-2 highlights that numeracy in higher education is sometimes legitimated through the mastery of specialized knowledge from different disciplines or fields. Another dimension that is often seen in opposition to specialized knowledge is that of the social relation. Yet this dimension also features in the analysis of data in this study. The question this surfaces is whether numeracy in higher education actually has no legitimating principles since it is scattered across the plane or whether there are shifts that need to happen in the planning for numeracy in a curriculum that move deliberately between the different principles of legitimation. The challenge to the curriculum is mistaking any one set of principles to be indicative of a comprehensive picture of numeracy. The 'go to' design of curriculum at the institution seems to imply that curriculum planning prioritizes one or two of these domains of specialised knowledge and knowers.

Another challenge is understanding the principles and planning for common sense. This initially appears to be a contradiction: how does one plan for common sense? However, this study highlighted that common sense is actually layered. The different layers of common sense, when probed, appear to include an integration of particular knowledges and particular dispositions at varying levels of cognitive demand.

There is a sense of this being ‘fractal’ in nature. In other words, every ‘layer’ of common sense includes an understanding of expected knowledge and particular dispositions. For example, at a foundational level the use of detergents at home expects that there is some understanding of ratio and dilution for use. Even something like ensuring that clothes are soaked with detergents could be performed using guess work, based on a sense of parts to the whole which is developed by engaging in this practice through trial and error or being exposed to the practice by others. As an everyday practice it ceases to be consciously thought about and is therefore tacit, it layers the level of common sense.

In this study, the practices described as common sense ranged from the ability to count money and do personal budgets to the numeracy practices involved with clinical assessment, such as nursing assessments and treatment plans. The numeracy practices evident in the examples provided in the study surfaced the need for conceptual understanding of specialized concepts from an academic perspective. As a professional in the workplace, a numerate graduate is expected to bring together specialized knowledges in particular ways in which the underlying numeracy practices are tacit within the professional practice. This phenomenon is modelled graphically in Figure 8-3, showing the ‘evolving’ layers of common sense.

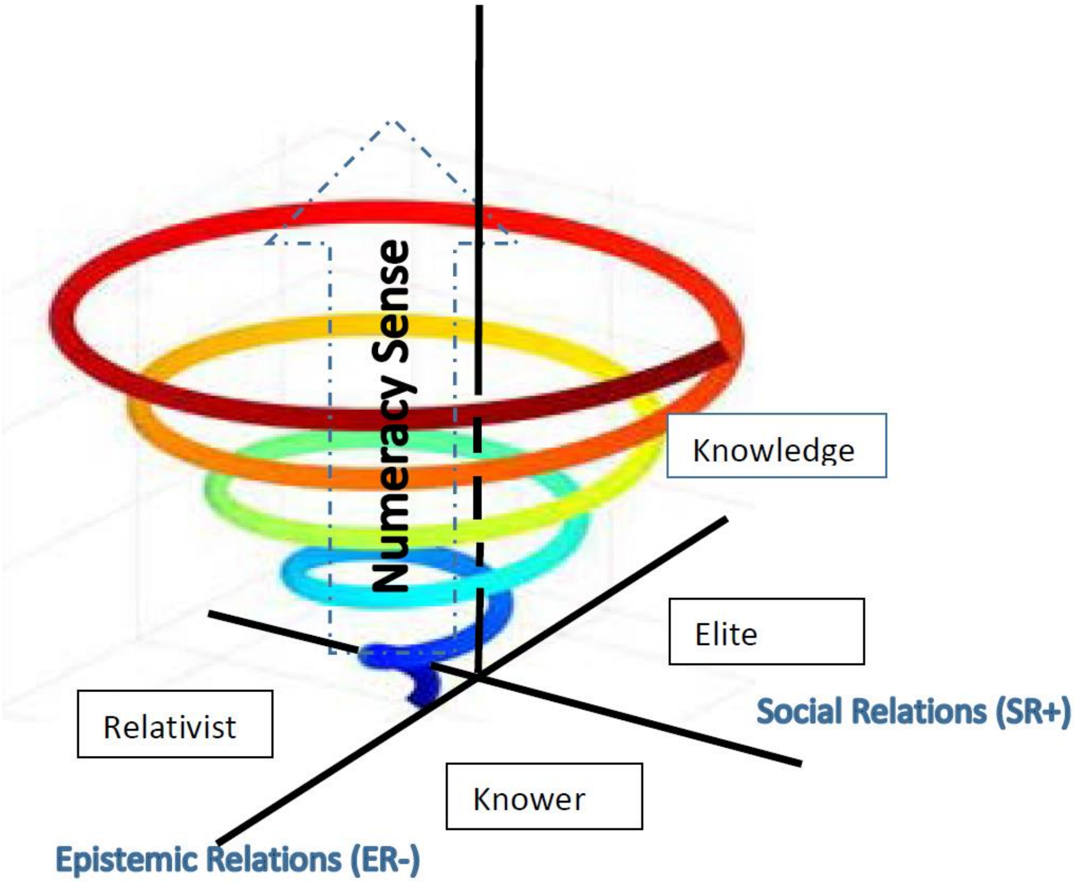


Figure 8-3 Numeracy sense

Figure 8-3 highlights that the development of increasingly sophisticated levels of numeracy sense is dependent on both knowledge building and knower building. However, more importantly, it suggests that even though the practice requires specialized knowledge and cultivated gazes, these become so ingrained in a person that they become tacit, mental processes that are not visible explicitly. In other words, the numeracy practices are part of an action or task, such as treating a patient, and are not used or seen on their own.

I battled to describe this numeracy 'common sense' in a way that distinguished it from other numeracy that is described as everyday common sense. I think it's particular to the higher education context and that this numeracy common sense materializes through cumulative knowledge and knower building in academia and in specialized disciplines and contexts. I thought of this as almost a 'specialized' common sense because this oxymoron drives home the notion that the common sense numeracy that informs clinical or professional judgements is based on specialized knowledges and behaviours specific to contexts which become everyday through practice. However, this did not capture the term numeracy within the description. I therefore chose the term 'numeracy sense' which captures the tacit nature of numeracy within other practices.

If this is related to Gramsci's (1971) description of 'good sense', then we can describe 'numeracy sense' as a practice or perspective that is diffused because it is connected to, and implicit in, practical life (personal, professional and societal) and through elaborating this practice or perspective it becomes a renewed commons sense possessing the coherence brought about through specialized knowledge building drawing from across multiple disciplines, contextual knowledge building and knower building. Numeracy sense, then, continues to evolve.

Common sense according to Gramsci is elusive which makes it difficult to plan. This study demonstrated, however, that it is possible to identify some underlying principles that differentiate the common sense numeracy practices in higher education programmes from the everyday numeracy that students would use prior to entering an undergraduate programme at a university.

The complexity of numeracy sense was brought to light by interpreting this within the analysis of participants' conceptions of numeracy using the LCT Semantics dimensions, as illustrated in Figure 8-4.

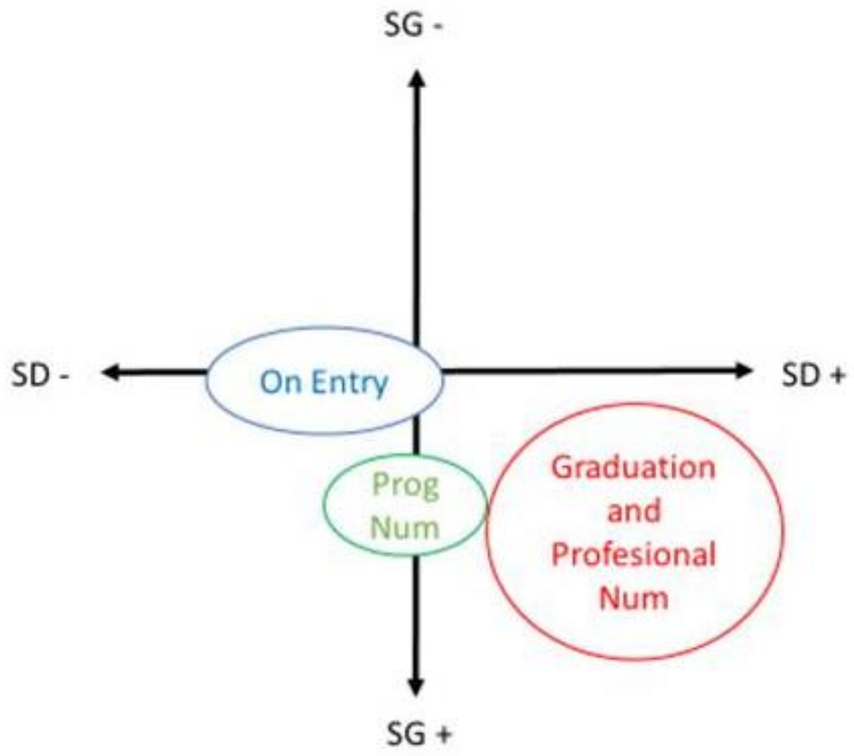


Figure 8-4 Semantics Analysis of the Conceptions of numeracy replicated

The semantics analysis discussed in Chapter 6 showed differences in the organizing principles of numeracy as related to conceptual complexity and contextual grounding. Often numeracy is described as 'basic' knowledge applied in everyday contexts. The data revealed, as shown in Figure 8-4, that a common conception of numeracy as being about simple concepts situated in context is one of the spaces (on entry) that is legitimated as numeracy. However, the analysis highlights also that there were other underlying principles describing the numeracy practices expected of students. The data predominantly showed the numeracy practices expected of a graduate to include conceptual understanding of complex numeracy concepts that are often a condensation of other simpler concepts while at the same time being relevant and appropriate to the contextual influences. As the programme became more specialized as the students progressed, the level of condensation and complexity and unfamiliarity of contexts increased.

This surfaced yet another false dichotomy of conceptual depth versus contextually-bound practices. The numeracy practices that dominated participants' conceptions of numeracy as they related to professional practice were legitimated by both complex conceptual understandings and contextual sense making, being 'worldly' dominated in most of the examples of numeracy that were provided. This expanded the concept of specialized knowledge, in relation to numeracy practices, to include both conceptual knowledge building and contextual knowledge building.

Duranti & Goodwin (1992, p. 2 as cited in Bansilal, 2014) describes a context as "a frame for the event being examined and provides resources for its appropriate interpretation" (p. 1160). Bansilal (2014) identifies four attributes that are important to engage in the contextual domain of the South African school subject Mathematical Literacy. As seen from the data, contextual sense making is an important domain of numeracy practice in the context of higher education as well and these attributes are thus relevant to the context of this study. They are as follows:

- **Contextual language**: This refers to words or phrases that have particular meanings because of their context; for example, the "centi-minutes" referred to in one interview in this study. This term is not commonly used in relation to time but was important in the context of garment production.
- **Contextual signifiers**: These are signifiers used to communicate specific information; for example, the signifiers "spices used are increased by 1 ml for every 400 g of meat above 5 kg" used in an example given in this study.
- **Contextual rules:** These are rules that 'govern' the practice within a context. For example, certain treatments require a product with a pH value of 7 or less; when purchasing a product as a rule, then, products with pH values of 7 and above cannot be considered even if they are cheaper.
- **Contextual Visual Mediators:** These are diagrammatic and graphical images that give meaning to a context. Again, these may not always follow the rules of mathematics for making sense of the information in the representation but is acceptable to the particular disciplinary context. To give an example, the analytical dimensions used in this study have been plotted on graphs which look similar to Cartesian planes, with positive and negative values. In this context, however, the negative as in SR-, or ER- is

not used in the mathematical sense but rather to indicate that the concept although present is weaker – not that it is absent or negative in value.

What this suggests then, is that numeracy practices that are legitimated require an understanding and application of the particular contextual language, contextual signifiers, contextual rules and contextual visual mediators. By implication, this means that contextual knowledge-building is likely possible through deliberate exposure to all four attributes. This increases the complexity of the specialized knowledge required implicitly in professional, personal and civic engagement. It appears, then, that numeracy practices are legitimated in different situations by varying degrees of integration of specialized knowledge, particular gazes and dispositions, cognitive expectations and contextual attributes.

With a deeper understanding of numeracy sense comes an engagement with multiple complex contexts that results in a "worldly" practice. This suggests that numeracy sense requires contextual sense-making and action that is likely to be made possible through contextual knowledge-building, specialized knowledge-building in respect of principles and conceptual understanding from multiple disciplines and knower building to develop particular gazes, habits of mind and dispositions. The variations of each of these factors impacts on the cognitive demands associated with the practice of numeracy relevant to the situation.

In essence then, the conceptions of numeracy expressed in the study show numeracy to be a complex phenomenon legitimated by differing principles at different times in different spaces. This is aligned to the New Literacies Studies perspective that views numeracy practices as socially, politically and historically influenced, which was discussed in Chapter 3. Again, we take cognizance of the NLS argument that numeracy should not be viewed as an autonomous set of skills that, when mastered, results in a person being numerate. There are, in fact, multiple numeracy practices (numeracies) that are legitimated by different organizing principles. This is also evident in this study.

The challenge is that adopting a social practice orientation to numeracy implies 'what is numeracy' would be different across contexts which makes planning for developing numeracy practices that can be adapted across various contexts very difficult. Planning for a set of autonomous skills would be far easier because these are more easily identifiable and described. As a result, planning for numeracy often ends up focussing on a limited number of autonomous skills, such as basic arithmetic, a generalised understanding of concepts such as measurement or percentage change. The irony is that the expected numerate graduate is legitimated through the valuing of many more practices than those on an easily identifiable list of skills. So, in essence the very nature of numeracy as a tacit practice makes planning to develop numeracy sense very difficult.

The next section discusses numeracy education in relation to the tacit practices of numeracy.

8.2.3 Practicing numeracy and numeracy education

Participants in this study found it difficult to articulate their conceptions of numeracy and frequently resorted to giving examples to 'show' their conception of numeracy. Although the academic staff in the selected programmes are themselves professionals, and although they expressed the view that numeracy practices were crucial to their programmes, they also described themselves as not feeling at ease with numeracy. This presents a tension: numeracy is seen to be important for students to master in order to be adequately equipped as professionals, yet the successful professionals themselves are not comfortable with numeracy. As professionals they have tacit numeracy sense, but are not able to identify or articulate this explicitly. Their numeracy sense is so embedded in their academic or professional practices that it is simply seen as an indistinguishable part of their professional, or clinical judgement.

Tacit knowledge, dispositions and contextual sense-making are difficult to plan for because they are 'invisible' to the practitioner. As a result, in a situation where a curriculum developer acknowledges the need for numeracy development but find it difficult to plan for because their understanding of it is tacit and difficult to articulate, they could choose to hand over the task of numeracy development to others who may be seen to have stronger identifiable/explicit understandings of numeracy.

The identifiable, explicit practices of numeracy are often associated with the specialized knowledge and processes involved in mathematics. This could be one reason that some academics felt that mathematics staff should deal with numeracy and could also influence the decision to take a module-based approach to numeracy planning that include generic mathematical skills for example that may only be able to take into account one particular combination of legitimating principles of numeracy.

This may be indicative of tensions between the practice of numeracy and numeracy education. The practice of numeracy draws on multiple disciplines that may have firmly established traditions; the practice of numeracy blurs these boundaries as it exists as an interdisciplinary phenomenon. Therefore, it is an entangled phenomenon. Numeracy education, on the other hand faces the tensions of attempting to disentangle the phenomena from its place of practice while targeting that immersed practice as the outcome of the educational initiatives that are designed to develop numeracy. The implications for developing numeracy are immense but the most obvious appears to imply that any development of numeracy will benefit from combining specialized knowledge, knower and contextual knowledge building at varying levels of complexity.

Each one of these aspects of numeracy education encompass multiple tensions. For example, specialized knowledge-building appears to require that a curriculum brings together the building of knowledge across multiple disciplines such as mathematics, statistics, business/finance and programme specific disciplinary knowledge. Similarly, knower building also requires multiple considerations. In attempting to combine all aspects we are alerted to, here again, the challenges experienced by curriculum developers to negotiate and hold together the multiple tensions at play within the phenomenon of numeracy in higher education. This relies on the agency of the curriculum developer in respect to numeracy.

Typically, one develops agency within a field through engagement with the knowledge and research in the field. The question is how easily accessible the knowledge of numeracy and research in numeracy is, not only in terms of availability but also in terms of accessing the discourse of numeracy in higher education for outsiders to the scholarship of numeracy.

8.2.4 Exploring numeracy education in higher education

A review of the literature relevant to the study found that more research has been done on the phenomenon of numeracy or quantitative reasoning in basic and vocational educational than in higher education and this broader context of numeracy literature was explored to provide a more comprehensive description of numeracy. Most of the scholars who adopted a social practice orientation advocated that numeracy practices are programme discipline specific and therefore should be embedded into the discipline-specific modules across a programme.

The embedded approach taken in some cases in the institution in this study aligned to this perspective. However, it remains extremely challenging to plan for an embedded approach when there are so many external factors to be negotiated, such as conceptual diversity, staff preparedness, time allocated to a module, and the volume of 'pure' disciplinary content that needs to be covered. Another consideration is that an embedded approach assumes that students already have a certain conceptual foundation in place, but many of the participants in this study felt that students often entered higher education without this foundation in place. A further concern is that when numeracy is embedded within modules it may be related to a specific activity and the underlying principles of numeracy may not be addressed; as a result, the student may be unable to transfer the practice they have learnt to another context. The literature review, as well as my personal conversation with a researcher in the field, indicate that there are a small number of research studies dedicated to numeracy development in higher education in South Africa. Most, but not all, of this research focuses on pedagogy discussing the processes of identifying the numeracy demands implicit in the programmes and/or specific modules and attempting to explore creative ways of embedding these in the teaching. Very little investigates curriculum planning at the level of programme design to develop numeracy in higher education. This could possibly imply that there is a small population of researchers working on the scholarship of numeracy in higher education focused in this particular site of the pedagogic process.

The data suggests that at the institution in this case study responsibility to plan for the inclusion of numeracy or quantitative reasoning was not delegated specifically to any particular individual or body. This suggests that a significant number of staff at the university (all programme curriculum developers) were expected to make sense of the imperative to address numeracy through unpacking what is numeracy and grapple with how it could best be developed. This absence of centralised leadership may have served as a catalyst for a number of variations in approaches to arise. Curriculum developers and curriculum development teams had minimal discussion about their conceptions of numeracy prior to planning the curriculum. A common understanding of numeracy was thus never established. The varying approaches that were taken to planning for numeracy may have resulted from the varying conceptions of numeracy that existed among curriculum developers. In other words, at this institution, beliefs about numeracy were heterogeneous across the large number of staff responsible for curriculum development. Without a process to identify and engage with the different underlying principles which legitimated numeracy in higher education programmes at the institution and staffs' views on the best approach to follow, a range of different approaches ensued.

The complexity of the phenomenon of numeracy lies in the fact that it involves practices that are tacit and entangled and therefore difficult to articulate, and that there are a range of different principles underlying the conceptions of numeracy among those responsible for curriculum planning. With a lack of a strong unifying understanding of the diversity of the phenomena or approach, situational factors could have a greater pull on decisions than if there was consensus and clearly identifiable practices of numeracy. The higher degree of diversity in the field makes it difficult to negotiate the situational forces and hold on to understandings of numeracy in the advanced planning for numeracy through the programme curriculum.

As discussed earlier the diversity within the field of numeracy in higher education, it is also an emerging field that does not yet establish traditions, but it draws on multiple disciplines which are well-established in the educational domain and possess their own traditions. Of the multiple disciplinary influences, the discipline with the strongest link to numeracy is mathematics. In terms of numeracy, the literature also alerts us to the distinctions between mathematics and numeracy/quantitative reasoning. The literature reviewed moves strongly away from a limited focus only on older mathematical traditions towards the emergence of a new younger field with its own organizing principles that are different to those of the discipline of mathematics. Mathematics is a well-established discipline and therefore has established traditions that are more explicit. It can become difficult for a new emerging field with diverse understandings and roots in multiple fields to maintain a diverse but distinct identity when interacting with mathematics.

In the analysis in this study, it is evident that the knowledge domain of numeracy in higher education comprises an integration of multiple disciplines. These included mathematics, statistics, accounting and other business-related fields as well as the professional discipline of the particular programme – such as nursing, for example. Each of these disciplines or fields possesses distinct underlying principles that inform its distinctive numeracy practices.

Another consideration that increases the complexity and challenge of planning for numeracy in an undergraduate curriculum is that typically numeracy is applied in the context of solving a problem or responding to a situation and, as such, is a forward-looking field. The literature affirms numeracy in higher education as a younger field that is forward-looking. This presents particular challenges. Firstly, as a young field numeracy has limited traditions to anchor it and from which curriculum developers can draw. Secondly, as the world changes more and more quickly it becomes increasingly difficult to plan a forward-looking curriculum because the future contains so many unknown variables.

As has been noted, there is the strong link between numeracy and mathematics. In fact, numeracy cannot be described without employing mathematical concepts. Because of the challenges that continue to cripple basic education in South Africa – including a history of exclusion, inadequate resources and inequitable learning experiences, students entering university have very often not mastered the principles and practices of mathematics or mathematical literacy adequately to handle the numeracy requirements of their university programme. This forces a backward-looking orientation as the institution addresses the gaps in students' basic education. Because the traditions and practices of mathematics are more established traditions, more easily identifiable and less context-driven, institutions can tend to focus on developing students' mathematical skills. This approach does not, however, achieve the goal of students 'being numerate' when they graduate, because numeracy itself can be neglected in this approach.

This suggests that when planning to develop in undergraduate programmes curriculum developers will have to negotiate a number of competing forces driven by situational factors such as in this study, the inadequacy of the basic education students receive before they enter the programme and the impossibility of anticipating all the numeracy practices students will need in the rapidly changing world after the exit the programme. This can result in curriculum planning wavering between forward-looking and backward-looking orientations and reaching for the stabilising influence of older traditions.

In this section I have also examined the challenges related to the implicit and evolving nature of 'numeracy sense' in higher education and the difficulty of planning a curriculum for a tacit practice that is not easily identifiable. As an interdisciplinary practice, numeracy in higher education is a young and emerging field that draws on multiple disciplines with older established traditions. Numeracy education thus has to hold together multiple internal and external forces in decisions at the site of recontextualisation where curricula choices are made. The next section explores the recontextualising space within the Epistemic Pedagogic Device.

8.3 Numeracy education within the Epistemic Pedagogic Device (EPD)

The Epistemic Pedagogic Device (EPD) is shown again in Figure 8-5 for reference.

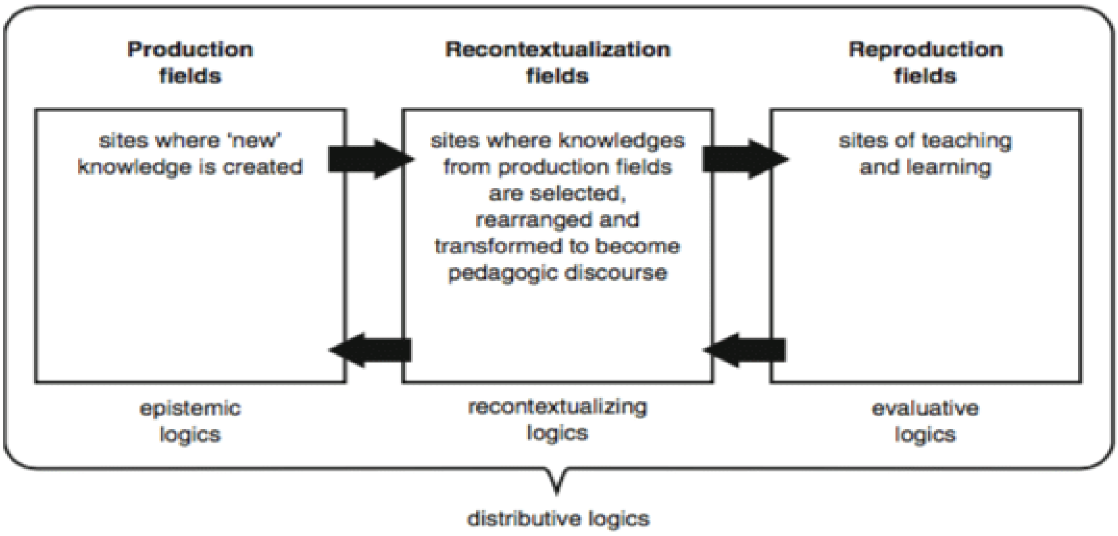


Figure 8-5 Epistemic Pedagogic Device (EPD) replicated (Maton, 2014, p. 74)

The site of recontextualisation is influenced by both the field of reproduction and the field of knowledge production. The analysis of data suggests that programme curriculum developers experienced multiple tensions in the curriculum planning (site of recontextualisation) of the entire programme due to a variety of forces that they had to negotiate.

Firstly, the curriculum renewal process was essentially a new experience for academics at this university of technology (UoT) as previously the curriculum had been designed at the national level for Technikons. Secondly, the staff involved in the curriculum renewal process were primarily professionals or practitioners from particular industries. As very few curriculum developers had qualifications in education, their professional knowledge typically superseded their educational knowledge of the particular discipline which they taught. Thirdly, the curriculum renewal project included large scale change introduced by the university's academic leadership. There was the pressure of addressing the more prominent large scale reform that required radical change to the structure and content of programmes at the institution. The other contextual and situational factors discussed in Chapter 7, such as the structure of undergraduate programmes and the expertise of staff, also had to be negotiated by staff in their role as recontextualising agents (curriculum developers) in the curriculum renewal process.

In the process of recontextualising (curriculum planning of the programme), curriculum developers are drawing from the field of knowledge production of the programme discipline and from teaching and learning (field of reproduction) in the programme discipline. Within this recontextualising field they include the imperative to develop numeracy. This can be represented visually in Figure 8-6 where the field of recontextualisation of the programme includes the EPD in relation to numeracy in higher education.

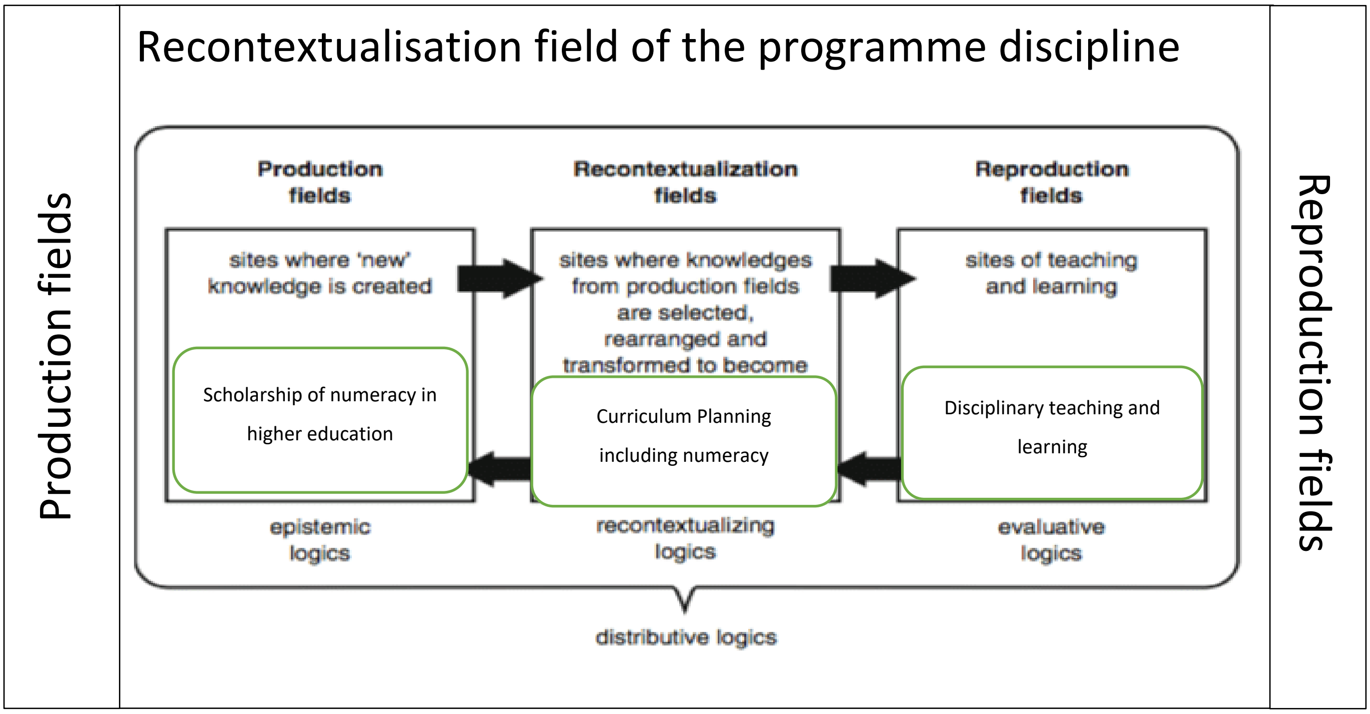


Figure 8-6 EPD of numeracy education within the recontextualisation of undergraduate programmes

The recontextualising agents responsible for curriculum development were usually professional practitioners. In other words, the academics involved in planning for numeracy drew on their strengths from the practice of their professions and their experiences in the learning, teaching and assessment practices they had previously engaged in within their disciplinary specific modules.

In respect of the EPD then, the prioritizing of numeracy or quantitative reasoning and planning for its development within an undergraduate curriculum in most instances drew strongly from the site of reproduction (teaching and learning) of the discipline. In designing the curriculum, the past experiences of academics/departments with teaching and assessment and their engagement within their respective industries as practitioners were strong influences. Thus, the site of reproduction impacting on numeracy planning was not from reflections of explicit teaching and learning with a focus on numeracy but rather was from the site of teaching and learning of programme modules where numeracy development existed incidentally or was absent. These past experiences also resulted in the staff having preconceived understandings of students' existing numeracy practices or lack thereof on entry to the programme due to their previous engagement with students in the programme's disciplinary modules and the challenges they experienced. In essence, the site of reproduction in terms of the teaching and learning of discipline-specific modules served as a major influencer on the recontextualisation of numeracy and not explicitly in terms of the teaching and learning practices in relation to numeracy education. There was also no evidence that this influence was driven by a scholarly critical reflection and scholarly engagement of the teaching and learning experiences. It did appear to be driven by anecdotal evidence.

The data also revealed that there was no real connection identified between the field of production in numeracy and the field of recontextualisation in this particular case. Drawing on the findings above, the programme curriculum developers based their decisions on practitioner insight either as a lecturer or a professional and showed no engagement with the scholarly knowledge production in the field of numeracy in higher education. This observation is made with cognisance of the fact that there is limited scholarship in the field of production of numeracy education as it relates to higher education. Apart from the capacity of the staff draw from the site of production of knowledge on numeracy in higher education, the limited influence of the field of production in the field of recontextualisation could also be attributed to the limited scholarship within the field for production itself with respect to numeracy in higher education. The review of the literature shows that scholarship on numeracy in higher education is increasing, however. The Numeracy online journal and the 'Adults learning Mathematics' (ALM) online journal, for example, are both relatively new publications dedicated to the production of knowledge in numeracy, although not exclusively to numeracy in the higher education context.

It can be noted that:

- Disciplinary experts as practitioners described numeracy as being crucial to their professions, but the examples they provided showed numeracy to be implicit in the professional practice. The difficulty they experienced in distinguishing numeracy from its practice in their professional context could have contributed to their lack of confidence and weaker positional autonomy with regard to numeracy in higher education. This could, in turn, have been a factor in their choice to not plan explicitly for numeracy in the curriculum or to hand over the development of numeracy to other staff who they saw as having greater competence or stronger positional autonomy with regard to numeracy.
- Numeracy is a complex concept which has varying principles of legitimation. A common perception is that because of its common sense nature it requires no specialized knowledge or skills. This can result in academics lacking motivation to plan for it or even recognising that there was a need to engage with conversations of what is numeracy in the context of the discipline before planning the curriculum. The study shows, however, that there is a need for specialized numeracy practices that are implicit.
- Thinking of an evolving ‘numeracy sense’ in the programme implies that it evolves through the development of specialized knowledge (conceptual and contextual knowledge) and particular knowers (cultivated gazes). The specialized knowledge of numeracy is an amalgamation of disciplinary phenomena, mathematical concepts and processes and knowledge of particular contexts in which the student is expected to function.

With respect to the EPD as represented in Figure 8-6, the following is reiterated:

- In respect of the EPD of numeracy education, planning for numeracy can be seen as a subset of activities that sits within the field of recontextualisation of the undergraduate programme as whole. Therefore, the factors acting on curricula choices with regards to the programme also act on the numeracy planning within the programme.

- The strongest considerations in the planning for curriculum in this study were driven by the site of reproduction in terms of teaching and learning in discipline-based modules from the specific programmes. These, in limited instances, also included numeracy related learning and teaching considerations but also was driven largely by other contextual factors that influenced learning and teaching at the institution specifically and with the national context.
- Together with these forces, the educational field of numeracy can also be described in reference to field of production, a field of recontextualisation and a field of reproduction. The literature review suggests that this field of production is very limited. Although there has been an increase in the literature around numeracy and how it could be developed in particular programmes in higher education, these appear to be specific to particular programmes for example, numeracy within the nursing qualification.
- In this study, reference to the site of production of numeracy was not a factor informing curriculum choices. In fact, it was completely absent in the planning for numeracy and there was a suggestion that participants were unaware that there was literature addressing the development of numeracy. At the same time, the data suggests that there was also very little consideration from the field of reproduction – the actual teaching and learning of numeracy.
- As an interdisciplinary phenomenon with very limited scholarship in the field of production, numeracy could be at risk of being 'colonized' by well-established disciplines, resulting in it being formed according to the principles of legitimation of that particular discipline, rather than the principles most appropriate to numeracy. On the other hand, isolating numeracy from the influence of other disciplines will also compromise the underlying principles of numeracy in authentic context and could result in it being neglected and even abandoned.

8.4 Understanding the underlying organising principles of the choices made in the planning for numeracy

The study has identified multiple tensions that have to be negotiated in the design of a curriculum that can result in planners taking a range of different approaches to planning for numeracy. The study has also highlighted that it is virtually impossible to define numeracy or 'being numerate' in a universal way because of the many factors that influence what is considered legitimate numeracy. Analysis of the data showed that different principles were used to legitimate numeracy in different situations. There are thus multiple numeracies that are valued within undergraduate programmes and expected of a professional graduate suggesting different numeracy sense.

The agency of the staff involved with planning for the development of numeracy and the lecturers expected to enact these plans in teaching and learning was shown to be limited in respect of their confidence to engage explicitly in numeracy education. This could be attributed to the fact that numeracy is an emerging field in higher education with a limited scholarship base which provides limited points of reference from the site of knowledge production. Coupled with this were many other considerations that have been discussed.

There were likely to have been many points in the curriculum planning process where key decisions had to be made. At these points the force of the situational and contextual factors and the dominance of disciplinary considerations would have interacted in different ways with the curriculum developers' agency to plan for the development of numeracy in the curriculum. This would have been impacted as well by the difficulty developers experienced to articulate explicitly their conceptions of numeracy in order to justify what they believed should be included in the curriculum.

Possibly the greatest challenge to numeracy is the common misperception that a person is either numerate or innumerate. The study argues for a move away from labelling of numerate or innumerate students and recognise instead numeracy sense that is different and expands common sense everyday numeracy to a kind of common sense numeracy which relies on conceptual knowledge from multiple disciplines, contexts and is associated with particular attributes and dispositions. The challenge for curriculum developers working to recontextualise knowledge for a programme is to recognise these key numeracy elements within the various disciplines and contexts on which numeracy draws and to make them explicit so that they can be planned for and integrated into the curriculum.

If numeracy is seen by curriculum developers to be the understanding and mastering of mathematical processes and concepts, this could lead to an approach to developing numeracy which is biased towards mathematics and attempts to apply these concepts and processes to contexts with a mathematical gaze that fails to recognise that numeracy requires contextual knowledge building. Such an approach may not address the opportunities in the curricula for the development of knowledge within the contextual domain. A view of mathematics and context-based numeracy as mutually exclusive could result in curriculum developers believing that they have to choose between these two approaches, and this choice would influence a set of further choices, such as deciding who is best qualified to manage the process of planning for numeracy development within the curriculum. However, the data analysis is suggesting for numeracy sense to be developed all these positions need to be accounted for in structured ways so as to develop students' numeracy sense to an adequate level by the time they graduate.

The next section identifies a 'missing link' in the planning that could bring the multiple approaches taken to planning for numeracy into dialogue and alignment with each other.

8.5 Using Epistemic Pedagogic Device (EPD) to identify the 'missing link' in the planning for numeracy

In this study the space of recontextualisation where the curriculum was planned was governed by several imperatives. The staff involved with developing the curriculum were playing a short term role as recontextualising agents, but as lecturers in their various programmes their primary role in the institution was as agents in the field of reproduction. Most had also been practitioners in their professions. A few have also been producers of knowledge as researchers in their programme disciplines. In Figure 8-7 below I represent the EPD relating to the programme discipline. It will be seen that numeracy planning is immersed within the curriculum planning. Within this space it can be diffused. On the right, the numeracy planning that is within curriculum planning is expanded and described in detail within the EPD that relates to numeracy.

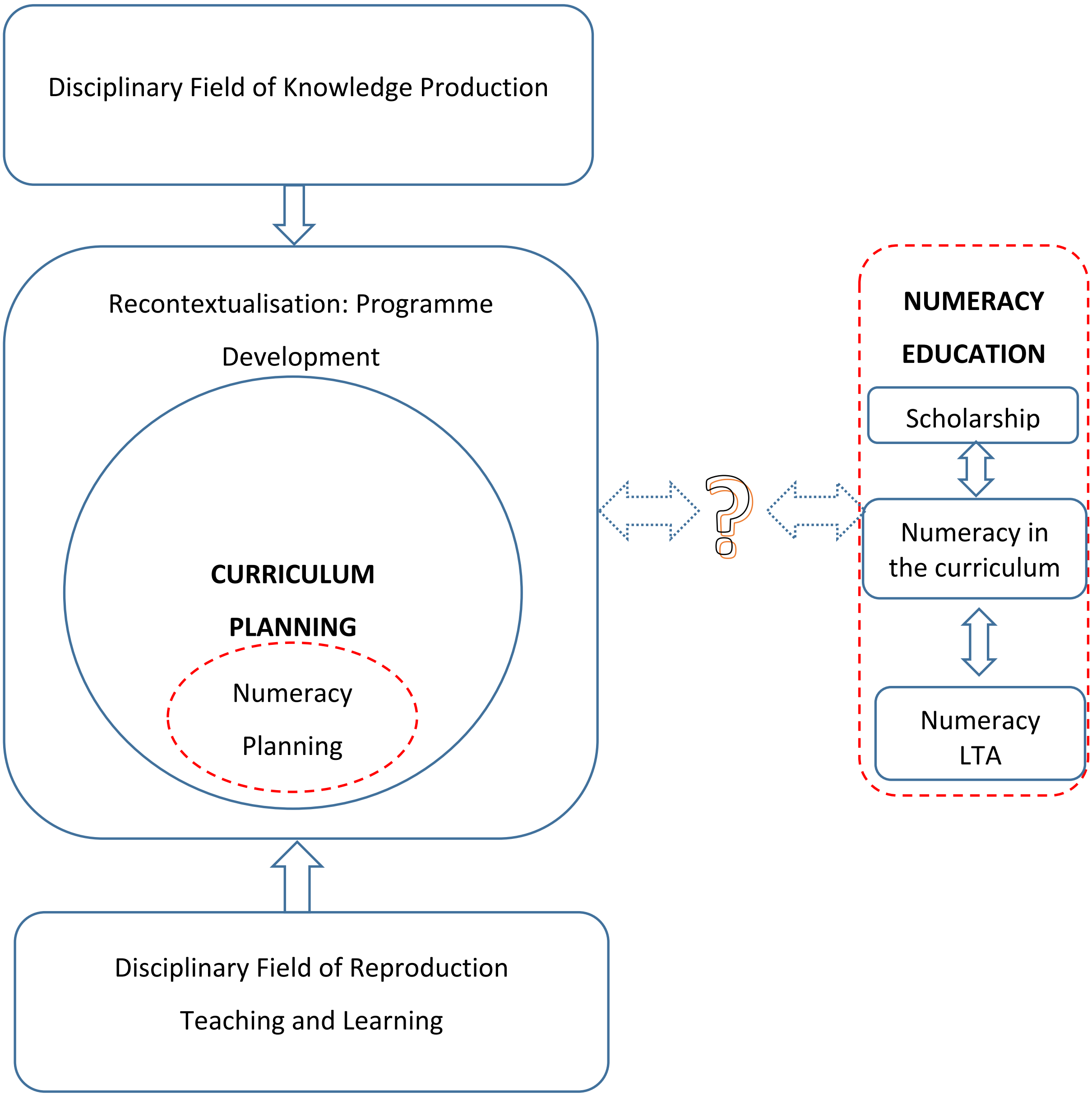


Figure 8-7 Linking the scholarship of numeracy to the curriculum planning

In the complex context of planning a curriculum, numeracy as one of the imperatives within the planning of an entire programme is particularly difficult to 'hold on to' as a distinct objective because it is so weakly insulated from other fields and external forces. It runs the risk of being diffused or completely lost.

One of the ways to enhance the chances of meeting the objective of numeracy development as part of a bigger programme plan could be to ground it more strongly in the scholarship on numeracy in higher education. However, numeracy is a young, emerging field with new traditions that draw on the traditions of more established fields and there are few scholars producing new knowledge in relation to numeracy in higher education, in particular. In addition, this study demonstrates that it is impossible and not aligned to a social practice orientation to numeracy to produce generalisable numeracy knowledge because the numeracies that are legitimated in different contexts depend on different specific and specialized content knowledge. While in a subject like mathematical literacy in secondary education, for example, a field of production can exist from which curriculum developers can 'dislocate' particular knowledge and practices and 'relocate' it into a curriculum, this does not appear to be possible in the case of numeracy sense in higher education. The field of production in numeracy in higher education is likely to expand through the development of specific numeracies such as numeracy in nursing. As North (2015) demonstrated, in the context of secondary education current implementation of mathematical literacy applies a mathematical gaze to a contextual problem. In the context of higher education in this case study, however, the numeracy sense that the curriculum needs to develop must bring together multiple disciplines. It is unlikely that any one discipline could take ownership of numeracy development because its organizing principles would likely result in only subset of the knowledge and processes that comprise numeracy being addressed.

In respect of numeracy in higher education, then, one cannot look to the field of knowledge production for specialized content knowledge solely that can be dislocated and brought to the site of recontextualisation to be relocated into a curriculum. Instead, the multiple approaches to the development of numeracy development could be brought into conversation with each other by engaging with the scholarship in numeracy education. These could focus on discussions of approaches to developing numeracy at a higher education institution that looks towards knowledge building through the integration of mathematical concepts and procedures, disciplinary or professional concepts and processes and contextual sense-making.

The non-engagement with the scholarship of numeracy education could be a reason for the influences of external forces being stronger than careful consideration of the variations in underlying principles of numeracy in specific contexts and the best combination of approaches that can develop the varying numeracy sense. However, as disciplinary experts who are themselves uncomfortable or unaware of the complexity of numeracy in higher education, engaging with the scholarship of numeracy education can be challenging.

8.6 Closing the gap between the scholarship of numeracy and curriculum planning

As I consider the implications of the gap between the scholarship of numeracy education and that of the programme design, I am left wondering how these two could be connected. North and Christiansen (2015) in their research on mathematical literacy in secondary education highlight positions associated with how knowledge and practice are distributed. These positions are that of the subject, apprentice, object and dependent. Dowling (1998 as cited in North and Christiansen, 2015) describe the 'subject' as one who has mastered the practices and underlying principles. This could be described as an expert of sorts who could be seen as having a deep understanding of the concepts and contexts and is able to negotiate the relationship of these concepts to varying contexts. The 'apprentice' is the one being trained – in this context towards an understanding of the specialized mathematical and contextual knowledge and processes and at some point, has the potential to become a subject. The 'object' is the position where the focus is on engaging in the actual situational context with no explicit activities for engagement with specialised concepts for example where the focus is the professional practice and there is no explicit engagement with the numeracy concepts. The dependent position is one that requires ongoing input and guidance from the subject, so for example someone who just follows instruction.

This prompted me to consider the curriculum developers in terms of these four positions. Does the planning for numeracy need someone to occupy the position of the 'subject' and, if so, who should that be? The analysis of the data showed that the principles that legitimated as numeracy were different than the principles that legitimated mathematics. It is thus unlikely that a mathematician would serve as a subject with regards to numeracy. On the other hand, the disciplinary academic operates more from an 'object' position since the focus is on resolving the problem at hand within the discipline and numeracy development is incidental. This incidental approach to numeracy development is strongly contextually bound, which could result in students mastering some practices but not others. This makes it difficult to plan a curriculum that provides access to the underlying principles of numeracy and allows for numeracy practices to be adapted in new contexts.

This study found that although there was a strong agenda to develop numeracy in the curriculum and this was supported by the leadership of the institution, this was an extremely complex endeavour, with many factors influencing the process. The process could have been enhanced if there was engagement with the complexities of numeracy. Because numeracy does not have a disciplinary home it may be unlikely to be given a 'structural home' as a department within an institution because of the academic structuring of the institution. This leaves the space open in terms of interpretation of what numeracy is and what is possible within the confines of the forces acting on undergraduate curricula choices as a result of institutional, professional bodies, national and international higher education contexts.

This raises questions: should numeracy exist as a separate field or discipline; is it possible to have numeracy experts in the field of production; and, if so, what would characterize such experts? It is my contention that numeracy in higher education can exist as a phenomenon within the field of production within the EPD and the numeracy 'expert' should be the scholars who are building knowledge on the development of numeracy in higher education. This knowledge building is unlikely to be limited to specialized knowledge of numeracy but would include research on the approaches that could be considered for planning for numeracy. Unlike other professions for example where the expert emerges from the study of specialised knowledge for example a doctor studies medicine, I believe that the "numeracy expert" does not emerge from a study of numeracy with a specialized body of knowledge because there is unlikely to be such a 'body of knowledge'. Numeracy experts are likely to come from other disciplines where they would have engaged with numeracy from an apprentice position. However, as they move to subjects ('numeracy experts') they would need to be some form of "unlearning, learning and relearning" because it is expected that the 'numeracy expert' unlearn certain existing disciplinary specificities and ways of being, learn new concepts and relearn within different disciplinary contextual settings.

How would this translate into the field of recontextualisation in respect of an institution involved with curriculum planning? As Maton (2014) suggests, through the EPD the field of recontextualisation is influenced by both the field of reproduction and the field of production. In the study, it was seen that the influence of the field of reproduction was dominant at the recontextualisation site. This institution and possibly any higher education institution could perhaps benefit from the creation of a structural entity that serves the purpose of closing the gap between the scholarship on numeracy and agents of recontextualisation, and could also bring together the different disciplinary experts in ways that prevent the dominance of any one identity. This structural entity could be a unit, centre, committee or other entity constituted by academics and tasked with bringing together experience from learning and teaching, the situational factors impacting on curriculum planning and the knowledge being produced in the field of production around numeracy education in higher education. Such a structure could also contribute to the development within the field of production through research and influence the field of reproduction in terms of enhancing the enactment of a curriculum through staff development on curriculum design and pedagogy relevant to developing numeracy across the programme.

It is unlikely, and also undesirable, that such an entity would generate a 'standard' set of practices across all programmes since its role would be to link the field of numeracy education to the planning for and enactment of numeracy development within the specific programmes. Without such a designated structural entity to serve as a home for numeracy, the numeracy agenda could be lost to the numerous demands and tensions that exist in the curriculum planning that includes the development of numeracy in higher education.

8.7 Conclusion

In this chapter, the analyses presented in the previous three chapters were brought together to propose an explanation for the approaches taken to planning for numeracy. The LCT dimensions helped to make the different principles of legitimation explicit and the interpretations were combined in this chapter to highlight the complexity of the process of planning for numeracy in undergraduate programmes in higher education.

The analyses showed that the principles by which numeracy was legitimated by participants varied and included a prioritizing of specialized knowledge, contextual sense-making and particular dispositions and attributes in varying combinations. The understanding of numeracy as common sense was highlighted but different layers of common sense were identified in numeracy. Interestingly, it was noted that common sense was constantly renewed through knowledge (conceptual and contextual) and knower building.

Drawing on the work of Gramsci (1971), I introduced the concept of 'numeracy sense' as an expansion of common sense. Numeracy sense moves the discussion away from the numerate/innumerate dichotomy and acknowledges the varying layers of numeracy sense, the specific nature of numeracy sense within particular professions and the tacit nature of numeracy.

It was evident from the data that the development of numeracy sense within programmes was open to influences from multiple dimensions because of the complexities of numeracy and the limited scholarship in this area. A missing link is identified between numeracy scholarship and the process of curriculum planning at the institution. It is argued that the creation of a structural entity that has an explicit numeracy agenda in higher education institutions could bring a scholarly perspective to the planning for numeracy in the curriculum which could strengthen the numeracy agenda.

The next chapter is the final chapter of the thesis. It reflects on the research process; discusses the contributions this study has made to the literature and identifies possibilities for future research.

Chapter 9
Reflections, conclusions and recommendations

9.1 Introduction

This thesis was inspired by the concern that while numeracy is often given priority on agendas for transformation, the process of developing students' numeracy in the context of a formal higher education institution is challenging. Specifically, my colleagues at the academic institution which was the subject of this case study frequently commented on the inadequacy of students' numeracy practices when they entered education and noted that employers also expressed dissatisfaction with the numeracy practices of graduates of the institution whom they hired. Many of the same concerns have been raised with regard to literacy, which appears to have sparked concerted growth in the scholarship and projects focusing on the development of literacies in higher education. The same response has not been seen with regard to numeracy, comparatively very little research has been done in respect of numeracy development in higher education nationally or internationally.

Foundational skills such as numeracy, writing and critical thinking are often viewed as being the responsibility of basic education: students should be competent in these skills by the time they enter higher education; if they are not, remedial programmes within higher education are seen as the appropriate vehicle to address them. The institution in this case study, however, had engaged in a curriculum renewal project which included an explicit imperative to plan for the development of students' numeracy/quantitative reasoning within the new curriculum. This presented a fascinating opportunity to study this phenomenon. What became evident, however, is that the intention to develop numeracy in the undergraduate curriculum did not translate seamlessly through the planning process into the curriculum that participants described employers sought from numerate graduates.

Adopting a social realist orientation aligned to realist ontology enabled me to gain insights which I could contribute to the discourse on developing numeracy in undergraduate programmes. This perspective presented me with an opportunity to make explicit the generative mechanisms that could motivate different approaches to planning for numeracy in higher education and interrogate the logic underlying these.

In this final chapter, I reflect on my research journey, the engagement of the research with the critical questions and objectives identified at the beginning of the study, the contributions of the study to understanding the phenomenon of numeracy in higher education and implications of the findings of this study for numeracy education. I am fully aware, though, that while the study yields powerful insights the extent to which these can be generalised is limited by the context, methodology and specific focus of the study. There is therefore a need to extend the research in this area to provide deeper and broader insights into numeracy as a distinct area: the production of knowledge in this field, the recontextualising of this knowledge into curricula and the reproduction of this knowledge through the teaching and learning of numeracy.

I start the chapter with reflections on the research journey.

9.2 Reflections on the research journey

In this section, I provide a brief overview of the chapters of this thesis, reflecting on the considerations, choices and results that built on and informed each other, culminating in the contribution of knowledge building in relation to addressing the objectives and critical questions of the study.

Chapter 1

This chapter addressed the need for the study in light of three factors. Firstly, numeracy was found to be considered important in every sector of society; in the context our current highly quantified world, lacking key numeracy practices can place individuals and societies in compromised positions that can limit their active participation. Secondly, performance on international tests highlighted inadequate levels in numeracy as a challenge internationally. South African learners and students' scores on international and national assessments of numeracy were also described as below expected levels in relation to their schooling, which has brought attention to the consequences of poor numeracy and the need to develop students' key numeracy practices. Thirdly, the attempts of academic institutions to developing students' numeracy practices have faced many challenges. A study such as this thus extends the understanding of the complexities characterising the development of students' numeracy practices by exploring how one higher education institution planned for the development of students' numeracy practices and why it used the approaches that it did.

Chapter 2

The discussion of the literature related to the phenomenon of numeracy and the development of numeracy across different academic sectors noted that although there is growth in the scholarship of numeracy, numeracy still remains a "slippery" (Coben, 2003, as cited in Yasukawa et al., 2018, p. 1m) term and new research in this area was not having a significant impact on the way numeracy was being approached in higher education (Yasukawa et al., 2018). The study engaged with both of these issues. Firstly, by investigating the principles which legitimated numeracy in higher education, the study attempted to contribute to an understanding of the 'slipperiness' of numeracy. Secondly, through offering plausible theory informed explanations as to why institutions followed particular approaches to developing students' numeracy, this study contributes to knowledge building in the scholarship of numeracy development design in higher education. This according to the literature reviewed appears to be limited and not aligned to the growth in the literature on the importance of numeracy or evolving definitions of numeracy.

Chapter 3

To understand deeply what numeracy is, how it is planned for and why it is planned for in particular ways required theoretical perspectives that were neither objectively positivist nor extremely relativist. The theoretical frames used in this study allowed me to explore beneath the surface and offer possible explanations of why numeracy was planned for the ways it was in the context of the case study. With social realism serving as an under-labourer, I aligned myself to the depth ontology and a separation of ontology from epistemology. The dimensions of Legitimation Code Theory (LCT) provided me with a toolkit to address the objectives of the study. Epistemic Pedagogic Device (EPD) an extension of the Pedagogic Device introduced by Bernstein, provided a framework to understand the planning for numeracy in undergraduate programmes as a process of recontextualising in relation to the existing knowledge production and the insights gained from the reproduction of knowledge through teaching and learning.

Chapter 4

The research design that was selected allowed for a comprehensive exploration of the case study focusing on the planning for numeracy in a curriculum at a University of Technology (UoT) to enhance understanding of the curricular choices. The study was therefore best served by a qualitative research approach that allowed me to engage with curriculum developers and other key participants at the institution and review curriculum plans in the curriculum documents. With a social realist orientation and a key purpose of understanding the organizing principles leading to particular plans for numeracy in the curriculum, data was collected from multiple sources.

While the curriculum documents offered useful insights into the formal plans for numeracy, the individual and focus group interviews allowed for a deeper engagement with what was considered legitimate numeracy and how external factors impacted on the planning for numeracy in the curriculum – or the lack of planning. The semi-structured interviews provided a useful space for participants to reflect on their actions and unpack their motivations, sometimes contextualising their actions by providing examples. As participants reflected on these examples of what it meant to be numerate in their professions as graduates, the nature of their explanation sometimes shifted. Responses which digressed from the interview question sometimes enriched the data considerably, which would not have been possible had a more structured approach been taken. Had I just focused on their answering “what is numeracy” for example and left it there, the interpretations would have been very limited. The approach taken to the interviews included some concepts from previous interviews being brought to the discussion. The semi structured interviews were therefore better suited than adopting a structured interview schedule.

In respect of the analysis, both inductive and deductive analysis were undertaken. Through an explanation of the process of the thematic analysis of the interviews and documents I was sure that the findings of the study were authentic. The dimensions of Maton's LCT provided the theoretical tools to analyse the underlying principles informing numeracy planning. Translation devices were developed using the codes associated with each LCT dimension to relate the data to theory. In this chapter, I discussed my positionality as an employee at the institution selected for the case study and the strategies I used to mitigate the impact of my insider status on the production, analysis and interpretation of data.

Chapter 5, 6 and 7

As this study sought to understand a phenomenon as it manifested in a particular case, a thematic analysis of the data was extremely important. It allowed me to remain true to the case study and provide interpretations that went beyond a descriptive engagement. At the same time, however, a theoretical analysis using the LCT toolkit provided me with the analytical concepts to delve deeper beyond the reality as 'experience' to the reality at a level of the real as described under realist ontology.

I chose to present the findings from both thematic and theoretical perspectives addressing each of the objectives of the study in order to hold the critical questions together in the narrative.

In **Chapter 5**, I showed that curriculum developers supported a range of different approaches to curriculum planning, but these approaches were not always those used in the actual planning. I argued that the range of approaches taken to planning for numeracy which comprised module-based, integrated and implicitly embedded approaches as well as initiatives external to the formal curriculum of programmes, were all considered legitimate at the institution. An analysis of these approaches using the Autonomy dimension of LCT highlighted that each approach valued different underlying principles in respect of initiatives that had explicit and focused intent of developing numeracy and others were numeracy was developed while addressing another purpose like teaching discipline concepts. Variation was also observed in the positional autonomy of the people responsible for developing the approaches that were legitimated at the institution.

Chapter 6 explored participants' conceptions of numeracy. I argued that numeracy drew on multiple disciplines, including mathematics, statistics, finance and business as well as discipline related to each particular programme of study. Particular attributes or dispositions were also found to be inherent in participants' conceptions of being numerate, such as confidence, positive attitude, critical thinking and other forms of literacies. Analysis using the LCT dimensions Specialization and Semantics found that participants' conceptions of numeracy varied across the relation of specialized knowledges expected, particular dispositions expected and that numeracy was within varying degrees of complexity in respect to concepts and contexts. The development of different numeracy practices was found to be dominant at different time points across the curriculum, which suggested the need to develop curriculum that move between different principles of legitimation in an undergraduate programme.

Chapter 7 explored possible contextual factors – both internal and external to the programme – that impacted on the curricular choices made. In this analysis it was highlighted that planning for numeracy was subsumed within a host of other larger changes and also that the current institutional culture and structure contributed to the tensions that needed to be negotiated in the planning for numeracy. The LCT dimensions of Density and Temporality provided an understanding of the challenges posed to maintaining a focus on the numeracy imperative in a context with multiple other considerations. Both thematic and theoretical analysis highlighted the complexity of the phenomenon of numeracy and the tensions associated with negotiating a multitude of external forces acting on curricular choices.

Chapter 8

This chapter focussed on making sense of the research questions by integrating the analysis presented in Chapters 5, 6 and 7 and interpreting this within the theoretical frame.

The integration of analysis showed that numeracy could actually be seen as a common sense practice, however this common sense was different across 'everyday' home practices, those expected of students on entry to higher education and those expected of the graduate. These were also different across different professions. The common sense described in the study expected certain specialized knowledges, particular dispositions and contextual insights at varying levels of cognitive demand which was an expansion of what would generally be considered as common sense. This led to a differentiation of the different numeracies identified as common-sense across the programme and the conceptualisation of 'numeracy sense'. Building on the work of Gramsci, 'numeracy sense' was introduced as a constantly evolving practice or perspective that is diffused because it is connected to, and implicit in, practical life (personal, professional and societal) and through elaborating this practice or perspective it becomes a renewed common sense possessing the coherence brought about through specialized knowledge building drawing from across multiple disciplines, contextual knowledge building and knower building. The study showed explicitly that evolving numeracy sense towards that expected of the profession requires cumulative knowledge building of concepts from different disciplines and contexts, cumulative knower building and opportunities to engage with problems that expected varying levels of cognitive engagement. The analysis showed that professionals who were tasked with its planning in programmes did not have particular understandings of the complexity of numeracy in that what was expected required developing renewed numeracy sense to engage in different numeracy practices at different points. The analysis clearly showed that the weakening of the numeracy agenda at the institution that was described by participants could be explained by curriculum developers lack of engagement with the complexity of the phenomenon of numeracy resulting in external contextual pressures tending to dominate the planning process. The absence of a 'home' for numeracy or an 'expert' who could bring to conversations the varying numeracy conceptions and the complexities of the principles underpinning these conceptions also may have contributed to the undue influence of contextual factors.

9.3 Contribution of the study

This study set out to answer two critical questions:

- How is numeracy developed in undergraduate programmes at a particular UoT?
- Why is numeracy developed in undergraduate programmes in these particular ways?

These questions were translated into three objectives that:

- Explore the practices used to plan for numeracy
- Explore participants' conceptions of numeracy
- Explore the external contextual and situational factors that impacted the choices made by curriculum planners

Inductive and deductive analysis of the data corresponding to these objectives revealed some of the complexities that impacted the planning for numeracy in the institution in this case study. These included, but were not limited to, the impact of the underlying principles of the conceptions of numeracy in higher education, the preparedness of curriculum developers in respect of understanding what numeracy practices is needed, and the pedagogic process that can support its development.

Importantly, the study revealed a gap between the research on numeracy education and the process of knowledge recontextualisation that included numeracy within the planning of professional programmes at this institution.

The contributions of the study to the scholarship on numeracy are discussed in greater depth in the following sections.

9.3.1 Numeracy in higher education

Numeracy as described in this study ranged from an understanding that prioritized mathematical procedures and concepts to being an implicit practice within professional, personal or societal activities. In some examples, numeracy appeared to be strongly insulated and very strongly linked to mathematics. More often, however, examples demonstrated an integration of knowledge from mathematics, finance, business, statistics and the programme discipline or field with contextual knowledge and expecting particular dispositions or values to be adopted. The challenge associated with acting in “numerate” ways implied that this integration of knowledges, dispositions and contextual insights happened “behind the scenes” and manifested in an act that was entangled. It therefore was not always visible.

This study managed to disentangle the examples of ‘being numerate’ within personal, professional or societal activities provided by participants to find the legitimating principles of numeracy being expected in the programme and then of future graduates of the programmes. It made explicit the variable nature of numeracy and suggested that increasing sophisticated numeracy practices are required of students as they progress towards graduation. The study demonstrated that while the term ‘numeracy’ tends to be thought of as commonly understood, participants did not find it easy to articulate or describe what numeracy was and, as a result, it was difficult to plan for its development. During the interviews, participants’ descriptions of numeracy often began with relating it to arithmetic skills studied early in mathematics. Yet the examples participants provided of numeracy in the programme or in everyday practices corresponded to different legitimating principles than that underlying mathematics.

One of the possible challenges to planning for numeracy is that if curriculum planners assume that all numeracy practices rely on the same underlying principles. They could therefore expect that a numeracy initiative should result in students being able to engage in all numeracy practices. This study made it clear, however, that different principles of numeracy were valued at different points across the curriculum of a programme which required development in respect of context, concepts and dispositions.

Numeracy in higher education and in the professional environment was shown in this study to be aligned to features of common sense practices. Numeracy can be considered a form of common sense as it is expected to happen automatically, mentally and in the background and manifests in professional, societal or personal practices.

In the study I introduced the concept of ‘numeracy sense’ as a way of explaining numeracy in higher education. Drawing on the work of Gramsci (1971) in respect of common sense and good sense, I describe numeracy sense as a practice or perspective that is diffused because it is connected to and implicit in practical life (personal, professional and societal) and through elaborating this practice or perspective it becomes a renewed numeracy sense possessing the coherence brought about through specialized knowledge building from integrating knowledge across multiple disciplines, contextual knowledge building and knower building in respect of gazes, attributes and dispositions.

This numeracy sense required across programmes and expected of graduates is layered and has aspects that become particular to certain professional attributes. Numeracy sense can thus become specialized in certain areas because each professional practice expects particular numeracy conceptual and contextual knowledge building. Numeracy is not purist and exists rather within other practices, such as professional judgement. This study, then, contributes to making some of that invisible numeracy visible.

9.3.2 Numeracy planning in the undergraduate curriculum at a UoT

The study contributed to the understanding of the multiple forces that impact planning for numeracy. The study made explicit lack of preparedness in higher education at various levels and among different stakeholders to enhance the planning for numeracy.

Primarily, it raised the notion of the curriculum developers' agency in terms of understanding of numeracy and in respect to negotiating the multiple forces encountered in the processes while still maintaining the numeracy agenda. An exploration of the tensions curriculum developers were required to negotiate highlighted issues around the preparedness of staff to develop numeracy within the programme at the institution in terms of their expertise, as well as the preparedness of students (in terms of their prior knowledge of, and attitude towards, numeracy).

Outside the programme, the issue of the preparedness of the university came to the fore. As indicated by Galligan (2013), the development of numeracy requires a whole organization approach. I also believe that this is necessary. While this distributes responsibility for numeracy development across the university, the preparedness of the staff (management and programme) and structures of the university to fulfil this responsibility also impacts on how this plays out. In this study, for example, it is possible that the university's preparedness to provide academic leadership or to put structures in place to enable staff to engage with what is numeracy in the context of the programme may have impacted on the choices staff made about how to plan for numeracy or the lack of explicit plans that resulted from the planning process.

The university's preparedness also comes into play in respect of recognizing numeracy in higher education as a specialist area which requires the same scholarly engagement and rigor as other specialist areas and thus providing the development and resources to handle it. Although the leadership of the university stressed the importance of planning for numeracy in the imperative it gave to staff, its preparedness in terms of structure, culture and agency to support this was limited.

Other challenges arose in terms of the flexibility of administrative and financial structures to be able to cater for development of practices that are implicit in nature but require intentional and explicit developmental approaches. Ultimately, the study suggests that numeracy in higher education is a diverse and dynamic phenomenon that is likely to see it remain 'slippery' and therefore difficult to articulate. However, there are certain principles that remain "a stable core". This being that students' numeracy sense must be developed through engaging in specialized knowledge building, contextual knowledge building and knower building over the course of a programme. The adaptation of plans to develop numeracy to the contexts of a specialised academic discipline, professional, societal and personal arenas needs to be negotiated which requires those academics engaging in the process to have a stronger sense of agency with regard to numeracy.

9.3.3 Academic expertise in numeracy

The concept of a numeracy 'expert', or numeracy existing as a specialized area seems contradictory to the very nature of numeracy. However, the study shows that numeracy education is a complex phenomenon in higher education and requires dialogue with the scholarship around knowledge production, curriculum planning and curriculum enactment to ensure that students are provided with the opportunity in the educational experience to develop appropriate numeracy practices.

The fact that numeracy does not have a disciplinary home and the perception that numeracy is a generic skill that can be developed by anyone, can compromise its development in two ways. Firstly, there is reliance on some other individual or department to meet this need and therefore each academic or programme may not focus on numeracy development resulting in it not happening at all. Secondly, if another, more established, discipline takes responsibility for planning for numeracy development in the curriculum it could end up being limited to the specific numeracy practices that are legitimated by that discipline or that it will be designed based on the traditions of that discipline which may not be the same as that of numeracy.

This study corroborated previous studies that distinguish numeracy from mathematics and literacy. It identified characteristics which are specific to numeracy which warrant its development in undergraduate curriculum as an independent initiative. The study also revealed that leaving the development of numeracy to disciplinary experts without providing structuring support could result in the numeracy that is developed being limited to contextually-specific practices which would not adequate prepare students for the numeracy requirements of their future professions.

The study demonstrated the impact on numeracy planning in undergraduate programmes when numeracy is not structured as a distinct area within the university.

9.3.4 Curriculum planning in higher education

While this study focused on planning for numeracy in higher education, other issues were identified that bear consideration. In any higher education institution, it is likely that academics are involved in both the production of knowledge in their respective fields and the reproduction of knowledge in the course of teaching and learning; the recontextualisation of knowledge through the process of curriculum design, however, requires different practices than those required in these other two roles. In this case study, I observed that the staff tasked with curriculum design identified strongly as lecturers (agents involved in the reproduction of knowledge) and producers of knowledge in that discipline or profession but far less strongly as curriculum developers (agents involved in the recontextualisation of knowledge). There was a stronger professional identity as for example accountants or nutritionists than as academics involved in the scholarship of curriculum design and pedagogy. This alerted to an area that needed to be strengthened – the development of the academic.

9.3.5 Using the LCT dimensions together

This is one of only a few studies that has utilised all five of the dimensions provided in the LCT toolkit. Most studies using LCT have used Specialization, Semantics or, more recently, Autonomy. Rarely has more than one dimension been used in the same study despite the fact that Maton (2014, 2016) notes the potential benefits of using multiple dimensions to gain a comprehensive understanding of a phenomena. In this study, each dimension was used to address different objectives in a way that provided a comprehensive understanding of the complexities associated with planning for numeracy in higher education.

The Autonomy dimension provided useful insights, revealing that the numeracy development approaches adopted by curriculum developers in their programme curriculum were typically characterised by lower positional autonomy. The approaches also adopted a range of initiatives that had a deliberate and explicit target of developing for numeracy within the curriculum to having no plans but an expectation that this will need to be addressed during the teaching and learning process. The analysis demonstrated that the university's reliance on disciplinary staff to plan for numeracy resulted in varying understandings of how best numeracy could be addressed. The view of these curriculum developers with regard to whether they considered teaching staff to have the expertise to implement different approaches to developing numeracy and their view of who, in the institution was best suited in respect of expertise in numeracy development have generated multiple positions on how planning for numeracy should be approached.

I was aware that planning for numeracy could be influenced in various ways by curriculum developers' conceptions of numeracy as well as the influence of external factors. The Specialization and Semantics dimensions of the LCT toolkit were used to analyse the underlying organizing principles of what participants valued as numeracy. The analysis highlighted the knowledge and knower structures valued through Specialization and the contextual and conceptual principles valued through Semantics. These two dimensions demonstrated that different principles underpinned the different numeracy practices required in different situations. For example, the valuing of specialized conceptual knowledge requiring varying levels of cognitive engagement was most dominant when participants described the numeracy practices expected of students when they entered higher education. At the point where they graduated from the programme, however, the dominant principles valued was implicit numeracy practices performed mentally as part of professional judgment or practice – such as when administering medication, for example. In these professional practices numeracy practices occurred tacitly. This highlighted the complexity and changeable nature of the phenomenon of numeracy in higher education.

Thematic analysis yielded insights into the contextual factors impacting on curricular choices. However, it was the analysis of numeracy planning using the LCT dimensions of Density and Temporality that highlighted why curriculum developers could have found it difficult to hold onto the agenda for numeracy development within the curriculum planning process. The dimensions revealed that the planning for numeracy was undertaken by a large population (all curriculum developers or curriculum development teams) who had varying understandings of what was numeracy and how best it could be developed. The analysis also showed that numeracy was not established as a specialised area in the institution. As a new emerging field numeracy in higher education there were no independent established traditions of numeracy that could be drawn from. The links to mathematics and other disciplines with more established traditions therefore could skew understandings of numeracy towards the traditions of established disciplines.

The LCT dimensions thus proved useful as analytical tools to make explicit the different principles which legitimated participants' conceptions of numeracy and planning choices. This would not have been possible using just one of the dimensions: for example, the dimension Specialization would not have yielded insight into why contextual factors had such a strong influence on curriculum developers' planners' choices.

Using the LCT dimensions also helped to identify possible alternatives in practice. The analysis showed a clustering of the dominance of practices in certain codes across the student journey, suggesting for example planning a curriculum with numeracy that shifts between knowledge building and knower building. In another instance, because of the lower positional autonomy identified and the identifying by participants of the need and benefit of an embedded approach driven by disciplinary experts, it raised the possibility that planning should consider initiatives targeted at strengthening the positional autonomy of disciplinary staff, such as offering more structured staff development or moving between initiatives that have an explicit focus on numeracy development towards opportunities to engage with numeracy within programme activities.

The use of the LCT toolkit in this study has thus demonstrated the benefits of using the dimensions together in a single study, laying the groundwork for future studies to explore the possibilities for using LCT dimensions in combination to yield more comprehensive insights. Further the use of the dimensions in this study generated possibilities for practice. While the tool highlighted the principles which legitimated the numeracy practices expected of students, it also provided a language to describe how a curriculum could move between the codes to facilitate students' development of the numeracy sense the programme targeted.

9.4 Recommendations for practice

The study affirmed an observation in the literature: the full range of numeracy practices that students need cannot be developed adequately through a single module dedicated to numeracy. This does not imply there is no place for a dedicated module; rather, it should be part of a more comprehensive approach. An embedded approach to numeracy appears to be favoured in the literature within social practice theories of numeracy and also by most participants since it arises implicitly in contextual settings manifesting tacitly. However, such an approach presents challenges for a variety of reasons, ranging from students' preparedness to the time allocated to particular modules and the disciplinary expectations of that module. The most challenging factor identified in this study, however, was the preparedness of staff to plan for the development of numeracy in their specific programmes. Participants articulated that the inadequate foundation students have in numeracy made it difficult for them to embed numeracy in their courses. They indicated that an intervention would be helpful to build students' foundational numeracy practices before reinforcing and developing this further in the programme modules.

Numeracy development should, ideally, permeate the curriculum. This could involve modules dedicated to numeracy as well as embedded approaches that complement these modules that focus on developing other numeracy practices not addressed with the modules. Even such a complementary approach, though, requires careful planning and monitoring so that numeracy development does not 'fall through the cracks'.

The LCT toolkit proved useful for making explicit the varying principles of legitimation of numeracy. As discussed in Chapters 6 and 8, these ranged from a valuing of knowledge to the valuing of dispositions and attitudes. Even in terms of knowledge, there were instances where simple concepts were valued and others where it was necessary to understand the relation of concepts across varying contexts from everyday routine activities to professional judgement. The dimensions of Specialization and Semantics were particularly important in terms of identifying these variations.

This understanding that different principles underlie numeracy in different situations could help curriculum developers to 'plot' a curriculum map that moves between these sets of principles in a strategic progression throughout the programme to develop the numeracy practices students will need by the time they graduate and enter their professions.

Numeracy sense, as a tacit practice that students will need by the time they complete their studies, relies heavily on the strengthening of conceptual and contextual knowledge and development of cultivated gazes. For this practice to become tacit or common sense, sufficient opportunities need to exist in the curriculum for students to engage in these practices at increasingly levels of complexity and these need to be made explicit in the curriculum.

The process of developing curriculum plans would benefit from the positional autonomy of professional staff being strengthened through staff development initiatives focused on 'unpacking' numeracy in the programme, identifying students' current practices and curriculum planning development. The study showed also that programme staff could benefit from a strengthening of their agency in regards to numeracy through staff development initiatives.

The strong links between numeracy and mathematics sometimes results in anxiety among students related to mathematics translating into an avoidance of numeracy. To address this, planning by curriculum developers for numeracy should foreground the affective domain by facilitating an appreciation for and critique of numeracy practices, by students, as it relates to their individual, professional and civic life.

9.5 Limitations of the study and future research

This case study yielded valuable insights. While, as a case study with a defined focus the findings cannot be generalised to higher education as a whole, they do contribute to the scholarship on numeracy in higher education. Further studies would be valuable to broaden the scholarship that is available to inform planning for numeracy in higher education.

This study focused primarily on the field of recontextualisation of knowledge: the stage of planning and designing the curriculum. A very dominant space that informed curriculum choices in this study was the field of reproduction: teaching and learning. A study of enacted curriculum to determine how closely it corresponded to the planned curriculum and whether the numeracy outcomes were achieved would be valuable.

The study was limited to a particular institution: a university of technology where professional qualifications dominated the programme offerings. Future research across higher education institutions would be useful to determine whether the findings of this study can be generalised to different institutional types and to programmes offering other kinds of qualifications.

The study was also limited in that only programmes which did not rely heavily on mathematics were considered for selection. An exploration of numeracy in programmes such as engineering or health sciences which involve continued study in mathematics could provide further insight into the role of mathematics in the development of numeracy.

A missing voice in the study was that of students. A key consideration which curriculum developers identified in the planning for numeracy was their perceptions of students' current numeracy practices or lack thereof and their perceptions of students' receptivity to numeracy development in their programmes.

The study identified multiple numeracies, which means that identifying students simply as innumerate, inadequately numerate or numerate is not useful. It is likely that the numeracy practices that students bring to higher education that fall beyond the scope of the formal school subjects of mathematics and mathematical literacy have not been identified explicitly to an adequate degree yet. A study into the principles of legitimation of the numeracy practices of students that go beyond solving mathematical word problems in the context of assessment could inform curriculum development in higher education so that it builds on the full set of students' existing numeracy practices and acknowledges that students have different numeracy sense.

Since the study was initiated, significant changes have happened at the institution in this case study and globally. Firstly, the curriculum renewal process, which required numeracy to be included as part of general education with the programmes, was initiated by the institution's leadership; changes in leadership over the past two years has resulted in several changes to the imperatives that drove the curriculum renewal process. One significant change is that the institutional-level modules dedicated to numeracy have been made the responsibility of the mathematics department. It would be useful to research how mathematicians negotiate numeracy education and whether this has resulted in different principles of legitimation informing numeracy development than informed approaches previously. Secondly, COVID-19 has caused major disruptions to higher education institutions as they address the need for remote teaching and learning. At the same time, COVID-19 has made it clearer than ever how important it is for individuals to be competent in the numeracy practices that enable them to make sense of information, medical treatment options or economic decisions and that would inform choices about how to modify personal behaviour. It would be interesting to investigate how, in such a context where the numeracy practices students need have become even more complex, the pressure to keep students on track in curriculum under adverse conditions impacts phenomena such as numeracy which are not tightly insulated and do not have quality assurance mechanisms in place. Studies that take into account these new contextual considerations may be useful to investigate if there are numeracy practices that remain stable across change.

9.6 Concluding remarks

This study was prompted by my belief that the development of students' numeracy practices is important to facilitate deep learning in their programmes and to empower them to access, and be critical of, powerful knowledge.

The case study selected for this research provided an ideal site for the exploration of numeracy in the undergraduate curriculum at a higher education institution specifically, a university of technology. Because numeracy was prioritised explicitly among the imperatives driving the curriculum renewal project, this case presented an opportunity to investigate how numeracy could be planned for in the context of an undergraduate programme.

Numeracy is generally viewed as common sense or basic. This brings with it the expectation that everyone should be able to master the same numeracy practices, irrespective of their social, cultural or and historical contexts. This view of numeracy as common sense, and even a view of numeracy as a set of skills that students should have mastered in secondary education, underplays the newness of the numeracy practices expected of students in higher education and in their future careers. As a result, students who lack these numeracy practices are viewed as deficient and the responsibility for this is often placed on the student.

This results in initiatives for developing students' numeracy practices that tends to focus either on framing the issue as an individual deficit which is addressed through remedial initiatives, and that ignores the role of a higher education institution in developing different numeracy practices. This study falls within the body of research – most of which has focused on literacy – which attempts to reframe numeracy as a social practice rather than as an individual skills-based practice by providing some understanding of why most development of numeracy follows an autonomous model that focus on the teaching of generic mathematical skills even though the shifts in conceptions have identified numeracy as being ideological in nature.

In the recent past, the use of multiple theoretical and analytical tools to investigate numeracy has increased. While this has enriched and broadened the terrain, the multiple contributions can make it difficult to navigate the terrain for someone unfamiliar with the terrain. Yasukawa et al. (2018) argue that in order for research on numeracy to provide useful inputs to policy, curriculum and to teaching and learning it should be "signposted and mapped" (p. 4) to clearly identify what these different perspectives offer in terms of understanding numeracy. This raises the issue, again, that the scholarship on numeracy generally – and even in the context of higher education besides being limited, needs signposts and a map of the terrain so scholars engaging with it can be guided towards recognising and drawing from the research what could enhance the numeracy agenda at a higher institution.

This study has made a contribution to the scholarship on numeracy planning in higher education by investigating the multiple factors which influence planning for numeracy within a formal undergraduate curriculum. It also explores the dynamic and complex nature of numeracy as a phenomenon in higher education. Finally, it has made a contribution to flagging the challenges with planning for numeracy in higher education that go beyond the contextual realities of a particular department, but rather alerts to a gap in higher education of recognizing numeracy as a specialized emerging field and accommodating this within its academic structures.

References

AACU. (2009). Quantitative Literacy VALUE rubric. Retrieved from https://www.aacu.org/value/rubrics/inquiry-analysis

Access Project Team. (2011). *SATAP Summary Report*. CELT: DUT.

Access Project Team. (2012). *SATAP Summary Report*. CELT: DUT.

Access Project Team. (2014). *SATAP Summary Report*. CELT: DUT.

Ackland, A. (2014). More… or less? Towards a critical pedagogy of Adult Numeracy. *Adults Learning Mathematics: An International Journal, 9*(2), 7-21. Retrieved from https://alm-online.net/

ALM International Journal. (2020). *Adults learning mathematics.* Retrieved from https://alm-online.net/alm-publications/alm-journal/

Arbee, A. (2012). *Knowledge and knowers in the discipline of marketing at the University of KwaZulu-Natal* (Doctor of Philosophy). University of KwaZulu-Natal, Durban.

Arbee, A., Hugo, W., & Thompson, C. (2014). Epistemological access in marketing - a demostration of the use of legitimation code theory in higher education. *Journal of Education, 59*(1), 39-64.

Archer, M. (1998). *Introduction: Realism in the social sciences*. New York: Routledge.

Askew, M. (2015). Numeracy for the 21st century: a commentary. *ZDM Mathematics Education 47*(4), 707-712.

Assarroudi, A., Nabavi, F. H., Armat, M. R., Ebadi, M. A., & Vaismoradi, M. (2018). Directed qualitative content analysis: the description and elaboration of its underpinning methods and data analysis process. *Journal of Research in Nursing, 23*(1), 42-55. Retrieved from https://doi.org/10.1177/1744987117741667

Babbie, E., & Mouton, J. (2010). *The practice of social research* (10th ed.). Cape Town, South Africa: Oxford University Press Southern Africa.

Bachchan, A. [@SrBachchan]. (2019, 19/09/2019). T3291 [Twitter Post]. Retrieved

Badat, S. (2010). *The challenges of transformation in higher education and training institutions in South Africa.* Retrieved from https://www.dbsa.org/EN/About-Us/Publications/Documents/ThechallengesoftransformationinhighereducationandtraininginstitutionsinSouthAfricabySaleemBadat.pdf

Baker, D. (1998). Numeracy as social practice. *Literacy and Numeracy Studies*, 8(1), 37-50.

Bansilal, S. (2011). *Exploring some complexities of Mathematical Literacy Assessment Tasks:* Paper presented at the Proceedings: Towards Effective Teaching and Meaningful Learning in Mathematics, Science and Technology. ISTE International Conference on Mathematics, Science and Technology Education, Mopani Camp in Kruger National Park, Limpopo, South Africa.

Bansilal, S. (2014). Exploring the notion of Mathematical Literacy teacher knowledge. *SAJHE, 28*(4), 1156–1172.

Bharath, P. (2015). *An Investigation of progression in historical thinking in South African history textbooks,* (Doctor of Philosophy (History Education). University of KwaZulu-Natal, Durban.

Baskarada, S. (2014). Qualitative case study guidelines. *Qualitative Report, 19*(40), 1-25. Retrieved from http://www.nova.edu/ssss/QR/QR19/baskarada24.pdf

Bell, J. (2005). *Doing your research project: A guide for first-time researchers in education and social science* (4th ed.). Buckingham: OUP.

Bennison, A. (2015). Supporting teachers to embed numeracy across the curriculum: A sociocultural approach. *ZDM Mathematics Education, 47*(4), 561-573. Retrieved from https://doi.org/10.1007/s11858-015-0706-3

Bernstein, B. (1990). *Class, codes and control, Volume IV: The structuring of pedagogic discourse*. London: Routledge.

Bernstein, B. (1996). *Pedagogy, symbolic control and identity: Theory, research, critique*. London: Taylor & Francis.

Bernstein, B. (1999). Vertical and horizontal discourse: An essay. *British Journal of Sociology of Education, 20*(2), 157-173.

Bernstein, B. (2000). *Pedagogy, symbolic control, and identity: Theory, research, critique*. Oxford: Rowman and Littlefield.

Bhaskar, R. (1998). Philosophy and scientific realism. in M. Archer (Ed.) *Critical Realism: Essential Readings* (pp. 16-47). London and New York: Routledge.

Bhaskar, R. (2008). *A Realist Theory of Science*. London and New York: Routledge.

Bonner, A., & Tolhurst, G. (2002). Insider-outsider perspectives of participant observation. *Nurse Researcher, 9*(4), 7-19.

Boughey, C. (2010). *Academic development for improved efficiency in the higher education and training system in South African*. Retrieved from https://www.dbsa.org/EN/About-Us/Publications/Documents/AcademicdevelopmentforimprovedefficiencyinthehighereducationandtrainingsysteminSouthAfricabyChrissieBoug.pdf

Bowen, A. G. (2009). Document analysis as a qualitative research method. *Qualitative Reserach Journal, 9*(2), 27-40.

Brady, K. (2014). *Developing first-year students' academic numeracy skills: Toward a whole-of-institution approach.* Paper presented at the 17th International First Year in Higher Education Conference, Darwin, NT, Australia. Retrieved from http://fyhe.com.au/past_papers/papers14/06D.pdf

Breen, L. J. (2007). The researcher 'in the middle': Negotiating the insider/outsider dichotomy. *The Australian Community Psychologist, 19*(1), 163-174.

Brooks, C. (2015). Making maths useful: How two teachers prepare adult learners to apply their numeracy skills in their lives outside the classroom. *Adults Learning Mathematics: An International Journal, 10*(1), 24-39.

Bryman, A. (2008). *Social research methods*. New York: Oxford University Press.

Burns, N., & Grove, S. K. (2005). *The practice of nursing research: Conduct, critique and utilization* (5th ed.). St Louis: Saunders Elsevier.

Cardetti, F., Wagner, M., & Byram, M. (2019). Intercultural citizenship as a framework for advancing quantitative literacy and reasoning across disciplinary boundaries. In L. Tunstall, G. Karaali, & V. Piercecy (Eds.), *Shifting context, stable core: Advancing quantitative literacy in higher education* (pp. 27-36). Washington DC: Mathematical Association of America.

Case, J. M. (2011). Knowledge matters: Interrogating the curriculum debate in engineering using the sociology of knowledge. *Journal of Education, 51*(2), 73-92.

Castro, C. (2009). The role of contextual, conceptual and procedural knowledge in activating mathematical competencies (PISA). *Educational Studies in Mathematics, 71*(2), 123-143. Retrieved from doi:10.1007/s10649-008-9167-8
Chen, R. T. H. (2010). *Knowledge and knowers in online learning: Investigating the effects of online flexible learning on student sojourner* (Doctor of Philosophy). University of Wollongong, New South Wales.
Clarence, S. (2014). *Enabling cumulative learning through teaching: A legitimation code theory analysis of pedagogic practice in law and political science* (PhD). Rhodes University, Makhanda.
Clegg, S. (2015). Adventures in meaning-making: Teaching in higher education 2005-2013. *Teaching in Higher Education,, 20*(4), 373-387. Retrieved from http://doi.org/10.1080/13562517.2015.1020781
Coben, D. (2000). Perspectives on research on adults learning mathematics In D. Coben, J. O'Donoghue, & G. E. FitzSimons (Eds.), *Perspectives on adults learning mathematics: Research and practice* (pp. 47-51). Dordrecht, NL: Kluwer Academic Publishers.
Coben, D. (2003). Adult numeracy: Review of research and related literature. London: NRDC.
Coben, D. (2006). What is specific about research in adult numeracy and mathematics education? *Adults learning Mathematics: An International Journal, 2*(1), 18-32. Retrieved from https://www.alm-online.net/images/ALM/journals/almij-volume2_1_nov2006.pdf
Coben, D. (2006). Common sense or good sense? Ethnomathematics and the Prospects for a Gramscian Politics of Adults' Mathematics Education. Retrieved from https://www.nottingham.ac.uk/csme/meas/papers/coben.html
Coben, D. C., & McCartney, N. (2016). Beyond compliance: Developing a whole organisation approach to embedding literacy and numeracy. In K. Yasukawa & S. Black (Eds.), *Beyond Economic Interests. Critical perspectives on adult literacy and numeracy in a globalised world* (Vol. 18). Rotterdam, Boston, Taipei: Sense Publishers.
Cockcroft, W. (1982). *Mathematics counts*. London: HMSO.
Collins, J. (2000). Bernstein, Bourdieu and the new literacy studies. *Linguistics and Education, 11*(1), 65-78.
Craig, J., Mehta, R., & Howard 11, J. P. (2019). Quantitative literacy to quantitiative literacies. In L. Tunstall, G. Karaali, & V. Piercey (Eds.), *Shifting context, stable core: Advancing quantitative literacy in higher education* (pp. 15-26). United States of America: Mathematical Association of America.
Creswell, J. W. (2003). *Research design: Qualitative, quantitative and mixed methods approaches* (2nd ed.). Thousant Oakes, California: Sage.
Crowther, G. (1959). *A report of the Central Advisory Council for Education (England)*. London: Her Majesty's Stationery Office. Retrieved from http://www.educationengland.org.uk/documents/crowther/crowther1959-1.html
Davis, P. J. (2006). *Mathematics and common sense: A case of creative tension.* India: A K Peters.
Denzin, N. K. (1986). *Interpretive biography*. Newbury Park: Sage.
Dieronitou, I. (2014). The ontological and epistemological foundations of qualitative and quantitative approaches to research with particular reference to content and discourse analysis of textbooks. *International Journal of Economics, Commerce and Mangement, 2*(10), 1-17.

DUT. (2014). *Durban University of Technology Strategic Plan 2015 -2019 : Towards Relevance, Responsiveness and Resilience*. Durban: Durban University of Technology.
DUT. (2015). *DUT general education guidelines*, Durban: Durban University of Technology.
Eley, R., Sinnott, M., Steinle, V., Trenning, L., Boyde, M., & Dimeski, G. (2014). The need to address poor numeracy skills in the emergency department environment. *Emergency Medicine Australasia, 26*(3), 300-302. Retrieved from https://doi.org/10.1111/1742-6723.12207
Elshafie, M. (2013). Research Paradigms: The novice researcher's nightmare. *Arab World English Journal, 4*(2), 1-13. Retrieved from www.awej.org
Erlingsson, C., & Brysiewicz, P. (2017). A hands-on guide to doing content analysis *African Journal of Emergency Medicine, 7*(3), 93-99. Retrieved from https://doi.org/10.1016/j.afjem.2017.08.001
Ernest, P. (2009). Mathematics education ideologies and globalization. In B. Sriraman, P. Ernest, & B. Greer, (Eds.), *Critical issues in mathematics education* (pp. 67-110). IAP. Retrieved from https://scholar.google.co.za/scholar?hl=en&as_sdt=2005&sciodt=0%2C5&cites=9432077988368439003&scipsc=&q=Ernest%2C+P.+%282009%29.+Mathematics+education+ideologies+and+globalization.+Critical+issues+in+mathematics+education%2C+67-110.&btnG=
Estrada-Mejia, C. E., de Vries, M., & Zeelenberg, M. (2016). Numeracy and wealth. *Journal of Economic Psychology, 54*(1), 53-63.
Evans, J., Yasukawa, K., Mallows, D.,& Creese, B. (2017). Numerical skills and the numerate environment: Affordances and demands. *Adults Learning Mathematics: An International Journal, 12*(1), 17-26.
Fisher, F. (2019). What do we mean by quantitative literacy? In L. Tunstall, G. Karaali, & V. Piercecy (Eds.), *Shifting contexts, stable core: Advancing quantitative literacy in higher education* (pp. 3-14). Washington, DC: Mathematical Association of America.
FitzSimons, G. (2006). Adult numeracy: Crossing borders of discourse. In V. Seabright & I. Seabright (Eds.), *Crossing borders – Research, reflection & practice in adults learning mathematics*. Proceedings of the 13th International Conference of Adult Learning Mathematics (ALM), Queens University Belfast, Northern Ireland (pp. 35 -43). Retrieved from https://www.alm-online.net/images/ALM/proceedings/alm-06-proceedingsalm13.pdf#page=34
Frith, V. (2011). Quantitative literacy provision in the first year of medical studies. *South African Journal of Higher Education, 25*(4), 725-740.
Frith, V. (2012). A quantitative literacy course for humanities and law students : the challenges of a context-based curriculum. *Perspectives in Education, 30*(2), 41-49. Retrieved from https://journals.co.za/content/persed/30/2/EJC121475
Frith, V., & Prince, R. (2006). Quantitative literacy. In H. Griesel (Ed.), *Access and entry level benchmarks, The National Benchmark Tests Project* (pp. 28-34; 47-54.). Pretoria: Higher Education South Africa.
Frith, V., & Prince, R. (2009). A framework for understanding the quantitative literacy demands of higher education. *South African Journal of Higher Education, 23*(1), 83-97.

Frith, V., & Prince, R. (2016). Quantitative literacy of school leavers aspiring to higher education in South Africa. *South African Journal of Higher Education, 30*(1), 138-161. Retrieved from https://doi.org/10.20853/30-1-552

Frith, V., & Prince, R. (2018). The National Benchmark Quantitative Literacy Test for Applicants to South African Higher Education. *Numeracy, 11*(2), 1-27. Retrieved from https://doi.org/10.5038/1936-4660.11.2.3

Galligan, L., & Taylor, J. A. (2005). *Investigating academic numeracy in non mathematics courses at university.* Paper presented at the 11th International Conference on Adults Learning Mathematics Conference, Kungalv, Goteborg Sweden.

Galligan, L., Loch, B., & Lawrence, J. (2010). *Building academic numeracy in a first year nursing course using an evaluative model of program development.* Paper presented at the 11th International Congress on Mathematical Education.

Galligan, L. (2011). *Developing a model of embedding numeracy in university programs: A case study from nursing* (PhD). Queensland University of Technology, Australia.

Galligan, L. (2013). A systematic approach to embedding academic numeracy at university. *Higher Education Research & Development, 32*(5), 734-747. Retrieved from https://doi.org/10.1080/07294360.2013.777037

Garfield, J., delMas, R., & Zieffler, A. (2010). Assessing statistical thinking. In P. Bidgood, N. Hunt, & F. Jolliffe (Eds.), *Assessment methods in statistical education: An international perspective* (pp. 175–186). Milton: John Wiley & Sons.

Gee, J. (1991). *Social linguistics and literacies: Ideology in discourses*. London: Falmer Press.

Geiger, V., Goos, M., & Forgasz, H. (2015). A rich interpretation of numeracy for the 21st century: a survey of the state of the field. *ZDM Mathematics Education, 47*(4), 531-548. Retrieved from https://doi.org/10.1007/s11858-015-0708-1

Gill, P., Stewart, K., Treasure, E., & Chadwick, B. (2008). Methods of data collection in qualitative research: Interviews and focus groups. *British Dental Journal, 204*(6), 291-295.

Giloi, S. L. (2015). *The knowledge-knower structures used in the assessment of graphic design practical work in a multi-campus context* (Doctor of Philosophy). Rhodes University, Makanda.

Ginsburg, L., Manly, M., & Schmitt, M. J. (2006). *The components of numeracy [NCSALL Occasional Paper].* Cambridge: Harvard School of Education. Retrieved from http://www.ncsall.net/fileadmin/resources/research/op_numeracy.pdf

Glaser, J., & Laudel, G. (2019, September). The discovery of causal mechanisms: Extractive qualitative content analysis as a tool for process tracing. In *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research, 20*(3), 1-32.

Goos, M., Dole, S., & Geiger, V. (2012). Numeracy Across the curriculum. *Australian Mathematics Teacher*, *68*(1), 3-7. Retrieved from https://files.eric.ed.gov/fulltext/EJ974975.pdf

Gramsci, A. (1971). *Selections from the prison notebooks of Antonio Gramsci, edited and translated by Q.Hoare and G.Nowell Smith*. London: Lawrence and Wishart.

Grant, M. J., & Booth, A. (2009). A typology of reviews: an analysis of 14 review types and associated methodologies. *Health Information & Libraries Journal, 26*, 91-108. Retrieved from https://doi.org/10.1111/j.1471-1842.2009.00848.x

Guba, E. (1990). (Ed.). *The paradigm dialog.* Newbury Park: CA: Sage.

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 105-117). Thousand Oaks, CA: Sage.

Gwele, T. (2012). The Curriculum Renewal Project at Durban University of Technology. Presentation at workshop on the Curriculum Renewal Project, Suncost, Durban.

Hartnett, L. & McNamara, M. (2020). *Using the semantic wave to support intellectual disability nursing students to apply theory and evidence in practice, learning disability practice.* Retrieved from DOI: 10.7748/ldp.2020.e2101

Hibbard, J. H., Mahoney, E. R., Stock, R., & Tusler, M. (2007). Do increases in patient activation result in improved self-management behaviors? *Health Services Research, 42*(4), 1443–1463. Retrieved from doi:doi:10.1111/j.1475-6773.2006.00669.

Hlatshwayo, M. N. (2018). *I want them to be confident, to build an argument: An exploration of the structure of knowledge and knowers in Political Studies* (Doctor of Philosophy). Rhodes University, Makanda.

Holmes, A. (2014). Researcher positionality: A consideration of its influence and place in research. Retrieved from www.scribd.com/document/305906312/Researcher-Positionality-a-Consideration-of-Its-Influence-and-Place-in-Research

Holmes, A. (2020). Researcher positionality - A consideration of its influence and place in qualitative research - A new researcher guide. *Shanlax International Journal of Education, 8*(4), 1-10. Retrieved from https://doi.org/10.34293/education.v8i4.3232

Hughes-Hallett, D. (2001). Achieving numeracy: The challenge of implementation. In L. A. Steen (Ed.), *Mathematics and democracy* (pp. 93-98): National Council on Education and the Disciplines.

Jain, P., & Rogers, M. (2019). Numeracy as critical thinking. *Adults Learning Mathematics: An International Journal, 14*(1), 23-33.

Johnston, B. (2007). Critical numeracy? In S. Kelly, B. Johnston, & K. Yasukawa (Eds.), *The adult numeracy handbook. Reframing adult numeracy in Australia,* (pp. 50-56). Sydney: NSW: Adult Literacy and Numeracy Australian Research Consortium.

Juan, A., Hannan, S., Zulu, N., Harvey, J., Prinsloo, C. H., Mosimege, M., & Beku, U. (2017). *TIMSSs Item Diagnostic Report: South Africa Grade 5 Numeracy*. Pretoria: Department of Basic Education. Retrieved from https://www.dropbox.com/s/xknuw5hzf7pox8l/Grade%205%20diagnostic%20report.pdf?dl=0

Kane, P. (2018). Estimation by kiwifruit orchard managers and urban refuse/recycling operators within their situated horticultural or civic workplace practices: Case studies from New Zealand. In K. Yasukawa, A. Rogers, K. Jackson, & B. V. Street (Eds.), *Numeracy as Social Practice: Global and Local Perspectives*. London: Rouletge.

Karaali, G. H., Villafane-Hernandez, E., & Taylor, J. A. (2016). What's in a name? A critical review of definitions of quantitative literacy, numeracy, and quantitative reasoning. *Numeracy, 9*(1), 1-34. Retrieved from http://doi.org/10.5038/1936-4660.9.1.2

Kemp, M. (2005). *Developing critical numeracy at the tertiary level* (PhD). Murdoch University, Perth. Retrieved from http://wwwlib.murdoch.edu.au/adt/browse/view/adt-MU2006080831.171947

Kuhn, T. (1977). Second thoughts on paradigms. In T. Kuhn (Ed.) *The essential tension: selected studies in scientific tradition and change* (pp. 293-320). Chicago: University of Chicago Press.

Labuschagne, A. (2003). Qualitative research: Airy fairy or fundamental? *The Qualitative Report, 8*(1), 100-103. Retrieved from http://www.nova.edu/ssss/QR/QR8-1/labuschagne.html.

Laforest, J. (2009). Guide to structure semi structured interviews with key informants. *Charting a course to save living*, vol 11. Canada: Québec. Retrieved from Canada: https://sswm.info/sites/default/files/reference_attachments/LAFOREST%202009%20Guide%20to%20Organizing%20Semi%20Structured%20Interviews.pdf

Lea, M., & Street, B. V. (2006). The "academic literacies" model: Theory and applications. *Theory into Practice, 45*(4), 368-377. Retrieved from https://doi.org/10.1207/s15430421tip4504_11

Leavy, P. (2017). *Research design: Quantitative, qualitative, mixed methods, arts-based, and community-based participatory research approaches*. New York, NY: The Guilford Press.

Lewis, P. (2000). Realism, causality and the problem of social structure. *Journal for the Theory of Social Behavior, 30*(3), 249-268.

Liamputtong, P. (2011). *Focus group methodology: Principles and practice*. London: SAGE.

Lillis, T., & Scott, M. (2007). Defining academic literacies research: Issues of epistemology, ideology and strategy. *Journal of Applied Linguistics, 4*(1), 5-32. Retrieved from doi:10.1558/japl.v4i1.5

Luckett, J. (2014). *Knowledge and knowing in the public management and public administartion programmes at a comprehensive university* (Doctor of Philosophy). Rhodes University, Makanda.

Lusardi, A., & Mitchell, O. (2007). Baby boomer retirement security: The roles of planning, financial literacy, and housing wealth. *Journal of Monetary Economics, 54*(1), (205-224).

Lusardi, A., & Mitchell, O. S. (2011). Financial literacy around the world: an overview. *Journal of Pension Economics and Finance, 10*(4), 497-508.

Madison, B. (2019). Quantitative literacy: An orphan no longer. In T. Luke, K. Gizem, & P. Victor (Eds.), *Shifting context, stable core: Advancing quantitative literacy in higher education* (pp. 37-42). United States of America: Mathematical Association of America (MAA).

Maguire, T., & O'Donoghue, J. (2002). *Numeracy concept sophistication – An organizing framework: A useful thinking tool.* Paper presented at the 10th Adult Learning mathematics to live and work in our world conference, Ströbl, Austria.

Marr, B., Helme, S., and Tout, D. (2003). Rethinking Assessment: Strategies for holistic adult numeracy assessment. A resource book for practitioners, policy-makers, researchers and assessors. Melbourne: Language Australia.

Marks, R., Hodgen, J., Coben, D., & Bretscher, N. (2015). Nursing students' experiences of learning numeracy for professional practice. *Adults Learning Mathematics: An International Journal, 11*(1), 43-58.

Mast, M. (2019). Are we at a watershed moment for the quantitative literacy movement? In L. Tunstall, G. Karaali, & V. Piercey (Eds.), *Shifting context, stable core: Advancing quantitative literacy in higher education* (Vol. 12). Retrieved from https://doi.org/10.5038/1936-4660.12.2.14

Maton, K. (2004). The wrong kind of knower: Education, expansion and the epistemic device. *Reading Bernstein, Researching Bernstein* (pp. 218-231). London: Routledge.
Maton, K. (2005). *The Field of Higher Education: A sociology of reproduction, transformation, change and the conditions of emergence for cultural studies* (Doctor of Philosophy). University of Cambridge, Cambridge.
Maton, K. (2010). Analysing knowledge claims and practices: Languages of legitimation. In K. Maton & R. Moore (Eds.), *Social Realism, Knowledge and the Sociology of Education: Coalitions of the mind* (pp. 35-59). London: Continuum.
Maton, K., & Moore, R. (2010). Analysing knowledge claims and practices: Languages of legitimation. In K. a. M. Maton, Rob (Ed.), *Social realism, knowledge and the sociology of education: Coalitions of the mind* (pp. 35-59). New York and London: Continuum.
Maton, K. (2014). *Knowledge and knowers: Towards a realist sociology of education*. London and New York: Routledge.
Maton, K. (2016). Legitimation Code Theory: Building knowledge about knowledge-building. In K. Maton, S. Hood, & S. Shay (Eds.), *Knowledge-building: Educational studies in Legitimation Code Theory* (pp. 1-23). London: Routledge.
Maton, K., & Chen, R. (2016). Legitimation Code Theory in qualitative research: Creating a translation device for studying constructivist pedagogy. In K. Maton, S. Susan Hood, & S. Shay (Eds.), *Knowledge-building: Educational studies in Legitimation Code Theory* (pp. 30-57). London: Routledge.
Maton, K., & Doran, Y. J.a (2017). Semantic density: A translation device for revealing complexity of knowledge practices in discourse, part 1 - wording. *Onomázein Special Issue,* March, 46-76.
Maton, K., & Doran, Y. J.b (2017). Systemic Functional Linguistics and code theory. In T. Bartlett & G. O'Grady (Eds.), *The Routledge Systemic Functional Linguistic Handbook*. London: Routledge.
Maton, K., & Howard, S. K., (2018, 1 June). Taking autonomy tours: A key to integrative knowledge-building. *LCT Centre Occasional Paper 1*, 1-35.
Mattick, K., Johnston, J., & de la Croix, A. (2018). How to…write a good research question. *The clinical teacher, 15*(2), 104-108. Retrieved from https://doi.org/10.1111/tct.12776
Mckenna, S. (2010). Cracking the code of academic literacy: An ideological task. In C. Hutchings & J. Garraway (Eds.), *Beyond the univesity gates: Provisions of extended curriculum programmes in South Africa* (pp. 8-15). Grahamstown: Rhodes Univesity.
Mercer, J. (2007). The challenges of insider research in educational institutions: Wielding a double-edged sword and resolving delicate dilemmas. *Oxford Review of Education, 33*(1), 1-17.
Merriam, S. B. (1998). *Qualitative research and case study applications in education: Revised and expanded from case study research in education* (2nd ed.). San Francisco, CA: Jossey-Bass Publishers.
Merton, R. K. (1972). Insiders and outsiders: A chapter in the sociology of knowledge. *American Journal of Sociology, 78*(1), 9-47.

Mistri, G. (2016). *A social realist analysis of participation in academic professional development for the integration of digital technologies in higher education* (Doctor in Philosophy). Rhodes University, Makanda.
Moore, R., & Maton, K. (2001). Founding the sociology of knowledge : Basil Bernstein, intellectual fields and the epistemic device. In A. Morais, I. Neves, B. Davies, & H. Daniels (Eds.), *Towards a sociology of pedagogy: the contribution of Basil Bernstein to research* (pp. 153-182) New York: Peter Lang.
Moore, R. (2004). *Education and Society. Issues and Explanations in the Sociology of Education*. United Kingdom: Polity Press.
Mtombeni, T. N. (2017). *Knowledge practices and student access and success in general chemistry at a large South African university* (Doctor of Philosophy). Rhodes University, Makanda.
National Benchmark Tests Project Team. (2014). *Durban University of Technology Institutional NBT Report*. CHERTL: UCT.
National Benchmark Tests Project Team. (2015). *National Benchmark Tests Project Performance Report for the Durban University of Technology Students (DUT 2015)*. CETAP: UCT**.**
National Center for Education Statistics. (n.d) Retrieved from https://nces.ed.gov/surveys/piaac/numproficiencylevel.asp
National Numeracy Network – numeracy online journal. (2020). *Numeracy.* Retrieved from https://scholarcommons.usf.edu/numeracy/about.html
North, M., & Christiansen, I. M. (2015). Problematising current forms of legitimised participation in the examination papers for Mathematical Literacy. *Pythagoras, 36*(1). 234-244. Retrieved from http://dx.doi.org/10.4102/pythagoras.v36i1.285
North, M. P. (2015). *The Basis of Legitimation of Mathematical Literacy in South Africa* (Doctor of Philosophy). University of KwaZulu Natal, Pietermaritzburg.
O'Donoghue, J. (2002). Numeracy and mathematics. *Irish Math. Soc. Bulletin 48*, 47-55. Retrieved from https://www.researchgate.net/publication/228905490_Numeracy_and_mathematics
O'Donoghue, J. (2003). *Mathematics or numeracy: Does it really matter?* Paper presented at the Policies and practices for adults learning mathematics: Opportunities and risks. 9th international conference of Adults Learning Mathematics (ALM9) - A Research Forum, London.
OECD. (2013). *PISA 2012 assessment and analytical framework: mathematics, reading, science, problem solving and financial literacy*. OECD Publishing. Retrieved from http://dx.doi.org/10.1787/9789264190511-en
OECD. (2016). *Education at a Glance 2016*. Paris: OECD Publishing.
OECD. (2018). *Education at a Glance 2018*. Paris: OECD Publishing.
Olsen, W. (2009). *Realist Methodology: A Review*. UK: SAGE.
Paxton, M., & Frith, V. (2015). Transformative or normative? Implications for academic literacies research in quantitative disciplines. In T. Lillis, K. Harrington, M. Lea, & S. Mitchell (Eds.), *Working with Academic Literacies: Case Studies Toward Transformative Practice* (pp. 155-162). Fort Collins, Colorado: WAC Clearinghouse/Parlor Press.
PIAAC Numeracy Expert Group. (2009). *PIAAC numeracy: A conceptual framework* (Vol. 35). Paris: OECD Publishing.

Pohl, M. (2000). *Learning to think, thinking to learn: Models and strategies to develop a classroom culture of thinking*. Highett, Vic: Hawker Brownlow Education.
Porter, A. (2006). Curriculum assessment. In J. Green, G. Camilli, & P. Elmore (Eds.), *Handbook of complementary methods in education research* (pp. 141-159). NJ: Lawrence Erlbaum Associates.
Prince, R., & Archer, A. (2008). A new literacies approach to academic numeracy in higher education. *Literacy and Numeracy Studies, 16*(1), 63-76.
Prince, R., & Frith, V. (2020). An investigation of the relationship between academic numeracy of university students in South Africa and their mathematical and language ability. *ZDM, 52*(3), 433-445. Retrieved from http://dx.doi.org/10.1007/s11858-019-01063-7
Program for the International Assessment of Adult Competencies (PIAAC). PIAAC Proficiency Levels for Numeracy. Retrieved from https://nces.ed.gov/surveys/piaac/numproficiencylevel.asp
Rose, J., & Johnson, C. W. (2020). Contextualizing reliability and validity in qualitative research: toward more rigorous and trustworthy qualitative social science in leisure research. *Journal of Leisure Research*, *51*(4), 432-451. Retrieved from https://doi.org/10.1080/00222216.2020.1722042
Rubin, H. J., & Rubin, I. S. (2005). *Qualitative interviewing: The art of hearing data*. Thousand Oaks, California: Sage Publications.
Saidin, K. (2016). *Insider researchers: Challenges and opportunities.* Paper presented at the International Seminar on Generating Knowledge Through Research, Universiti Utara Malaysia, Malaysia.
Sayer, A. (1992). *Method in social science: A realist approach* (2nd ed.). London: Routledge.
Schoenfeld, A. H. (2001). Reflections on an impoverished education. In L. A. Steen (Ed.), *Mathematics and democracy: The case for quantitative literacy* (pp. 49-54). Princeton, NJ: The National Council on Education and the Disciplines.
Schwandt, T. A. (1989). Solutions to the paradigm controversy: Coping with uncertainty. *Journal of Contemporary Ethnography, 17*(4), 379-407.
Schwandt, T. A. (2001). *Dictionary of qualitative inquiry* (2nd ed.). Thousand Oaks: Sage.
Seidman, I. (2012). *Interviewing as qualitative research: A guide for researchers in education and the social sciences*. London and New York: Teachers college, Columbia University.
Shay, S. (2015). Curriculum reform in higher education: a contested space. *Teaching in Higher Education, 20*(4), 431-441.
Singh A. S, & Masuku, M. B. (2014). Sampling techniques & determination of sample size in applied statistics research: An overview. *International Journal of Economics, Commerce and Management, 2*(11), 1-22.
Singh, P. (2002). Pedagogising knowledge: Bernstein's theory of the pedagogic device. *British Journal of Sociology of Education, 23*(4), 571-582.
Skovsmose, O. (2004). Critical mathematics education for the future. Retrieved from https://www.researchgate.net/publication/252205485
Stake, R. E. (1995). *The art of case study research*. London: Sage.
Steen, L. (2001). The case for quantitative literacy. In L. Steen (Ed.), *Mathematics and democracy: the case for quantitative literacy* (pp. 1-22). Princeton: National Council on Education and the Disciplines. Retrieved from http://www.maa.org/ql/mathanddemocracy.html

Street, B. (1996). Preface. In M. Prinsloo & M. Breier (Eds.). *The social uses of literacy: theory and practice in contemporary South Africa*. Philadelphia, PA: John Benjamins.
Street, B. (Ed.) (2001). *Literacy and Development: ethnographic perspectives*. London: Routledge.
Street, B. V. (1995). *Social literacies: Critical approaches to literacy in development, ethnography and education*. London: Longman.
Tinto, V. (2012). Enhancing student success: Taking the classroom success seriously. *The International Journal of the First Year in Higher Education, 3*(1), 1-8. Retrieved from https://doi.org/10.5204/intjfyhe.v3i1.119
Tout, D., & Gal, I. (2015). Perspectives on numeracy: reflections from international assessments. *ZDM Mathematics Education, 47*(4), 691-706. Retrieved from doi:10.1007/s11858-015-0672-9
Tout, D., Coben, D., Geiger, V., Ginsburg, L., & Hoogland, K., Maguire, T. & Thomson, S. (2017). *Review of the PIAAC Numeracy Assessment Framework: Final Report*. Retrieved from https://www.oecd.org/skills/piaac/Review%20of%20the%20PIAAC%20Numeracy%20Assessment%20Framework_2017_ACER.pdf
UCT Numeracy Centre. (2020). *Courses & interventions – Overview*. Retrieved from http://www.numeracycentre.uct.ac.za/nc/course_intervent/overview
Unluer, S. (2012). Being an insider researcher while conducting case study research. *The qualitative report, 17*(58), 1-14.
UTS ePRESS. (2020). *Journal of Literacy and Numeracy Studies.* Retrieved from https://epress.lib.uts.edu.au/journals/index.php/lnj/index
Vithal, R. (2012). Mathematics education, democracy and development: Exploring connections. *Pythagoras, 33*(2), 1-14.
Venkat, H. (2010). Exploring the nature and coherence of mathematical work in South African Mathematical Literacy classrooms. *Research in Mathematics Education, 12*(1), 53-68.
Warburton, P. (2010). Numeracy and patient safety: The need for regular staff assessment. *Nursing Standard (Royal College of Nursing, Great Britain), 24*(27), 42-27.
Weist, L., Higgins, H., & Frost, J. H. (2007). Quantitative literacy for social justice. *Equity and Excellence in Education, 40*(1), 47-55.
Wheelahan, L. (2010). *Why knowledge matters in education: a social realist argument*. Abingdon: Routledge.
Wheelahan, L. (2012). *Why knowledge matters in curriculum: A social realist argument*. New York and London: Routledge.
Wilmot, K. (2019). *Enacting knowledge in dissertations: An exploratory analysis of doctoral writing using Legitimation Code Theory* (Doctor of Philosophy). University of Sydney, Sydney.
Wilson, D. and W. Dixon (2006). 'Das Adam Smith problem. A critical realist perspective', *Journal of Critical Realism, 5*(2), 252-272.
Winter, L. (2019). *Embedded numeracy teaching practices at an Institute of Technology: Vocational tutors' characterisations of embedding numeracy and related professional development* (Masters in Education). University of Waikato, Hamilton. Retrieved from http://researchcommons.waikato.ac.nz/

Wood, S., Liu, P., Hanoch, Y., & Estevez-Cores, S. (2015). Importance of numeracy as risk factors for financial elder exploitation in a community sample. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences, 71*(6), 978-986. Retrieved from https://doi.org/10.1093/geronb/gbv041

Yasukawa, K., Jackson, K., Kane, P., & Coben, D. (2018). Mapping the terrain of social practice perspectives of numeracy. In K. Yasukawa, A. Rogers, K. Jackson, & B. Street (Eds.), *Numeracy as social practice: Global and local perspectives* (pp. 3-17). Routledge. Retrieved from doi:10.4324/9781315269474

Yazan, B. (2015). Three approaches to case study methods in education: Yin, Merriam, and Stake. *The Qualitative Report, 20*(2), 134-152. Retrieved from https://nsuworks.nova.edu/tqr/vol20/iss2/12

Yeld, N. (2009). The National Benchmark Tests Project: Addressing student educational needs in the tertiary education system. In In J. Hofmeyer (Ed.), *Recession and recovery* (pp. 76-83). Cape Town: Institute for Justice and Reconciliation.

Yin, R. K. (2002). *Case study research: design and methods* (3rd ed.). London: Sage.

Yin, R. K. (2014). *Case Study Research Design and Methods* (5th ed.). Thousand Oaks, CA: Sage.

Young, M. (2014). Curriculum theory: What it is and why it is important. *Cadernos De Pesquisa, 44*(151), 191-201.

Annexure A

Translation device for Autonomy dimension: practices used to plan for numeracy

Autonomy		Description of concepts in relation to study
Strong Positional Autonomy	**PA +**	numeracy-specific modules planned by numeracy/independent professional
Weak Positional Autonomy	**PA-**	activities that include some numeracy practices planned by disciplinary staff or others not considered independent numeracy professionals
Strong Relational Autonomy	**RA +**	target is for the intention of developing numeracy practices
Weak Relational Autonomy	**RA -**	for any other purpose, such as understanding disciplinary concepts

Annexure B

Translation device: Specialization analysis of the institution's conceptions of numeracy

Aspect	Concept	Description of concept	How concept can be manifested in the study	Examples from data
Epistemic relation	**ER+**	Knowledge, skills and procedures that are strongly bound and controlled	Emphasis is on specialized knowledge: for example, mathematical concepts and procedures	This requires ratio and proportion background. A percentage increase and decrease where the student has to be able to apply these and perform the calculations. . . . so the mass of an object is kind of proportional to its volume, right? So you know, the bigger the volume of something the bigger the mass – this is assuming that the density doesn't change. Volume: it's length – cubed, right? So if you calculate the volume of a box, it's length times length times length: length cubed, right?
	ER-	Knowledge, skills and procedures that are weakly bound and controlled	The specialised concepts and procedures are underplayed and there is some degree of overlap with other disciplines or contexts	For us it will be like to the ability to reason clinically, so that you can base some judgments on whether you proceed with a certain action on your treatment plan, quantify things – for instance, things like blood pressure, that is similar to things like your glucose level: that is all quantity. Taking all of these qualities in account, now you have to clinically use your physiology and bring it together. So, for me, it can't be separate.
Social relation	**SR+**	The subject as the author is emphasised	Emphasis is placed on dispositions and habits of mind	there is a logical brain, confidence, everything, the men, 10 time better with machinery At what point are you numerate? To me it's more than just "Can you do ABC at this level?" It's more an issue of culture. It will be critical thinking in everyday sort of situation.
	SR-	The subject of the author is downplayed	Dispositions and attributes are downplayed	Follow the correct procedures and perform the four operations.

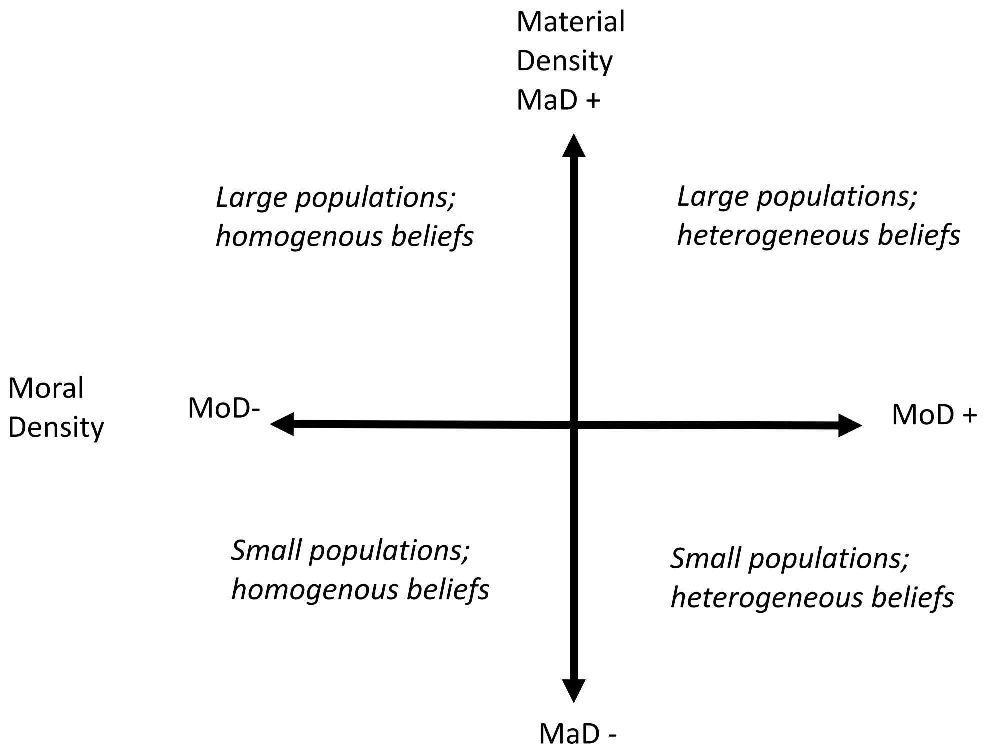
Annexure C

Translation device for Semantic analysis of conceptions of numeracy

Aspect	Concept	Description of Concept	How concept is manifested in the study	Examples from data
Semantic Gravity	**SG+**	Contextually dependent	Problem is based on particular context	What is our current unemployment rate? So, ok, the official rate is 27.7. And what does this mean and how many people in South Africa are in the 60 age group; how many people are working and how many are not working? What is the unofficial unemployment rate? What does it mean to have the official unemployment rate for youth?
	SG-	Contextually independent	Technical/abstract concept	To actually read a trend graph or develop a trend graph Perform operations of addition, subtraction, multiplication and division
Semantic Density	**SD+**	Complex concept: High condensation of meaning	Condensation of meaning	A higher level of numeracy that is very important would include, optimization: for example if I give you a sheet of metal and I want you to give me the most cost-effective way of producing a coke can from this.
	SD-	Simple everyday concepts	The concepts are everyday and non-technical	It’s working with quantities – for example, diluting detergents

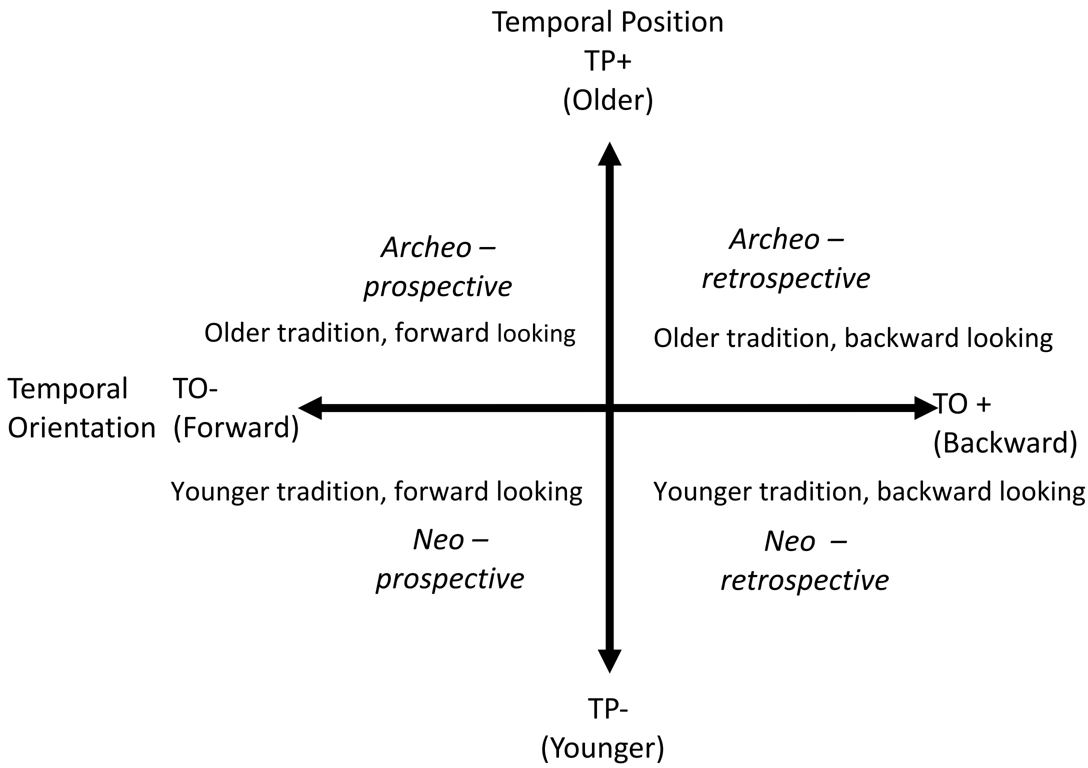
Annexure D

Translation Device for Density Analysis of Numeracy Planning



Annexure E

Translation Device for Temporality Analysis of Numeracy Planning



Annexure F

Module Descriptor Template

MODULE DESCRIPTOR

<table>
<tr><td colspan="2">**Faculty**</td><td></td><td colspan="2">**Department**</td><td colspan="3"></td></tr>
<tr><td colspan="2">**Contact details for department/ programme co-ordinator**</td><td></td><td colspan="2">**Version number**</td><td colspan="3"></td></tr>
<tr><td colspan="2">**Site/s of delivery**</td><td></td><td colspan="2">**Date**</td><td colspan="3"></td></tr>
<tr><td colspan="8"></td></tr>
<tr><td>**1**</td><td>**Module title**</td><td></td><td>**2**</td><td>**Module code**</td><td colspan="3"></td></tr>
<tr><td rowspan="2">**3**</td><td rowspan="2">**Gen Ed Theme (name where applicable)**</td><td rowspan="2">n/a</td><td rowspan="2">**4**</td><td rowspan="2">**Gen Ed Code (where applicable)**</td><td>**W**</td><td>**QR**</td><td>**KZN**</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>**5**</td><td>**HEQSF level**</td><td></td><td>**4**</td><td>**HEQSF Credits**</td><td colspan="3"></td></tr>
<tr><td>**7**</td><td>**CESM**</td><td></td><td>**6**</td><td>**Annual/semester**</td><td colspan="3"></td></tr>
<tr><td>**9**</td><td>**Year in which offered (Yr 1, 2, 3 etc)**</td><td></td><td>**8**</td><td>**Compulsory or elective**</td><td colspan="3"></td></tr>
<tr><td>**11**</td><td>**Total notional hours**</td><td></td><td>**10**</td><td>**Contact hours**</td><td colspan="3"></td></tr>
<tr><td rowspan="3">**13**</td><td>**Pre-requisite module/s**</td><td></td><td rowspan="3">**12**</td><td>**Co-requisite module/s**</td><td colspan="3"></td></tr>
<tr><td>Title</td><td></td><td>Title</td><td colspan="3"></td></tr>
<tr><td>Code</td><td></td><td>Code</td><td colspan="3"></td></tr>
<tr><td>**15**</td><td colspan="2">**Programme/s name/s**</td><td colspan="5"></td></tr>
<tr><td>**16**</td><td colspan="2">**Purpose of this module in relation to the programme/s**</td><td colspan="5"></td></tr>
<tr><td>**17**</td><td colspan="2">**Learning outcomes**</td><td colspan="5"></td></tr>
<tr><td>**18**</td><td colspan="2">**Graduate attributes developed and/or assessed in this module**</td><td colspan="5"></td></tr>
</table>

19	**Module content**		
20	**Teaching and learning**		
		Learning activity	**% learning time**
21	**Assessment and moderation**	Does assessment include a final examination?	
		If **YES**, indicate the weighting of the year / semester mark and the exam mark in the calculation of the final mark **-**	
		If **NO**, indicate how the final mark will be calculated and how assessment/s will be moderated	
22	**Feedback to students on assessment**		
23	**Resources required to offer this module**		
24	**Student numbers**		
25	**Quality assurance**		
26	**Motivation for additional credits**	n/a	

Tracking changes to the module descriptor [to be completed by CQPA]				
Version	**Section number and details of change**	**Approved by**	**Date of approval**	**Relevant departments informed**
2				
3				
4				

Programme overview: CURRICULUM MAP

DATE OF MODIFICATION TO OVERVIEW	*September 2016*	DATE APPROVED BY FACULTY BOARD	*Insert date*
SECTION A: DETAILS OF QUALIFICATION			
Qualification type (Diploma, B degree, etc.)		**Programme name as registered with SAQA**	
SAQA ID number		**HEQSF level**	
Total number of HEQSF credits		**HEQSF Credits at each level**	
CESM Category/Categories			
Programme department		**Head of Department**	
Purpose of the qualification			
Exit Level Outcomes			
Graduate attributes			

SECTION C: OVERVIEW OF [MAINSTREAM] PROGRAMME													
Year of study (1, etc.)	**Study Period (SP)[3]**	**Module title**	**HESQF Level of module (5-9)**	**CESM (at module level)**	**Module code**	**SAQA Credit for the module**	**HEMIS Credit for the module**	**Compulsory or Elective**	**General Education Theme**				
									Theme[4] Introduced [I]; Reinforced [R]; Assessed [A]	***Credits for the Gen Ed theme***	***Writing; quantitative reasoning; KZN Introduced [I]; Reinforced [R]; Assessed [A]***		
					Insert code				*Insert theme/s number indicate I/R/A*	*Indicate credits*	***W***	***QR***	***KZN***
1	SP1		5	100602		12	0.100	C					
1	SP1		5	100602		8	0.067	C					
1	SP1		5	100602		8	0.067	C				IA	
1	SP1		5	040599		8	0.067	C				IRA	
1	SP1		5			12	0.100	C		12			
1	SP1	•	5			12	0.333	E		12			
1	SP2		5	100602		16	0.444	C	5	2			IA
1	SP2		5	100602		12	0.100	C	4	2			
1	SP2		5	040105		12	0.100	C	4	2			
1	SP2		5	040599		12	0.100	C	5 & 6	2	IA	IA	IA
1	SP2	•	5			8	0.067	E		8			
TOTAL CREDITS FOR THE YEAR			**SAQA =120**		**HEMIS = 1**								

Annexure H

Ethics Approval

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

09 November 2017

Ms Shoba Rathilal (971167589)
School of Education
Pietermaritzburg Campus

Dear Ms Rathilal,

Protocol reference number: HSS/1432/017D
Project title: Planning for numeracy in higher education: A South African University of Technology case study

Approval Notification – Expedited Application

In response to your application received on 11 August 2017, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted **FULL APPROVAL.**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

Dr Shamila Naidoo (Deputy Chair)

/ms

Cc Supervisor: Professor Wayne Hugo
Cc Academic Leader Research: Dr SB Khoza
Cc School Administrator: Ms Tyzer Khumalo

Humanities & Social Sciences Research Ethics Committee
Dr Shenuka Singh (Chair)
Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Telephone: +27 (0) 31 260 3587/8350/4557 **Facsimile:** +27 (0) 31 260 4609 **Email:** ximbap@ukzn.ac.za / snymanm@ukzn.ac.za / mohunp@ukzn.ac.za
Website: www.ukzn.ac.za

1910 - 2010
100 YEARS OF ACADEMIC EXCELLENCE

Founding Campuses: Edgewood, Howard College, Medical School, Pietermaritzburg, Westville

Annexure I

DUT Permission Letter

Directorate for Research and Postgraduate Support
Durban University of Technology
Tromso Annexe, Steve Biko Campus
P.O. Box 1334, Durban 4000
Tel.: 031-3732576/7
Fax: 031-3732946
E-mail: moyos@dut.ac.za

12th May 2017

Ms Shoba Rathilal
c/o College of Humanities
University of Kwa-Zulu Natal

Dear Ms Rathilal

PERMISSION TO CONDUCT RESEARCH AT THE DUT

Your email correspondence in respect of the above refers. I am pleased to inform you that the Institutional Research Committee (IRC) has granted provisional permission for you to conduct your research "Planning for numeracy in higher education: A South African University of technology case study" at the Durban University of Technology.

However, kindly note that the committee requires you to provide proof of full ethical clearance prior to you commencing with your research at the DUT.

The DUT may impose any other condition it deems appropriate in the circumstances having regard to nature and extent of access to and use of information requested.

We would be grateful if a summary of your key research findings can be submitted to the IRC on completion of your studies.

Kindest regards.
Yours sincerely

PROF SIBUSISO MOYO
DVC (ACTING): RESEARCH, INNOVATION AND ENGAGEMENT
DIRECTOR: RESEARCH AND POSTGRADUATE SUPPORT

Annexure J

Participation and Informed Consent

Higher Education Studies,
School of Education
University of KwaZulu-Natal,

Participation in Research Information Form

Dear Participant

My name is Shoba Rathilal. I am a registered student for a PhD in Higher Education at the University of KwaZulu-Natal (UKZN) in Durban.

My research topic is titled: Planning for numeracy in undergraduate programmes: A South African university of technology case study. The purpose of my study is to examine how the imperative to include numeracy or mathematics within undergraduate programmes at the institution was translated into curriculum.

It is intended that the study will contribute to the understanding of the peculiarity and historical specificity of numeracy in higher education. An exploration of the institution case study will offer insights into how numeracy is conceptualised within higher education, how it is implemented within the constraints of a fixed term period of an undergraduate and an indication of what forces act on this educational field within higher education to create the different configurations of curriculum with numeracy.

The intention of the study is not to evaluate programmes or the institution, but rather focusses on gaining understanding of how particular knowledge is included in the curricula and why, taking into account the factors impacting on the recontextualising process.

It is anticipated that the research will contribute to an understanding of the underlying organising principles of numeracy within the different programmes allowing for these to be made explicit to students which can contribute to student success.

This project will be conducted under the supervision of Prof Wayne Hugo from the Faculty of Education at UKZN, PMB campus, South Africa.

I am hereby requesting your participation in this study. I believe that your participation in the study will add tremendous insights in respect of numeracy in higher education. This will involve you agreeing to being interviewed at least once either individually or part of your departmental focus group. You have a choice as to whether you want to be interviewed alone. It may be necessary to have a follow up interview. Your participation in the interview is voluntary. You may choose to withdraw from the study at any point. Your confidentiality will be maintained. Anonymous referencing or coding will be used in the analysis. In order to ensure I capture the interview correctly, I would be audio recording. You have the choice to decide if you do not want to be recorded.

Upon completion of the study, I undertake to provide you with a full research report should you be interested. I will also share with departments who form part of the study the findings of the research.

If you require any further information, please do not hesitate to contact me on 031 3732771 or shobar@dut.ac.za or Prof Wayne Hugo on 033 260 5567 or hugow@ukzn.ac.za

You may also contact the Research Office through: P. Mohun, HSSREC Research Office, on 031 260 4557 or mohunp@ukzn.ac.za

Thank you for your time and consideration in this matter.

Yours sincerely,

Shoba Rathilal

Informed Consent for Participation in an individual interview or focus group interview

I agree to participate in the research being undertaken by Shoba Rathilal titled: Planning for numeracy in higher education programmes: A South African university of technology case study.

The purpose of this document is to specify the terms of my participation in the research through interviews or focus group interviews.

1. I have been given sufficient information about the study.
2. The purpose of my participation has been explained to me
3. I am aware that I will be interviewed once initially, but may be interviewed again, no more than three times
4. I allow the researcher to take notes and record the interview through use of :

	willing	Not willing
Audio equipment		

5. I have the right not to answer any of the questions that I am uncomfortable with
6. I will be allowed to terminate my participation in this study at any point.
7. I have been given the assurance that if I wish, the researcher will not identify me by name or function.
8. I have read and understood the points and statements of this form and I voluntarily agree to participate in the study.

____________________ ___________________________

Participants Signature Date

Annexure K

Interview Schedule: Guiding Questions

The following questions formed the reference points for the questions to participants. Not all questions were asked but the interviews sought to get responses in these broad areas.

Key Informants

- How would you define numeracy?
- What is the importance of numeracy?
- What is the role of numeracy in higher education and for a graduate?
- What are the possible consequences of being not appropriately numerate?
- Provide examples of numeracy in life.
- Provide examples from the disciplines
- In a “perfect world” would you include numeracy in higher education programme, why?
- What with that look like?
- What concepts do you think should be included? Why?
- What is your perceptions of students numeracy practices, to what degree does this impact on what was included in the programme?
- How would you have planned for numeracy development within a programme?
- What was your perceptions of the way the imperative to develop numeracy was implemented at the institution?
- What could have influenced these decisions?

Module Developers

- What is your conceptions of numeracy?
- Why did you design a numeracy specific module?
- What did you hope to achieve?
- How do you see your module fit into the greater scheme of things, gen ed programmes?
- What purpose is it meant to serve?
- What compelled you design it in this particular way?
- Do you think there is or should be a difference between common sense numeracy and scholarly numeracy?
- What is your understanding of how best it can be implemented?
- What is the bare minimum you would like to see achieved?
- How can the benefits of this module be complemented in programmes

Annexure L

Turnitin Report

Planning for Numeracy in Higher Education: A South African University of Technology Case Study

by Shoba Rathilal

Submission date: 30-Oct-2020 04:59PM (UTC+0200)
Submission ID: 1431236239
File name: Full_thesis_26_Oct.docx (3.23M)
Word count: 95500
Character count: 537012

Planning for Numeracy in Higher Education: A South African University of Technology Case Study

ORIGINALITY REPORT

6%	5%	2%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES