STUDENTS' EXPERIENCES OF LEARNING STATISTICS IN A THRESHOLD CONCEPTS-ENRICHED TUTORIAL PROGRAMME

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ABSTRACT

Fear and anxiety often characterises students' feelings towards studying statistics. As such, high failure rates and concerns about the quality of learning and teaching in introductory statistics is a preponderate concern in the extant literature. Set against the backdrop of the South African educational landscape, these concerns may be compounded by the challenges posed by the gaps evident in students' key academic literacies. There is a need for deep qualitative understanding of students' learning in statistics, and of ways in which it may be facilitated. This calls for an alternate framing than the one inherent in the quantitative investigations of performance that predominate in statistics education research in this country and internationally.

Therefore, this study adopted the threshold concepts framework (Land, Meyer, & Flanagan, 2016; Meyer & Land, 2003) - a theoretical perspective that offers an encompassing view of disciplinary learning not previously used in this context – in order to explore statistics students' learning in a higher education tutorial programme. This qualitative, interpretive study, was informed by social constructivist principles in teaching and learning as well as research methodology. The case study was set in a threshold concepts-enriched tutorial programme based in Business Statistics II at the Durban University of Technology, and attended by seventeen volunteers from the mainstream class. Interactive Qualitative Analysis (Northcutt & McCoy, 2004) was used to generate and analyze data through a rigorous protocol involving focus group generated affinities (themes) reflecting students' learning, from which a system diagram was constructed. The characterisations or fundamentals of the affinities were elaborated in individual interviews, supplemented by participants' written reflections. Elements gleaned from the discussion threads posted on the study participants' WhatsApp group chat served as

a source of data-triangulation and confirmability of the IQA protocol generated data. Together the data provided rich descriptions of learning in the voices of the student participants.

The primary driver of learning was the *Tut Group* affinity — pedagogies and peer interactions in the tutorials — which influenced the other affinities: the J*ourney of Understanding* through cognitive and metacognitive constructs to the *Personal Journey* participants related, and the *Emotions* which permeated and influenced the course of disciplinary learning. The comprehensive nature of this representation of learning and the influences among its features offers an idiosyncratic mind map of the complexity and variation in students' experiences of disciplinary learning.

The thesis offers a visually rich and in-depth conceptual representation of the experiences and processes of disciplinary learning in the threshold concepts-enriched tutorial programme. This study's findings, abstracted from participants' descriptions, offers a tentative model which depicts disciplinary learning as a challenging and transformative process - a pedagogical pilgrimage - bringing on cognitive (mind) and affective (soul) shifts in students' disciplinary learning journeys. In this case study, the multiplicity of pedagogies used in the tutorial programme - small peer-group learning, the use of real-world, relatable activities which incorporated the generation of real data, the keeping of reflective journals, being handed the solution to tutorial activities; and teacher immediacy – collectively supported the 'DNA' (cognitive and affective constructs) of disciplinary learning. Moreover, if the discipline, as experienced, elevates students' sense of self, students will aspire to engage in deeper, more meaningful interactions with disciplinary concepts, and will harness their inner psychological resources to sustain academic commitment, thereby facilitating cognitive and metacognitive shifts. This view of learning can open up a vista of understanding of what it means to learn and to teach in statistics, in particular, and in higher education, in general.

SUPERVISOR'S PERMISSION TO SUBMIT

Statement by supervisor

I, Suriamurthee M. Maistry, as the candidate's supervisor, agree to the submission of this thesis.

[redacted]

Supervisor's signature

4/09/2019

Date

DECLARATION

I, ANISHA ANANTH (993221552), declare that:

(i) The research reported in this thesis, except where otherwise indicated, is my original research.

(ii) This thesis has not been submitted for any degree or examination at any other university.

(iii) This thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.

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LIST OF ACRONYMS AND ABBREVIATIONS

ART	Affinity Relationship Table
BCAL 101	Business Calculations I
BSTS 201	Business Statistics II
CHE	Council on Higher Education
CoTT	coherence theory of truth
CsTT	constructive theory of truth
CTT	correspondence theory of truth
DUT	Durban University of Technology
GAISE	Guidelines for Assessment and Instruction in Statistics Education
GIS	Geographic Information System
ICT	Information and Communication Technology
IQA	Interactive Qualitative Analysis
IRD	Inter-relationship Diagram
ITCK	Integrated Threshold Concept Knowledge
LAN	local area network
NSFAS	National Student Financial Aid Scheme
PCK	pedagogical content knowledge
PsyCap	Psychological Capital
SID	System Influence Diagram
SRLE	Statistical Reasoning Learning Environment
SRTL	Statistical reasoning, thinking and literacy
STAT SA	Statistics South Africa

STEM	Science, Technology, Engineering and Mathematics
TCITF	Threshold Capability Integrated Theoretical Framework
TCF	Threshold Concepts Framework
UKZN	University of KwaZulu-Natal
WTP	Ways of Thinking and Practising
ZPD	Zone of Proximal Development

CHAPTER 1

INTRODUCTION

1.1 Introduction

Data and statistics form the bedrock for informed decision-making in contemporary society. Data gathering and statistical analysis increasingly informs policy decisions that impact on nearly every facet of life – from the economy, to politics, health, sports, education, etc. (Zewotir & North, 2011).

In response to this increasing need for basic statistical knowledge, in almost all disciplines an increasing number of students are enrolling into introductory statistics classrooms in institutions of higher education. Since these students may have majors in other disciplines, they often make for very reluctant learners of statistics. This may be attributable to statistics often being described as a difficult subject to learn, due to the abstract nature of some of its concepts, the distinct way of thinking and analysis of problems that it requires, or the way in which it is traditionally taught. Moreover, many students confuse statistics with mathematics and expect the focus to be on numbers and formulae, whereas, at the same time, students have difficulties with the underlying mathematics (Garfield & Ben-Zvi, 2008). These issues manifests in high failure and dropout rates, and in concerns about the quality of learning (and teaching) in introductory statistics courses (Aliaga et al., 2010; Loveland, 2014).

This study was motivated by my unanswered questions about statistics students' learning. In my experience of teaching statistics at a South African university of technology, I have observed that some students seem to struggle to grasp fundamental disciplinary concepts and practices. This holds back their learning, and affects progression in the discipline. Even among those who have passed the introductory statistics course, some appear unable to transfer their knowledge to their specific research domain, or to apply it meaningfully to interpret real-world events. In South Africa, features of this country's higher education context may intensify the challenges faced by both students and teachers[1] of statistics, with research reflecting concerns around poor academic performance and low throughput in introductory statistics classes across higher education institutions. This literature is dominated by quantitative studies determining the impact on performance due to students' characteristics and prior academic attainment, behaviour and motivation, or educational interventions, in terms of pedagogical or teacher-focused interventions (Galagedera, 1998; Galagedera, Woodward, & Degamboda, 2000; Kasonga & Corbett, 2008; North, Gal, & Zewotir, 2014; North & Zewotir, 2006; Zewotir & North, 2007, 2011).

Little or no qualitative or conceptual enquiry has been undertaken, and the understanding of how students learn statistics in South African higher education is superficial. Questions around the processes and experiences of learning statistics, and the sources and nature of difficulty encountered by students, remain largely unexplored. Consequently, teachers' knowledge of how to support or facilitate learning is not supported by qualitative research, specifically research findings arising from qualitative studies that investigate learners' experiences of disciplinary learning.

In a higher education landscape characterised by rapid change[2] and enduring inequality, teachers of statistics in higher education face escalating challenges, which traditional approaches to pedagogy and curriculum seem increasingly less fit to address. There is clearly a need to deepen understanding of students' learning, and explore the potential ways in which it may be more effectively supported and facilitated, in introductory statistics in the South African context. Unanswered questions that emerge are broader than the focus of the existing body of quantitative research: contemplating the experiences and processes of students' learning, and the sources of difficulty they encounter implies a holistic and deep exploration of learning. Difficulty in itself has strong connotations of personal experiences and affective responses, which are not accounted for in the predominant quantitative approach (Sharma, 2010), and seem to require a more

[1] I use the terms "teacher", "lecturer", "instructor" and "educator" interchangeably depending on the teaching/learning role that I wish to emphasise.
[2] In a drive to ensure that the future South African labour force is equipped with the skills required to meet the fourth industrial revolution, calls have been made in the higher education sector for a comprehensive plan to develop appropriate educational programmes and to embrace new ways of teaching in order to meet these skills requirements (Mzekandaba, 2018).

encompassing framing that can account for individual learners and their personal context in interaction with the discipline (Rattray, 2014, 2016).

Such a perspective on learning is inherent in the body of scholarship that has become known as the Threshold Concepts Framework (TCF) (Land et al., 2016). This view of learning emerged in economics education research, but has found resonance amongst higher education researchers of various disciplines, and as such, the literature has grown rapidly and has become widely influential (Flanagan, 2018; Tight, 2014). According to this view, every discipline has a limited number of distinctive concepts that disciplinary experts identify as being ‘threshold concepts’(Meyer & Land, 2003). A mastering of these educationally critical concepts is of paramount importance if a student is to advance in learning and understanding in the discipline.

The troublesome and transformative nature of encounters with disciplinary threshold concepts means that affective aspects of learning are entwined with cognitive ones, where disciplinary learning cannot be conceived of separately from the learner or her personal context (Cousin, 2006b). The TCF thus offered an appropriate framing for a holistic, qualitative, contextualised understanding of statistics students’ learning that could accommodate and illuminate the questions I wished to pursue. In order to explore statistics students’ learning at close range, I developed a tutorial programme informed by a threshold concepts orientation (Thompson, 2008) and by pedagogical approaches recommended in the extant statistics education research literature (Garfield & Ben-Zvi, 2007; Garfield & Ben-Zvi, 2009; Garfield, delMas, & Zieffler, 2012), which ran alongside mainstream large-class lectures in an introductory statistics course. Seventeen participants in this threshold concepts-enriched programme subsequently took part in further data generation and analysis, giving effect to the qualitative, interpretive approach I sought to take in this research.

In the following sections of this chapter, I provide some background on disciplinary understandings of learning. I then sketch the South African higher education context, and consider existing research in statistics higher education in this country. Thereafter, I return to the rationale for this study, introduce the research questions and describe the research design used, before outlining the organisation of the chapters that follow.

1.2 Statistical literacy, thinking and reasoning

The notion that students should attain the three-pronged goal of being statistically literate and be able to think and reason statistically, recurs in the international statistics education literature as the central objective of teaching and learning in the discipline. It may be construed as shorthand for saying that students ought to have internalised the key concepts, principles and tools of statistics analysis, as well as know when to apply them appropriately to new situations (BenZvi & Garfield, 2004). Statistics knowledge can be specified in terms of abstracting new ideas or methodology from a specific problem, and adapting and incorporating what has been learned into a theoretical scaffold so that it may be applied to different variations of the original problem in innovative ways (Fienberg, 2014; Wild, Utts, & Horton, 2018). Statistics may be thought of as a meta-discipline as it "*thinks about how to think* about turning data into real-world insights" (Wild et al., 2018, p. 7). Possessing statistics knowledge also requires a thorough understanding of underlying disciplinary concepts, along with an understanding of the constraints and limitations of statistical inference and the ability to communicate these (Hohle, 2018).

In today's data-driven technocratic society, being statistically literate is paramount for informed, critically evaluated decision-making (English & Watson, 2016; Watson, 2014). In the literature, statistical literacy is characterised as a complex construct, requiring students to not only possess the basic skills of reading, comprehending, and communicating statistical information, but also develop higher cognitive skills of interpretation, prediction, and critical thinking (Sharma, 2017). This characterisation of statistical literacy as a way of thinking and reasoning aligns with learning theories from mathematics education that include the process of 'enculturation' as the core idea (Resnick, 1988; Schoenfeld, 1992). Enculturation has its roots in the socio-constructive theories of learning (Resnick, 1989; Vygotsky, 1978b) and holds the view that learners "develop habits and skills of interpretation and meaning construction though a process more usefully conceived of as socialization [sic] than instruction" (Resnick, 1989, p. 39). A student may be enculturated into a disciplinary community through a socio-cognitive process; thereby assuming the perspectives and points of view of the community (Schoenfeld, 1992). The conceptualisation of mathematics learning as "an inherently social (as well as cognitive) activity, an essentially constructive activity instead of an absorptive one" (Schoenfeld, 1992, p. 18) may well be applied to statistics learning with its idiosyncratic ways of thinking and practice, with the teacher playing the role of mediator or enculturator (Ben-Zvi, 2004). The defining principles, conceptual skills and ways of thinking just described must be mastered if students are to become proficient participants in the discipline. The principles and practices characterising the discipline as defined here would find wide agreement among statisticians; after all, there is a need to master the fundamental tenets before one can contest them, or move on to alternative or critical views.

For students, learning statistics can be viewed as requiring a mastery of essential concepts and modelling techniques that are associated with developing a new way of thinking, as they move through introductory modules and application to individual research interests – that is, a form of 'transnumerative-thinking' whereby students possess the skill to make sense of different representations of data in order to make sense of the world around them and their place in it (Chick, Pfannkuch, & Watson, 2005). Students often experience this conceptual crossing or transformation as a difficult process, and many struggle to develop statistics understanding and acquire the necessary statistical ways of thinking and practice. While this difficulty is widely acknowledged in statistics education research, its sources, and the processes by which students reach conceptual mastery are diverse, and are often characterised in the research literature as being either cognitive or affective in nature (Zieffler, Garfield, & Fry, 2018). The idea that disciplinary learning requires mastery of particular transformative and troublesome ideas has been formalised and elaborated in the theory of threshold concepts (Meyer & Land, 2003), which (as noted above) frames this study, and is discussed more fully in Chapter 3. Furthermore, in this view, disciplinary features interact with individual and contextual aspects in affecting the course of learning. The following section describes the South African higher education context and the challenges it presents.

1.3 Features and challenges of the South African higher education context

The dramatically transformed higher education landscape, in post-apartheid South Africa, has seen the overhaul of a fragmented and racially discriminatory system into a single, integrated national system. The implementation of a governing framework has aided in unifying quality assurance processes, qualification types, funding arrangements, and enrolment planning processes for the educational offerings in the eleven traditional (research) universities (offering degree programmes), six comprehensive universities, and eight vocationally-oriented universities of technology (Council on Higher Education (CHE), 2016). Since the advent of democracy in 1994, there has been a marked increase in access to university study with enrolment at public universities having doubled to reach almost a million students (Council on Higher Education (CHE), 2016).

Growth in student numbers in South Africa mirrors the global massification of higher education since the 1990s. Additionally, academic staff numbers have not kept pace with the growth in enrolments, thus student to staff ratios have worsened considerably (Council on Higher Education (CHE), 2016). Moreover, issues pertaining to student funding, but increasingly incorporating political issues around institutional and curricular transformation, have in the past few years given rise to disruptive and costly student protests which are likely to intensify (Council on Higher Education (CHE), 2016).

Increasing enrolments have been accompanied by concerns about throughput rates. South Africa's history of racial discrimination and social inequalities also negatively influences the university first-year experiences of black students from historically disadvantaged families. The high first-year dropout rate for black students may be attributable to a lack of money and academic readiness to embark on tertiary education (Chetty & Pather, 2016). Furthermore, lectures that are conducted in English pose a problem for black students for whom English may be a second, or indeed third language, making it difficult to attend to lectures of a high standard and pace, and to write essays proficiently (Chetty & Pather, 2016). Thus, students entering institutions of higher education "do so from positions of extreme inequality in terms of: schooling, race, class, and financial and other resources" (Chetty & Pather, 2016, p. 1), with success rates skewed by race and prior education (Council on Higher Education (CHE), 2016). As such, the interdependence between the tertiary, secondary, and primary education sectors is one of the largest challenges facing South Africa, since the dysfunction in the primary and secondary sectors manifests itself as "large gaps" in students' skills and knowledge that prevent them from entering and/or succeeding in higher education (Chetty & Pather, 2016, p. 2).

Gaps in key academic literacies are compounded if students struggle to grasp 'rules' about how the university learning environment works, that is, both the explicit rules (structures of authority, formal contact arrangements, course outlines), and the implicit principles that underlie discipline specialisations, such as evaluation criteria and expectations of academic text (Cross, Shalem, Backhouse, & Adam, 2009). Negotiating the transition to university study thus makes particularly increasing demands on the academic and social resources of students from educationally disadvantaged backgrounds (Cross et al., 2009). This lack of ‘preparedness’ is cited as one of the reasons why students fail, or take longer than the regulation time to complete their degrees (Scott, Yeld, & Hendry, 2007).

Three specific and interrelated aspects of academic under preparedness that are particularly relevant to students’ learning in the discipline of statistics centre on their numerical skills, their accustomed approaches to learning, and technology skills, each of which see elaboration briefly below.

Quantitative literacy (or numeracy) is recognised as critical for epistemological access to a range of disciplinary practices, yet many students in South Africa are poorly prepared to meet the quantitative requirements of academic disciplines (Frith & Lloyd, 2013). Statistics as currently taught is strongly quantitatively oriented, and mathematical ability is an important determinant of student success (Johnson & Kuennen, 2006; Lai, Tanner, & Stevens, 2011; Silvia, Ciancaleoni, & Chiesi, 2008). Gaps in students’ quantitative skills as they emerge from the schooling system may thus significantly constrain their access to and progression in the discipline.

The metaphor of “deep” and “surface” approaches to learning (Biggs & Tang, 2007) distinguishes between students who take an “understanding” and those who take a “reproduction” approach to learning. The rote-learning approach is still typical of much schooling in South Africa, and many students continue to apply this “knowledge reproduction” approach, which has served them well at school, rather than the “knowledge construction” required at university level (Bradbury & Miller, 2011). In statistics, many students seem to rely on the memorisation of algorithmic techniques of the discipline, which may allow them to solve narrowly specified problems, but does not imply a deep understanding of the theory, or the ability to transfer either techniques or theory to other contexts, such as real-world applications or subsequent courses (Jacobbe, Foti, & Whitaker, 2014; Sharma, 2017). Some of the problems in statistics teaching and learning in our context can thus be characterised in terms of the predominance of surface learning approaches, and the need to find ways of promoting deep learning instead.

International statistical pedagogical reforms recommend that appropriate technological tools are integrated within the statistics classroom (Garfield & Ben-Zvi, 2009). As highlighted earlier, in

South Africa, many students entering higher education come from disadvantaged, poor socio-economic backgrounds, with many of these students not having had prior access to school or community library computers. As such, “[t]o use computers for the purpose of teaching statistical applications, the lecturer must virtually start from scratch” and “[e]ven the use of pocket calculators, which is essential in any statistics course, is almost a burden for the simple fact that the students must be taught how to use it” (de Wet, 1998, p. 576).

Infrastructural and access constraints pose a further challenge to the widespread implementation of technological/e-learning pedagogy in South African higher education institutions. The number of internet users are higher than the availability of personal computers, with South Africa boasting the highest internet costs in Africa, and one of the most expensive in the world. Limited bandwidth negatively impacts on the teaching and learning environment in terms of limiting the types of technological tools that may be incorporated into curriculum design,[3] and disparate access levels exist between demographic groups – between users in rural and urban areas (Brown, Thomas, van der Merwe, & van Dyke, 2008). Additionally, there exists disparities between institutions arising from apartheid-era discrimination, resulting in historically advantaged and historically disadvantaged institutions in terms of resources provided (Bharathram & Kies, 2012). This study was conducted at a historically disadvantaged institution[4], where students’ limited access to technology may lead to gaps in their technological skills, which may significantly constrain their access to and progression in the discipline.

While not an exhaustive list, it seems clear that these factors are significant contributors to challenges in introductory statistics teaching and learning in South Africa, including high dropout and failure rates and concerns that students have not always attained the expected competencies and may be unable to transfer or apply their knowledge. The following section briefly reviews the existing research on statistics students’ learning in this country.

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[3] A discussion of the impact of the use of technological tools and resources on statistics teaching and learning is provided in chapter 2.

[4] The ML Sultan campus, of the Durban University of Technology, on which this study was conducted is a typical example of a historically disadvantaged institution in South Africa. The campus has only one student local area network (LAN) facility with approximately 80 computers to serve the needs of a few thousand students on the campus.

1.4 Research on learning in introductory statistics in South Africa

There is a paucity of research into statistics students' learning in South Africa (Wessels, 2011) and the few studies that have been conducted has been largely quantitatively oriented, using education production functions to identify determinants of success (or performance), which are summarised here. Prior academic attainment particularly in students' mathematics marks and attitude towards mathematics — has been found to impact significantly on their performance in statistics (Galagedera, 1998; Galagedera et al., 2000; Nolan, 2002). The challenge posed by teaching statistics to students majoring in other disciplines is also highlighted in the literature (Coetzee & Van der Merwe, 2010; North & Zewotir, 2006; Zewotir & North, 2007). Having to train mathematics teachers to teach the statistics content in the high school mathematics curriculum is indicated as a further significant hurdle (North et al., 2014; Umugiraneza, Bansilal, & North, 2018; Zewotir & North, 2011), while evidence regarding the impact of age, language, and gender is less conclusive (Coetzee & Van der Merwe, 2010; de Wet, 1998). Educational interventions, such as technology-based interventions and innovative assessment models have been proposed to affect performance positively (Barr & Scott, 2008; Kasonga & Corbett, 2008).

The empirical findings from this line of enquiry are largely internally consistent, intuitively sensible, and congruent with international findings. Nonetheless, they contribute a relatively small piece to the puzzle of understanding students' learning, as the success factors that are identified as significant, account for a very small proportion of the entire variance in student success in disciplinary learning. This suggests a need for further — and arguably broader — investigation, to reach a more holistic understanding of statistics students' learning.

Research pertaining to the qualitative dimensions of students' disciplinary learning in this country is non-existent, as far as I could determine. In this study, I therefore set out to deepen understanding of the experiences and processes of statistics students' learning, using a case study design and a qualitative, interpretive research approach intended to elicit rich, descriptive insights from the students' perspective. The next section presents the research design and guiding questions, introduces the study site and my position within the research, and outlines the ways in which the study may contribute to knowledge.

1.5 Research design and statement of research problem

This is a qualitative, interpretive study, which used a case study research design set in the threshold concepts-enriched tutorial programme running alongside the mainstream Business Statistics II (BSTS 201) course on the ML Sultan campus of the Durban University of Technology (DUT), in the second semester of 2017.

DUT is one of the universities of technology in South Africa, where I have taught statistics for fifteen years. This has afforded me some insights into students' learning. Pertinent here is that the content of the introductory statistics curriculum is very similar to those in most 'Western' universities: comprising topics from both probability and inferential statistics and taught predominantly through large-class plenary lectures, supplemented with tutorials[5] focused on exercises and problem sets. These similarities meant that I could draw useful inferences from existing international scholarship on teaching and learning in introductory statistics, and likewise that the findings of this study — though specific to the case — may have broader resonance.

Many students appear to find learning and applying disciplinary concepts and techniques extremely challenging, and as an aspiring reflective practitioner, it seemed important to understand more about how students learn in the discipline, why they struggle, and where they are likely to become stuck — and to reach this understanding of the processes and experiences of their learning through the views of the students themselves, I decided to apply a systematic research approach to the study of my practice that is informed by theory. Having found that the perspective of the threshold concepts framework aligned with my observations of students' experiences of learning, I set up a tutorial programme informed by principles inherent in the framework and the existing scholarship of disciplinary teaching and learning, using a series of teaching and learning activities that embedded statistics threshold concepts (Dunne, Low, & Ardington, 2003; Thompson, 2008). This programme could be characterised as an "arranged situation" (Naidoo & Vithal, 2014) within which I could use active, cooperative pedagogical approaches empirically established as conducive to learning, but not feasible within the mainstream lectured course. The programme allowed me to

[5] The term used at DUT for additional scheduled sessions in which students work through written exercises and their solutions, assisted by postgraduate tutors. It ought to be noted here that in this study, there was no assistance from tutors.

observe the participants' learning under these enhanced conditions at close range, and afforded me access to their own perspectives on their learning.

Volunteers from the mainstream class participated in the tutorial programme and the related data-generation processes. I used Interactive Qualitative Analysis (IQA) (Northcutt & McCoy, 2004) to generate and analyse data, in focus group sessions and in-depth individual interviews; these were supplemented by participants' reflections on their learning, written over the course of the semester. Additionally, the core thread of students' posted messages to the WhatsApp™[6] group chat created for the participants in the tutorial programme, were noted and used to augment the findings of this study.

The purpose of this study was to explore students' learning in an introductory statistics course. The research questions that guided my study were:

- How do statistics students learn in a threshold concepts-enriched tutorial programme?
- Why do students learn in this programme in the ways that they do?

1.6 Significance of the study

As a qualitative, interpretive researcher, I set out to understand the multiple realities at play, informed by a social constructivist approach in both research, teaching, and learning. My position within the research entailed multiple roles. I was the lecturer of the mainstream, semester-long module, and also responsible for its assessment on the local campus.[7] I was the tutor in the programme which I developed, in which I engaged with students in a much more informal way, facilitating group discussion, rather than teaching. As the researcher undertaking this study, I was a key research instrument (Creswell, 2013), and in many respects an insider — invested in and central to the study, and shaping and influencing both the learning process and the investigation thereof. I was aware of the inevitable power imbalances between the participants and myself, and

[6] WhatsApp is an instant messaging mobile application that allows users to exchange messages without being charged for individual messages, using only internet data (WhatsApp, 2014).

[7] The BSTS 201 module is taught across two separate campuses in Durban and Pietermaritzburg, and is centrally coordinated, with a common curriculum and synchronous assessments.

sought to mitigate their impact on both the tutorial programme, and the processes of data generation. I offer deeper reflections on this dual role in Chapter 4.

The pedagogical approach in the tutorials reflected constructivist principles in its active, cooperative emphasis, and was enriched with a threshold concepts orientation inherent in the activities that structured students' interactions in the tutorials (Bulmer, O'Brien, & Price, 2007; Thompson, 2008). My research methodology used IQA, an approach in which participants generate and — crucially — are empowered to analyse and interpret data, to construct their view of reality as a group. This group reality is subsequently elaborated on at individual level, providing rich and varied perspectives.

The study findings offer insights into the experiences and processes of students' learning in statistics, drawn from rich, contextualised, qualitative description based on participants' own construals of their learning in the threshold concepts-enriched tutorial programme. The research addresses both conceptual and methodological gaps in South Africa, where the (limited) statistics higher education scholarship is dominated by quantitative investigations of performance, qualitative methodological orientations are non-existent, and most of our research-informed understanding of learning has been based on international accounts, related from the perspectives of academics and educational researchers.

Threshold concepts theory has become established as an influential and generative framework for research across a range of disciplines in the UK, Australasia and USA (Entwistle, 2008; Flanagan, 2018; Peter et al., 2014; Tight, 2014). However, its application in South Africa and other developing countries remains minimal. The study findings thus contribute to a contextual gap in threshold concepts scholarship. The foregrounding of students' voices offers additional perspectives that may deepen the understanding of disciplinary learning beyond the study context.

The combination of the threshold concepts framework and IQA (a research methodology that has not been used in any statistics education research, as far as I could determine) enabled me to sketch some possible answers to questions not usually asked in statistics education research (and to date, neglected in South African contributions to this area), about the processes and experiences of students' learning in statistics, and to draw some inferences for enhancing the conditions of that learning. These insights may be relevant to statistics educators and to researchers using the threshold concepts or related orientations, and ultimately, through pedagogical and curricular responses, may be of benefit to statistics students.

1.7 Organisation of the study

This chapter has introduced the study, offering some detail on the background, rationale and focus which guided it. Chapter 2 reviews the terrain of existing scholarship around teaching and learning in statistics. I consider two interlaced strands of research — the cognitive and the affective constructs of disciplinary learning — and offer a synopsis from extant literature of likely sources of disciplinary difficulty. Chapter 3 presents the threshold concepts view of learning that frames the study, traces its theoretical lineage, considers critiques, reviews its application in statistics, and reflects on where this study may contribute to scholarship within the framework and in relation to broader statistics education research. Chapter 4 describes the research methodology used to seek answers to my research questions. After sketching the case study in more detail, it describes the rationale and realisation of the threshold concepts-enriched tutorial programme and explain the use of IQA to generate and analyse data. Considerations of rigour and ethics are followed by some reflections on the methodology. Chapter 5 details the application of IQA in the focus group sessions, and presents the group's understanding of their learning in the tutorial programme. The affinities (or themes) the participants identified as comprising their learning are introduced, and their interrelationships depicted in a Systems Influence Diagram (SID) — a mindmap derived according to IQA protocol, depicting the group's construal of their learning. Chapters 6 and 7 elaborate these affinities, relying largely on the participants' own words to describe their construals of each affinity, and the relations of influence among them. Chapter 8 abstracts ten key findings from the affinity descriptions of the previous two chapters, discussing each in relation to existing scholarship — both within the TCF, and in broader statistics education research. Chapter 9 provides an overview of the study, notes some limitations, and draws out implications for practice and further research, before offering a tentative model grounded in the study findings, and some concluding reflections.

CHAPTER 2

LITERATURE REVIEW: RESEARCH IN STATISTICS HIGHER EDUCATION

2.1 Introduction

The first chapter outlined the context and rationale for this study, highlighting and aligning global, as well as the limited body of South African research concerns around students' learning in statistics. This chapter serves to provide the reader with a critical evaluation and synthesis of the extant literature on teaching and learning in the statistics discipline. It offers a discussion of significant research findings in the statistics higher education scholarship in recent decades relevant to the current study, while highlighting its originality. Informing this review is the defining principles of the discipline and the conceptual skills that a statistics student should master.

A large proportion of statistics education research papers are produced from research conducted in developed countries (for example, the USA, Australia and New Zealand) and other developed European countries (for example, the UK, The Netherlands, Spain, Belgium France, etc.) Ultimately, the disparities that exists between developed and developing countries in terms of educational infrastructure, the availability of technology in the classroom, the quality of teacher training, and the presence of educational monitoring bodies, informs the type of statistics educational research that is undertaken in these countries, and impacts on the results obtained (Petocz, Reid, & Gal, 2018).

This study is set within a developing country context, and as such, in areas where a disparity exists, between the prevailing international literature and the South African context on the challenges facing statistics students and educators, the disparity was highlighted and elaborated upon in Chapter 1 (see sections 1.3 and 1.4). Section 2.2 describes the rationale for the teaching reforms that have been advocated for in the introductory statistics classroom in recent decades. The current span of statistics education research based on teaching and learning in the introductory statistics course may be considered to comprise two intertwining strands.

The first strand deals with the discussion of cognitive aspects that impact on students' learning of the various disciplinary concepts, and the second strand comprises of research into the affective aspects that impacts on students' understanding in the discipline. Both strands of disciplinary learning are well-represented internationally, but are scarcely represented in South Africa. The cognitive strand focuses on teaching inputs and learning outputs. It is dominated by quantitative studies that identify the determinants of conceptual attainment and measures and evaluates performance associated with a teaching intervention and also offers guidance on teaching innovations.

The second strand deals with concerns pertaining to the identification and impact of affective constructs on students' learning in the discipline. This strand examines the process of how students' learn in the discipline and draws upon research into educational psychology. This strand lends itself to the threshold concepts view of learning (Rattray, 2016). Application of the threshold concepts framework to learning in the statistics discipline is under-represented in the international literature (Bulmer et al., 2007; Khan, 2014; Thompson, 2008), and is the topic of a solitary South African statistics education research paper focused on the identification of disciplinary threshold concepts (Dunne et al., 2003). Included in section 2.3 is an overview from the extant statistics education literature of features of the discipline that may present difficulty to students since these sources of difficulty or 'troublesome knowledge' is a central tenet of threshold concepts theory. Section 2.4 offers concluding comments, which lays the ground for the elaboration of the threshold concepts framework in Chapter 3.

2.2 Research around teaching and learning in statistics

Globally, statistics is taught at varying levels of complexity at the school and tertiary level. At the school level, statistics is generally accommodated within the mathematics curriculum and at the tertiary level, statistics is taught across an extensive array of faculties and departments as a disciplinary major or as an introductory course. As such, the international literature on statistics education research interrogates the challenges and associated intricacies of teaching and learning in the discipline at the various educational levels in which it is offered; spanning a gamut of topics and approaches to understand teaching and learning with discernible variations in emphasis: (i) research that focuses on 'inputs' such as educational interventions and its corresponding 'outputs'; (ii) teacher(s) self-directed examination of pedagogical practice; and (iii) research conducted by various other disciplinary scholars who investigate issues pertaining to the learning or teaching of statistical topics as it relates to issues of interest in their particular discipline (Petocz et al., 2018).

For this study, focus will be placed on reviewing the extant literature that evaluates reforms, recommendations and reflections around teaching and learning in the introductory statistics course at the higher education level. In the discussion that follows, I have grouped the broad themes evident in the literature into two strands: cognitive aspirations and affective aspirations. In reality, these two strands of research are entangled with many areas of overlap and mutual influence that cannot be simply disentangled.

2.2.1 Cognitive aspirations: developing students' statistical literacy, thinking and reasoning

Characteristically, an introductory statistics course curriculum comprises topics in descriptive statistics (data collection, representation and summary) and topics in inferential statistics (for example, simple linear regression, sampling methods, hypothesis testing), and probability. In order to mirror the basic process of analysis undertaken by practicing statisticians, the scope and sequence of topics covered in introductory statistics courses constantly need to be reviewed and modified (Zieffler et al., 2018). As an example, recent advances in computing have had a significant impact on statistical practice, therefore, in order to meet the challenges posed by an increasing need for statistically literate citizens and a statistically trained workforce, statistics educators are called upon to review and update the content and pedagogy in the introductory statistics classroom.

The American Statistical Association's Guidelines for Assessment and Instruction in Statistics Education (GAISE, 2016) reports that the goal of an introductory statistics course should be the emphasis and focus on conceptual understanding and attainment of statistical literacy and thinking by "teaching statistics as an investigative process of problem-solving and decision-making" (GAISE, 2016, p. 6), with less emphasis on learning a set of tools or procedures. To this end, the GAISE calls upon statistics educators to encourage students' self-construction of fundamental statistical concepts and methods. This was clearly evident in the advice offered by Jessica Utts, the 2016 President of the American Statistical association, to introductory statistics teachers:

> So I encourage those of you who teach introductory statistics to a general audience to stop wasting time on things like why we use $(n-1)$ instead of n, or presenting formulas that don't help with understanding, and start incorporating stories, especially ones that will help students become educated consumers of statistical information. We have important stories to tell, and for most students we have only one quarter or semester to tell them. Let's not waste that chance (Utts, 2016, p. 1380).

Over the years, the calls for teaching reforms in statistics has given rise to a profusion of investigations (mainly quantitative in nature) focused on identifying key factors affecting student performance (Beckman, delMas, & Garfield, 2017; Ben-Zvi, 2011; Garfield, 2013; Garfield et al., 2012; Pfannkuch, 2011; Pfannkuch et al., 2016). There are also normative and philosophical debates around the content that is (or ought to be) taught (Cobb, 2015). Pedagogical content knowledge (PCK), a phrase coined by Shulman (1987) to describe the knowledge needed by teachers to successfully impart disciplinary knowledge to their students, has been appropriated, refined and extended by mathematics and statistics researchers to describe the professional knowledge teachers need to aid students' in their disciplinary understanding (Groth, 2017). This has been identified as a core issue in the literature and a growing number of statistical education research papers have focused on exploring how teachers need to develop professional knowledge in addition to statistical subject matter knowledge, in order to help students understand disciplinary content (Groth, 2017; Groth & Meletiou-Mavrotheris, 2018; North et al., 2014; Pfannkuch & Ben-Zvi, 2011). However, there is a very limited body of scholarship that offers a deep, rich qualitative perspective based on teaching methods and interventions.

The questions around what and how statistics should be taught is strongly linked to concerns about students being able to access an eminent standard of learning in the discipline. Thus, statistics pedagogical reform goals, aim for the attainment of the desired disciplinary holy trinity of statistical literacy, statistical reasoning, and statistical thinking (Assessment Resource Tools for Improving Statistical Thinking, 2006). An attempt to define and distinguish between the vertices of this statistical pedagogical triangle appears in the following schematic:

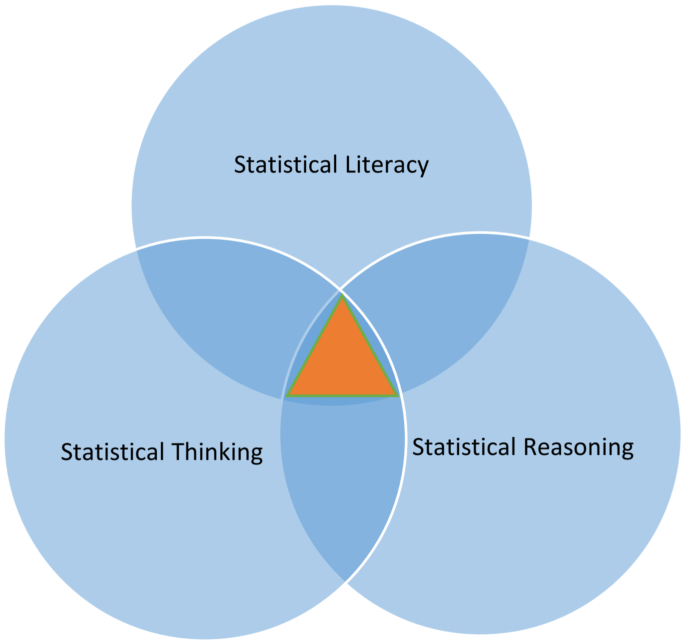

Figure 1. The hierarchical overlap of statistical literacy, thinking and reasoning

(Adapted from Assessment Resource Tools for Improving Statistical Thinking (2006))

Figure 1 depicts statistical literacy, thinking and reasoning as distinct learning outcomes, but with a hierarchical overlap, showing literacy as providing the foundation for thinking and reasoning (Assessment Resource Tools for Improving Statistical Thinking, 2006). Statistical literacy is defined as having two distinct learning outcomes: statistical competence and citizenship (Rumsey, 2002). Being statistically competent implies that one possesses the basic knowledge underpinning statistical thinking and reasoning, while statistical citizenship aims at empowering individuals to become "educated consumers of quantitative data who are able to think critically and make good decisions from the information" (Parke, 2008, p. 2).

Statistical thinking is described as the ability to take an all-encompassing view of the statistical process, from determining the most suitable data collection process followed in order to gather the relevant data, to answering the pertinent questions of the study, interrogating the results (bearing in mind the limitations of statistical techniques used), and finally relating the data results, and understanding its relevance, in relation to the context of the study (Chance, 2002).

Possessing statistical reasoning ability implies that one can make sense of statistical information by making inferences and drawing conclusions from the given information, and this may only be competently achieved if one has sound conceptual understanding of important statistical ideas (Garfield, 2002). These desired learning outcomes have increasingly informed innovations in statistics pedagogical research over recent decades. These pedagogical reforms have been advocated for to replace traditional approaches to teaching statistics where, arguably, the focus is on procedures and computations (The International Collaboration for Research on Statistical Reasoning, 2018).[8]

Cognitive goals for introductory statistics classrooms aims at implementing discipline-specific pedagogy that will develop and enhance students' statistical literacy, thinking and reasoning. Since the introductory statistics course may be the only experience with statistics that many students may encounter in their academic career, it has been argued that "it is essential that the curriculum be optimized [sic] to promote the key ideals of statistical inference and probabilistic reasoning … that allows students to effectively apply these principles beyond the classroom in applications they encounter as students, professionals [and] citizens …" (Beckman et al., 2017, p. 419). Thus, in the literature, student-centred pedagogical practices such as activity-based learning, flipped classrooms and cooperative learning approaches are offered as potential alternatives to the traditional rote skills, computations and procedures intense, lecture-dominated classroom format (Zieffler et al., 2018).

These emergent teaching innovations have been informed by previous research conducted on the teaching and learning in statistics such as the Statistical Reasoning Learning Environment (SRLE) (Garfield & Ben-Zvi, 2009), one of the earliest models designed to develop students' statistical reasoning. The SRLE is a proponent of the idea that students ought to be actively engaged in the statistics classroom in order to attain statistical literacy, thinking and reasoning. The model has its foundations in the constructivist theory of learning since constructivist theory grounds student learning as an active engagement of constructing and restructuring new knowledge based on previously learned concepts (Kalaian & Kasim, 2014; Vygotsky, 1978a).

[8] The drive for statistics education to prioritise statistical literacy, reasoning and thinking resulted in the establishment of the Statistical Reasoning, Thinking and Literacy (SRTL) International Collaboration in 1999. The SRTL International Collaboration fosters current and innovative research studies that examines the nature and development of statistical literacy, reasoning and thinking as desired learning goals for students. Recently, the Tenth International Research Forum on Statistical Reasoning, Thinking and Literacy was held in New Zealand, in July 2017 (The International Collaboration for Research on Statistical Reasoning, 2018).

The SRLE is based on the following six principles of instructional design (Garfield & Ben-Zvi, 2009):

a) a focus on developing central statistical ideas;
b) the use of real and motivating data;
c) the use of classroom activities to develop students' statistical reasoning;
d) the integration of the use of appropriate technological tools;
e) the promotion of classroom discourse; and
f) the use of alternative assessment.

Arguably, the shift from a traditional classroom to an SRLE will involve challenges, but will ultimately create an atmosphere in which students are meaningfully engaged in statistical reasoning about conjectures using data and focusing on the big ideas in statistics (Garfield & Ben-Zvi, 2009). Generally, research findings suggests that in statistics classrooms where the six tenets of the SRLE has been applied, the statistical reasoning of students were seen to have (statistically speaking) significantly improved (Chan, Ismail, & Sumintono, 2015; Conway IV, 2015). Thus, the SRLE, is clearly "an effective and positive statistics learning environment that develops in students a deep and meaningful understanding of statistics and helps students develop their ability to reason statistically" (Ben-Zvi, 2011, p. 3).

In the following sections, I will proceed to deconstruct the cognitive strand of statistics education research according to three broad categories as informed by the guiding principles of the SRLE: (i) studies focussed on students' statistical reasoning featuring active learning activities that incorporate the use of real data; (ii) the use of technology and alternative formats of delivery in the statistics classroom; and, (iii) the promotion of statistics discourse in the classroom.

2.2.1.1 Pedagogical approaches: Small-group, active learning strategies incorporating the use of real data

As the discipline of statistics has evolved and become more distinct, teaching reforms have been proposed, and encouraged (BenZvi & Garfield, 2004; Tishkovskaya & Lancaster, 2012; Utts, 2016). Dissatisfaction with the introductory statistics course at the higher education level has led to the discussion of teaching instruction reforms in the domains of course content, pedagogy, and technology. Course content reformations place emphasis on data analysis of real-world problems using real-world data, fewer lectures, and more co-operative, activity-based learning is encouraged, along with the use of technology for data analysis, visualisation and simulations (Carlson & Winquist, 2011; Fawcett, 2017; Forbes, Chapman, Harraway, Stirling, & Wild, 2014).

In the extant literature, pedagogical reforms encourage an active learning curriculum wherein small-group learning as an instructional method has been advocated in the tertiary classroom as a supplement to or replacement of traditional lectures (Kalaian & Kasim, 2014). From as early as the 1990s, it has been noted within the statistics education research literature, that small-group learning methods, such as cooperative learning, is an often discussed instruction style, when the issue being focused on is improving teaching, regardless of the discipline or level of instruction and that students learn better and retain more if they engage in learning activities that require them to think and process information, rather than passively listen to lectures (Garfield, 1993). This is possibly because this approach to learning fosters deep, rather than surface approaches to learning (Zieffler, Garfield, Alt, Dupuis, Holleque, et al., 2008).

A meta-analysis[9] performed on statistical education research studies that measured the effectiveness of small-group learning methods on statistics achievement (Kalaian & Kasim, 2014) reveals that the key recommendation across the studies reviewed was the use of various small-group active learning methods, including cooperative,[10] collaborative,[11] inquiry-based or problem-based learning[12] methods and activities to either replace or supplement traditional lecture-based instruction.

Thus, the major goals achieved by the small-group active learning pedagogy, based on the context of constructivism theory, is the development of students' statistical-reasoning and problem-solving

[9] A statistical technique used for "amalgamating, summarizing [sic] and reviewing previous quantitative research" (Neill, 2006, p. 1).
[10] A structured, systematic, and teacher-guided small-group instruction strategy in which students work together in small groups to maximise their own and each other's common learning goals.
[11] An unstructured form of small-group learning that incorporates a wide range of formal and informal instructional methods, in which students interactively work together in small groups toward a common goal.
[12] A small-group instructional method for seeking information and knowledge in which students work in teams to solve a problem or inquiry through exploring, developing, and asking relevant questions, investigating, making discoveries, presenting the results of the discoveries to other students in the classroom, and writing a scientific report.

skills, as well as their reflective critical and higher-order, and meta-cognitive thinking skills. It also helps to develop effective communication, teamwork and social skills, and students are better able to retain the newly learned statistical concepts for subsequent and future applications, and apply the learned statistical materials and concepts to new scientific problems and situations (Kalaian & Kasim, 2014, p. 2). Although “teachers of statistics [should] take care not to overestimate their students’ reasoning skills, even if their students have performed well in an introductory course” (Zieffler, Garfield, Alt, Dupuis, Holleques, et al., 2008, p. 8), this type of instruction – small-group active learning – does seem to yield promising results. This may be attributable to the fact that small-group activities allow students to informally express their statistical reasoning abilities within the group, thus providing opportunities for the teacher or peers to discover and correct faulty statistical reasoning that may be articulated.

One of the drawbacks of the studies reviewed by Kalaian and Kasim (2014) is that, although the use of small-group active learning exercises showed particular gains in terms of higher performance in the specific courses using this intervention, these results do not necessarily indicate that these instructional interventions resulted in an improvement in students’ statistical reasoning in specific topics when compared to other ‘traditional’ methods – thus, “studies that examine the impact of particular activities or approaches on students’ understanding of particular concepts or learning outcomes rather than achievement in general appear to be more informative” (Zieffler, Garfield, Alt, Dupuis, Holleques, et al., 2008, p. 14). While not reviewed in detail here, some key findings of this body of work are noted, as they feed into the issue being highlighted.

Another pedagogical tool to have emerged from the statistical teaching reformation is the incorporation of the use of real-data in active learning activities. Several leading statisticians in the reformation movement in statistics instruction advocate for the use of real data to develop a deeper understanding of the analytical process (Dunn, Smith, & Beins, 2007; Neumann, Hood, & Neumann, 2013; Neumann, Neumann, & Hood, 2010). Within the constructivist SRLE, the need to use real and motivating data to develop students’ statistical reasoning skills is emphasised. This enables students to construct knowledge based on their experience of using real data, and this new knowledge may be integrated with existing knowledge to interpreting the data, using relevant statistical analytical methods (Garfield & Ben-Zvi, 2009; Neumann et al., 2013). It has been noted that the use of real data sets also offers an opportunity for students to reflect upon their data analysis work which may aid in conceptual understanding (Neumann et al., 2013), and that statistical reasoning is further developed through the connection between contextual knowledge of the data set and students' emergent statistical knowledge (Pfannkuch, 2011).

A qualitative investigation into students' perceptions of using real-life data in learning in an introductory statistics course (Neumann et al., 2013) offers an illuminating perspective on this teaching strategy – the results indicated both cognitive (reflected in the emergent themes of student responses, categorized as: Aided Learning and Understanding) and affective (reflected in themes: interesting, motivating and engaging) aspects of learning are impacted by the use of real-life data. Students in the study indicated that the use of real data sets had a "real-life relevance" (Neumann et al., 2013, p. 7) for them, thus augmenting the meaning-making achieved by this practical approach to learning in the discipline. The themes that emerged in the study by Neumann et al. (2013) is congruent with the findings from similar studies (Garfield & Ben-Zvi, 2008; Garfield & Ben-Zvi, 2009), where working with real-life data is a constructivist approach that assists students in their construction of knowledge of statistical concepts and is a "motivating tool that allows deeper understanding of statistical methods" (Neumann et al., 2013, p. 7).

Generally, incorporating meaningful contexts and the use of real-data in classroom activities that use constructivist-based active learning techniques in teaching topics in descriptive statistics (Libman, 2010) and inferential statistics (Garfield & BenZvi, 2008; Garfield et al., 2012) has proved to be a valuable pedagogy. As observed by Libman (2010), creating realistic circumstances and meaningful contexts in classroom activities will enable students to properly apply what has been learned, and to create statistical understanding. By generating contexts in which students may see the 'bigger picture' - the value and meaning of statistical concepts may be fully realised, rather than narrowly focusing on facts, theories, and formulae. Presenting students with a complex learning situation of statistical concepts based in a real-life context encourages curiosity and interest, and relevant, contextual teaching of statistical concepts is likely to motivate students to construct or reconstruct their previous (mis)conceptions. The notion of relevance implies that students would want to acquire the knowledge if they are acquainted with how (and why) the application of statistical concepts is relevant in their lives. Furthermore, complex and realistic contextual teaching grounds the statistics learner in the interconnectedness of statistical ideas and encourages more meaningful statistical conceptual reasoning and understanding, thus enabling students to transfer these statistical ideas to new, unlearned problems. Finally, teaching practices that encourage student-led investigation of a statistical topic in a realistic setting reinforces the role of the learner as the owner of their self-constructed knowledge regarding the statistical topic that they are tasked with investigating. It is also empowering in the sense that the student becomes a partner in the selection of subject-matter to be studied and the curriculum is no longer fixed or rigid (Libman, 2010, p. 4 and 5).

On the statistical topic of probabilistic thinking and learning, in the extant literature, various models have been proposed to characterise probability thinking and modelling and the key proponent of the various frameworks is to embolden the idea that both theory-oriented and data-oriented learning contexts are essential for the development of probabilistic thinking (Pfannkuch et al., 2016). The standout feature is that even in the area of probability thinking and modelling, emphasis is placed on pedagogical instruction that links theory with practical skills.

It has been argued that given the mathematical content in the statistics discipline and the abstract nature of many statistical concepts, the importance of the use of analogy, metaphor and imagery by educators ought not to be overlooked, as such processes may help students make sense of the abstract. One recommendation is that statistical instruction should be grounded in concrete physical activities to help students develop an understanding of abstract concepts and reasoning (delMas, 2004). To facilitate students' statistical thinking, Ben-Zvi (2004) adapts the idea of enculturation to the statistics student. This process refers to the development of cognitive skills by immersing the student into the culture of statistical practice. The teacher plays the role of mentor or enculturator. Relating this to disciplinary learning raises the idea that the purpose of pedagogical interventions is to develop students' abilities to reason statistically. Thus, it is easily conceivable from the foregoing review of the literature that the enculturation of a student into statistical ways of thinking and practice (WTP) may be achieved through the pedagogical intervention of small-group active learning strategies, incorporating the use of real-life data.

From the studies reviewed above, ranging across a vast terrain of statistical topics, namely descriptive statistics, inferential statistics, probability thinking, and modelling, the common thread running through the above studies' findings is that the incorporation of small-group activities involving the use of real data into the statistics curriculum is key to helping students develop sound statistical reasoning.

However, these studies simply reflect an 'output' to a pedagogical 'input'. In order to gain a deeper understanding and measurable impact of these pedagogical innovations and the learning processes involved in constructing disciplinary knowledge through the use of small-group strategies incorporating the use of real-life data, one would need to have an understanding of students' cognitive abilities and affective attitudes towards learning in statistics before the intervention. Also, the researcher would need to determine the best method (in terms of how and when) for incorporating real-data sets into class activities. Only once it is ascertained how far along students have travelled on their journey of understanding in statistics can the effectiveness of the interventions be reasonably measured and evaluated. The issue highlighted here will be returned to in the discussion of the key findings of this research study.

In the following sections, I offer a synthesised review of the existing literature on the impact of pedagogical instruction that involves the use of technology and alternative classroom delivery on students' statistical literacy, thinking and reasoning.

2.2.1.2 Pedagogical approaches: Use of technology and alternative classroom delivery

Technological advancement has transformed the way statistics is applied, where problems that were once considered intractable analytically now have approximate solutions, and the simplifying assumptions made about statistical models is no longer required. Thus, these technological advances have had a direct impact on how statistics is taught. In recent decades, the use of technology has allowed focus to shift from having students work through tedious mechanical computations to allowing students to concentrate on understanding statistical concepts, and interpreting the results. Consequently, statistics educators are increasingly embracing technology in their classrooms (Chance, Ben-Zvi, & Garfield, 2007).

In light of these technological advances, cognisance must be taken of Moore's (1997, p. 134) forewarning to statistics educators, and cautioning them that technology will have an impact on statistics learning only if it is used correctly and that "technology should serve content and pedagogy". If applied correctly, the benefits of the use of technology in statistics instruction can be discerned in its promotion of active knowledge construction – students learn by "doing" and "seeing" statistics, and it provides opportunities for students to reflect on observed phenomena. This has the desired effect of helping students develop their metacognitive abilities – knowledge of their own thought processes, self-regulation and control, and provides opportunity for a renewal of statistics instruction and curriculum through strong synergies among content, pedagogy and technology (Ben-Zvi, 2000, p. 128).

Research on the use of technology in statistics pedagogy can be divided into two broad categories: (i) the development and use of technological tools to enhance students' reasoning in statistics (Biehler, Ben-Zvi, Bakker, & Makar, 2012; Dinov, Christou, & Gould, 2009; Gonzalez, Jover, Cobo, & Munoz, 2006; Utts, Sommer, Acredolo, Maher, & Matthews, 2003); and (ii) the effectiveness of online and hybrid classrooms,viz. a mix of face-to-face and online classrooms (Johnson, Zhang, & Evans, 2009; Yang, 2017).

There are a variety of technological tools and resources available for the teaching and learning of statistics. These include, but are not limited to statistical software packages,[13] spreadsheets,[14] applets,[15] graphing calculators,[16] and multimedia materials.[17] These technological tools aid students' statistical reasoning through encouraging an exploratory working style, by allowing students to practice graphical and numerical data analysis and by enabling students participation in statistical experimentation through computer simulations which allows them to construct, analyse, and compare statistical methods (Biehler et al., 2012).

However, there is no best way of incorporating these technological tools into classroom activities. Instructors are encouraged to experiment with these materials and build on complexity involving these demonstrations based on students' alertness and progress in comprehension and understanding (Dinov et al., 2009).

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[13] These are statistical programmes designed for performing statistical analyses, such as SAS (SAS, n.d.), SPSS (SPSS, n.d.), the freely accessible and programmable *R* package (R, n.d.), and StatCrunch (StatCrunch, n.d.).
[14] Such as *Excel* (Microsoft Excel Online, n.d.) can be used to help students learn to organise and represent data.
[15] a small application that is written in the JAVA programming language and that can be downloaded from the internet to any computer (Webopedia Staff, n.d.).
[16] Can be used for analysing and exploring data, perform statistical procedures and calculations.
[17] Combines text, audio, still images, animation, video and interactive media to teach statistics.

A review of the literature based on the efficacy of online classrooms illuminates mixed results. Some of the earlier studies conducted (Summers, Waigandt, & Whittaker, 2005) indicated no significant differences in students' grades between online and traditional classrooms, but showed significantly less satisfaction with the online classroom with regards to the course instructor – in terms of explanations, enthusiasm, open-ness and concern towards students and their learning – and with class discussion, quality of questions/problems and evaluation and grading of statistical concepts appropriate to an introductory statistics course. Also, findings from a more recent study (Hahs-Vaughn et al., 2017), suggests that delivery format is not statistically related to a graduates' statistical literacy in an introductory statistics course.

An important implication of using technology to conduct statistics lessons may be discerned from the above studies. Insofar as quality learning being based on final course grades, there seems to be no statistical difference between online and traditional lectures. But if quality learning is to take into account the affective aspects of students' learning in the discipline, then the online classroom delivery format seems to be failing statistics students. A technology-based delivery format needs to holistically embrace students' learning needs – this means that students' cognitive and affective aspects of learning needs to be acknowledged and enhanced. This concern will be re-visited as it pertains to the findings in this study.

In the section that follows, a review of the extant literature will focus on the use of alternative classroom delivery to improve learning in statistics due to its ability in making statistics visual, interactive and dynamic, while offering an opportunity to focus on concepts rather than computations through an engaging experimentation with data (Olive & Makar, 2010).

2.2.1.3 Pedagogical approaches: Promotion of classroom discourse

In the current extant literature, another type of classroom experience that features quite frequently is the flipped classroom.

> In the flipped classroom model, what is normally done in class and what is normally done as homework is switched or flipped […] A guiding principle of the flipped classroom is that work typically done as homework (eg. Problem-solving, essay writing) is better undertaken in class with the guidance of the instructor. Listening to lecture or watching

> videos is better accomplished at home. Hence, the term *flipped* or *inverted classroom*. (Herreid & Schiller, 2013, p. 62).

The traditional lecture is substituted with active learning techniques, such as group work and lectures are delivered outside the classroom, for instance, as a video-recording to be viewed online before class. This approach is proving to be quite popular as innovative pedagogical activities are reportedly being adopted in an attempt to promote student learning (Zieffler et al., 2018). The flipped classroom approach to teaching and learning in statistics (Schwartz, 2014) and variations thereof (Carlson & Winquist, 2011) has been generally met with a favourable response from students. Students exuded pride in being able to successfully learn statistics in this format, viewing it as a noteworthy personal accomplishment whilst also acknowledging the flipped class format as an intense learning experience (Schwartz, 2014). Students articulated having more confidence in their statistical abilities and statistical understanding, and like statistics more even though they found statistics to be more difficult than those students who were taught in a traditional class set-up (Carlson & Winquist, 2011). Thus, the flipped class approach to statistics instruction has both cognitive and affective implications on students' learning in statistics - having impacted on their meta-learning abilities (students acknowledged finding this approach more difficult to cope with but recognised that their perseverance with the course and their ultimate successful attainment of statistics understanding as a noteworthy accomplishment), and heightened their self-worth and self-confidence.

There is a paucity of research on the implementation of technological pedagogy in the introductory statistics course in South Africa. Thus, key findings (see Chapter 8) from this body of scholarship will have a significant bearing on this aspect of the extant South African statistics education research literature.

2.2.1.4 Synthesis: Cognitive aspirations

Interestingly, the current findings, in each of these various examples of current statistics pedagogy, echo the findings from past research, and reiterate and confirm the advice offered by the statistics education reformation movement that statistical pedagogical techniques should be grounded in real-word application, encompass real-data handling and embrace a cooperative learning approach (Neumann et al., 2013); (Forbes et al., 2014); (da Silva & Pinto, 2014); (Magalhaes & Magalhaes, 2014).

The assessment instruments and research methods that I have reviewed serves to elucidate student's difficulties in reasoning about statistics.

However, an incommodious attribute of the extant statistics education literature is that it is dominated by quantitative research approaches. Quantitative instruments, such as multiple choice type items and pre- or post-tests, may not adequately measure students' statistical reasoning. This is due to the fact that students' reasoning and learning in statistics is not one-dimensional, and students' understanding in the discipline may be influenced by both cognitive and affective factors. Furthermore, the research reviewed is conducted through the lens of the researcher in terms of the interventions ('inputs') that statistics educators wrought in order to bring about a perceived difference in student learning outcomes ('outputs'). These studies suggest a troubling inconsistency and disparity between what students are able to achieve in a final grade on a statistics exam, and their ability to reason about statistics afterwards. This echoes a cautionary note, as mentioned earlier, from Zieffler, Garfield, Alt, Dupuis, Holleques, et al. (2008) to statistics instructors, to not overestimate their students' reasoning skills, even if their students perform well in an introductory statistics course. Therefore, it is imperative that statistics educators reflect on the types of tasks that they use to elicit information about their students' reasoning skills and understanding in the discipline. In the reviewed literature, limited qualitative instruments were used (interviews and/or questionnaires) to ascertain students' experiences of learning statistics through the various interventions and to gauge how meaningfully the students engaged with the subject matter. There is scope for the use of a variety of qualitative research methods to be more extensively applied to explore and interrogate students' interactions with and learning in statistics. For example, students should be encouraged to keep reflective journals, in which they can reflect on their learning in the subject as they work in pairs or in small groups on an activity. Reading through these journals is likely to offer insight into the cognitive and affective processes and challenges that students grapple with during their statistics learning journey. By providing thick, rich descriptions of students' experiences of learning statistics from their own perspective, this qualitative research study may contribute to the discussions of students' experiences of learning in the discipline.

The following sections will offer a review of the statistics education literature that focuses on the affective aspects of students' learning in the discipline.

2.2.2 Non-cognitive aspirations: students' beliefs and attitudes towards learning statistics

Non-cognitive aspects of teaching and learning in statistics consist of affective and social constructs such as attitudes, beliefs, emotions, dispositions, motivation and numerophobia[18]. Overcoming anxiety and negative attitudes and cultivating curiosity and awareness amongst statistics students are some of the challenges that have been identified in the introductory statistics classroom. It is widely acknowledged that for many students, their apprehension towards studying statistics centres around their mathematics anxiety and numeraphobia, as students often conflate mathematics with statistics (Zieffler et al., 2018), and this apprehension and anxiety may affect their learning in statistics. Therefore, I will separate my literature review of the non-cognitive aspects of statistics learning into two parts, namely: (i) mathematics anxiety and numeraphobia; and (ii) statistics anxiety and statistics attitude.

Section 2.2.2.1 will offer a review of the statistics education research literature that has examined the link between mathematics anxiety and numeraphobia and understanding in statistics. Section 2.2.2.2 offers a brief overview of the impact that mathematical preparedness has on South African students' understanding in statistics.

2.2.2.1 Mathematics anxiety and numeraphobia

Statistics is commonly characterised as a branch of mathematics, and as such, statistics academics have over the years offered various explanations on the differentiation between the two disciplines

[18] An anxiety disorder born out of fear of dealing with numbers or mathematics (Wikipedia, 2018b)

(Cobb & Moore, 1997; De-Veaux & Velleman, 2008; Fienberg, 2014). To adapt an oft-cited statement by John Tukey,[19] statistics, unlike mathematics "is [more] about being approximately right than exactly wrong". In statistics, one is not looking for the exact solution to a problem, but rather looking for a general solution to a problem. However, statistics often adopts mathematics in its attempts to analyse data to gain insight into real-world problems (Wild et al., 2018) and "to offer to other fields of study a coherent set of ideas and tools for dealing with data" (Cobb & Moore, 1997, p. 801). The role of context is the key distinguishing characteristic of the discipline, "Statistic[al] […] methodology focuses on how to go from the particular to the general and back to the particular again" (Fienberg, 2014, p. 6). Thus, statistical meaning-making of real-world problems involves extracting from the tangible using abstract generalisations in order to gain meaning from the real-world context (Wild et al., 2018).

From as early as the 1990s, statisticians have been urged to de-emphasise the mathematical content in statistics curricula, so as to maintain the statistical identity of the content matter, where:

> [a]n undue emphasis on its mathematical foundations is detrimental to the discipline - it leads to restrictions on its perceived value so that statisticians and those who might otherwise benefit from its methods lose out. Although mathematics lies at its core, statistics as a discipline involves several essential components beyond mathematics. Notably among these are an appreciation of the concepts and methods of the area to which statistical techniques are being applied and computational skills. The range of potential applications of statistical ideas is vast-and is growing. It is important that the discipline of statistics should not let itself be marginalized [sic] by an apparent obsession with mathematical niceties (Hand, 1998, p. 245).

Notwithstanding the above distinctions between mathematics and statistics, the general consensus in the extant literature is that students' mathematical competence and statistical performance is positively related (Galagedera et al., 2000; Johnson & Kuennen, 2006; Lunsford & Poplin, 2011; Nasser, 2004). These studies reflect intricate relationships among students' mathematical competence, mathematics attitude, and anxiety in relation to statistics attitude and anxiety and

[19] A renowned American mathematician who made several significant contributions to statistics such as the development of the box plot and articulating the all-important distinction between exploratory data analysis and confirmatory data analysis (Wikipedia, 2018a).

statistics performance (Carmona, Martinez, & Sanchez, 2005; Silvia et al., 2008). Troublesome statistical concepts and terminology, numerophobia and mathematics anxiety pose a major barrier preventing students from comprehending fundamental statistical theory (Bulmer et al., 2007), (Gyuris, Everingham, & Sexton, 2012), (Thompson, 2008), (Dupuis et al., 2012), (Primi, Donati, & Chiesi, 2016).

However, although Lai et al. (2011) research findings indicate that competence in mathematics and statistics are related, their findings also supports the proposition that "mathematics and statistics are two separate disciplines, each deserving of its own pedagogy" (Lai et al., 2011, p. 115).

These research findings are limited in the sense that they do not offer any insight into how statistics educators may alleviate students' mathematics anxiety and numeraphobia so that students can engage meaningfully with statistical concepts. This issue has a significant bearing on the key findings of this study, and will be elaborated upon in Chapter 9.

From documented research (de Wet, 1998; Galagedera, 1998; Galagedera et al., 2000), tacit knowledge, anecdotal knowledge, and my experience in practice, the challenge posed by statistics students with poor mathematical preparedness and/or mathematical anxiety is a critical issue facing statistics instructors in South African institutions of higher education. The high levels of inequality in mathematical preparedness amongst South African school-leavers is viewed as a blight on the country's educational landscape (McCarthy & Oliphant, 2013).

The following section highlights the impact of mathematical preparedness on South African students' learning in an introductory statistics class.

2.2.2.2 The impact of mathematical preparedness on South African students' understanding in statistics

International concerns centred around students' learning and understanding in an introductory statistics course is somewhat exacerbated in the South African context, due to the limited mathematical proficiency amongst school leavers (NACI, 2017). In order to place the above statement in perspective, it is essential to provide some background to the mathematics taught in the South African high school context. In the South African secondary school system, at the beginning of Grade 10, learners are required to choose between studying Mathematics or Mathematical Literacy until their matriculation from high school at the end of Grade 12. This choice would ensure that students matriculate with a mathematically-oriented subject. The subject Mathematics is characterised as an academic study of the discipline in terms of the technical and abstract nature of mathematical concepts whereas the subject Mathematical Literacy seeks to equip a learner with functional mathematics skills through the application of mathematical concepts to everyday situations. At its inception in 2006, South Africa was the first country in the world to offer Mathematical Literacy as a school subject (Christiansen, 2007).

A further differentiation between the two high school mathematics may be based on comparing and contrasting the scope and depth of statistical content knowledge included in the two syllabi, with the Mathematical Literacy syllabus containing a limited coverage of statistical content knowledge, as compared to the Mathematics syllabus (Department of Basic Education, 2011a, 2011b).

However, the difference between the two subjects is not merely limited to the level and range of statistical content offered. In recent years, Mathematical Literacy has come under increasing criticism (North, 2015, p. 2), where it is perceived to be a significantly easier qualification (based on its high pass rates) as compared to Mathematics; there is also a concern that the quality of the subject does not afford access to various avenues of tertiary study. There are concerns about the shortcomings in the Mathematical Literacy assessment taxonomy in relation to the support and development of reasoning and problem-solving skills critical to mathematical literacy (Jansen, 2012a, 2016);[20] (Venkat, 2010; Venkat, Graven, Lampen, & Nalube, 2009). It is further argued that the Mathematical Literacy curriculum places emphasis on theoretical rather than practical knowledge, that is, prioritised mathematised forms of engagement within a contextual scenario, and that the contexts invoked are too simple to gain meaningful insights into the underlying

[20] Professor Jonathan Jansen is a vociferous critic of the Mathematical Literacy curriculum and the following extract of his newspaper article is indicative of the prevailing criticism of the subject Mathematical Literacy in South Africa: “If you still believe mathematical literacy should remain in the school curriculum, consider the following question from the Grade 12 Paper 1 examination written last week: ‘State whether the following event is CERTAIN, MOST LIKELY or IMPOSSIBLE: Christmas Day is on December 25 in South Africa’. For this brainteaser you would get two marks. I am not sure what upsets me more the fact that there are three options to this question, the cultural bias against non-Christian pupils, or that the mathematics in question 1.1.7 is not obvious at all.” (Jansen, 2012a)

complex phenomena that is being described, thereby “refut[ing] learners’ agency in determining similarities between activities or practices” (Christiansen, 2007, p. 91).

Another concern relates to the teaching of Mathematical Literacy. In practice, there are Mathematics teachers who do not adapt their style of teaching to suit the Mathematical Literacy curriculum, and there are non-Mathematics teachers who lack the mathematical content knowledge and skills to competently teach the subject (Botha, 2011). Research has revealed that “mathematics teacher training and teaching experience played a significant role in the productivity of the teachers’ practices [and] suggest that although mathematical content knowledge is required to develop PCK, it is teaching experience that plays a crucial role in the development of teachers’ PCK” (Botha, 2011, p. 3). This finding suggests that Mathematical Literacy ought to be taught by “specially trained, competent, dedicated teachers who value the subject” (Botha, 2011, p. 4). Building capacity for developing statistical literacy in South African schools is further constrained by factors such as the varying levels of preparedness and awareness of statistics amongst mathematics teachers, and the extents to which existing textbooks can help teachers to design lesson plans for students of differing skill level (North et al., 2014).

Thus, a typical South African introductory statistics classroom is likely to comprise students with varying degrees of mathematical preparedness. Some students may have matriculated having passed with the “softer” option of Mathematics Literacy, as opposed to other students who would have matriculated with Mathematics. From the above research findings, it would seem that students who have matriculated with Mathematics are comparatively better prepared to study statistics in terms of their development in reasoning and problem-solving skills. In other words, it would seem reasonable to expect students with highly developed cognitive reasoning and problem-solving skills, to be better equipped to carry out statistical analysis, as this requires a scaffolded-reasoning approach to problem-solving. Thus, the statistics teacher’s challenge is to develop the reasoning and problem solving-skills of the former Mathematical Literacy students, so that they are on par with the former Mathematics students, as well as bring the entire class to a level that is deemed suitable for statistical thinking and reasoning.

In response to the challenge of developing preparedness and awareness of statistics amongst mathematics teachers (Zewotir & North, 2011), Statistics South Africa (STATS SA), launched the maths4stats campaign (Statistics South Africa, 2014) and the ISIbalo-4: Maths, Stats and

Geography Education programme (Statistics South Africa, 2016) . The maths4stats campaign is a series of activities that was initiated in an attempt "to encourage the development of mathematics education, which is an important bedrock for statistics" (Statistics South Africa, 2014, p. 1). This campaign also aims to provide statistics training to mathematics teachers in order to "create a specialised body of teachers with a passion for mathematics, and to instil a love for and interest in mathematics and statistics in teachers and learners" (Zewotir & North, 2011, p. 3). The ISIbalo – 4: Maths, Stats and Geography programme includes efforts in "enhancing the learning and teaching of mathematics, statistics and human geography, the latter as a basis for demography and GIS[21] applications" (Statistics South Africa, 2016, p. 1). In line with STATS SA's acknowledgement of, and response to fostering a deeper appreciation and understanding in the discipline, my own concerns and observations of students' learning in statistics served as impetus for this study.

Thus, there is an urgent need to examine pedagogical approaches that may facilitate learning in introductory statistics classes in South Africa. Pedagogical approaches that will help alleviate the symptoms arising from students' levels of mathematical preparedness and mathematical anxiety. It is against this educational landscape that the key findings of this study will have a direct bearing and significance.

The following section will consider the literature pertaining to the affective constructs of statistics anxiety and statistics attitude as it relates to students' learning in the discipline.

2.2.2.3 Statistics anxiety and attitude towards statistics

As early as the 1980s, statistics anxiety was identified "as the feelings of anxiety encountered when taking a statistics course or doing statistical analysis" (Cruise, Cash, & Bolton, 1985, p. 92) and as a multidimensional construct consisting of six factors: (a) Worth of Statistics; (b) Interpretation Anxiety; (c) Test and Class Anxiety; (d) Computation Self-Concept; (e) Fear of Asking for Help; and (f) Fear of Statistics Teachers.

An explanation of the six factors is offered below.

[21] Geographic Information System (GIS) is a framework for gathering, managing and analysing geographical data.

> Worth of Statistics relates to an individual's perception of the relevance of statistics to the individual. Interpretation Anxiety refers to the feelings of anxiety encountered when interpreting statistical data. Test and Class Anxiety deals with the anxiety involved when attending a statistics class or when taking a statistics test. Computation Self-Concept relates to an individual's self-perception of his or her ability to understand and calculate statistics. Fear of Asking for Help assesses the anxiety experienced when seeking help. Lastly, Fear of Statistics Teachers refers to an individual's perception of the statistics teacher (Chew & Dillon, 2014a, p. 1178).

As to the essential difference between the affective constructs of statistics anxiety and attitude towards statistics, Nasser (2004, p. 2) notes that "the literature makes little if any distinction between the concepts of attitudes and anxiety and the terms are often used interchangeably." Among researchers who make a distinction between statistics anxiety and attitude towards statistics, the general consensus is that negative attitudes towards statistics results in statistics anxiety (Chew & Dillon, 2014b).

It has also been observed that

> [f]actors that have been found to manage or alleviate statistics anxiety include discussion of student concerns, humour, instructor sensitivity, and instructor interpersonal style. The common theme among them appears to be that they are all instructor behaviours that reflect a psychological availability, also known as immediacy, on the part of the instructor (Williams, 2010, p. 7).

Research findings suggest that instructor immediacy is significantly related to statistics anxiety with instructor immediacy explaining between 6% and 20% of the variance in students' anxiety levels (Williams, 2010). Augmenting the research on factors that aggravate or alleviate students' statistics anxiety levels are studies that investigated the impact of specific pedagogical interventions on students' statistics anxiety levels (Kinkead, Miller, & Hammet, 2016; Lee, Zeleke, & Meletiou-Mavrotheris, 2014). Student participants in the research study conducted by Lee et al.

(2014) indicated that they learn better when actively participating in the learning process and through a variety of instructional approaches, such as: (i) in-class exercises; (ii) hands-on activities; (iii) lecture; (iv) real-world projects; and (v) cooperative learning. Additionally, affective factors such as instructor attitude may greatly influence students' learning experience and improve students' attitudes and motivation. A couple of these instructional approaches, namely the use of real examples and instructor characteristics, were also found to be significant factors in helping students develop a positive attitude towards studying statistics in a South African study of students' attitudes towards statistics (Mutambayi, Odeyemi, Ndege, Mjoli, & Qin, 2016).

Factors affecting students' motivation to study for a subject were categorised as being intrinsically motivating, goal/career oriented, value oriented, and socially/environmentally oriented influence; and that the most important motivating factors were: major (is studying statistics a degree major?); fun (is statistics fun to learn?); grade (is it relatively easy to score well in statistics?); instructors' caring for students and career (is studying statistics pivotal to students' future careers?); answering yes to these factors tended to increase students' motivation to do well in statistics (Lee et al., 2014).

The affective factors influencing students' learning in statistics mentioned above resonates with this study's findings and will be referred to and expounded upon (in relation to the findings of this study) in greater detail in Chapter 8.

2.2.2.4 Synthesis: non-cognitive aspirations

The foregoing review of the extant literature of the social and affective aspects of statistics teaching and learning serves to illuminate the non-cognitive aspects of statistics students' learning journeys. As the research findings suggest, statistics students' learning journeys are often complex, meandering, and at times confounding. A myriad of factors influence the students' learning journey and these factors may not necessarily affect all students in the same way. The idiosyncrasies of individual students' learning journeys in statistics yearns for future researchers to take cognisance of this uniqueness. Some students' learning journeys may be influenced, separately, by either cognitive or non-cognitive factors or some student's learning journeys may be impacted by both these factors. Research conducted on students learning in statistics should not be conducted within silos of cognitive and non-cognitive constructs, but instead envelop the two strands of statistics education research.

The extant research on statistics teaching and learning is somewhat limited, as it does not offer fine-grained analysis and nuanced insights into how students with limited mathematical preparedness and other learning challenges might achieve the required level of competence for success in statistics. There appears to be a dearth of research based pedagogy as it relates to the teaching and learning of statistics mainly because extant literature has focused on investigating students’ understanding of various statistical concepts using quantitative methods of enquiry. As such, the complexities of teaching and learning as it relates to statistics remains an area that is in dire need of rich, deep, qualitative enquiry (Sharma, 2010) The use of qualitative approaches to statistics education research may offer an in-depth and enriched understanding of students’ cognitive and affective processes in learning statistics, and thus facilitate improvements in statistics education and practice (Petocz & Newbury, 2010).

In the absence of substantive, established theories of teaching and learning in statistics education, this study will draw on an established framework from a related discipline, namely economics (Land, Cousin, & Meyer, 2005; Land, Cousin, Meyer, & Davies, 2005; Meyer & Land, 2003, 2005). An evolving conceptual framework that has emerged from the economics education literature is that of the threshold concepts framework (Meyer & Land, 2003). A more detailed consideration of the threshold concepts framework and associated relevant research is provided in Chapter 3.

In preparation for that discussion, it is necessary to review the potential sources of difficulty encountered by statistics students as proposed by the statistics education research literature. A central tenet of the threshold concepts framework is the premise of troublesome knowledge, in the form of encounters with new disciplinary knowledge that may prove to be troublesome if students find them counter-intuitive, conceptually difficult, alien or incoherent (Meyer & Land, 2003). Section 2.2.3 provides an account of statistics features that is congruent with this notion of troublesome knowledge.

2.2.3 Potentially troublesome disciplinary knowledge

Potential sources of troublesome disciplinary knowledge may be due to students' experiences in learning, the nature of the discipline, teaching approaches and content. The following discussion presents a broad-sweep of the spectrum of the extant research. However, the understanding of the bearing that troublesome knowledge has on students in a South African context is largely speculative, since these issues have not been extensively and deeply explored in this country.

First, a significant hurdle documented in the literature on disciplinary teaching and learning involves learning the 'language' of statistics: the lexicon of the discipline used for communicating the conceptual underpinnings of the discipline. This new disciplinary language may be described as a combination of general English,[22] statistical English,[23] discipline English,[24] and mathematical English[25] (Dunn et al., 2016). As such, students need to discern how this tactical language, as it is used in statistics, differs from its lay, everyday use and avoid confusing the two meanings. Also, in statistics, a combination of words, graphs and mathematical symbols are used to convey theoretical concepts and relationships. Newcomers to the discipline are required to master all three and initiates must be adept at translation across the languages in order to express understanding of disciplinary concepts.

Mathematics is entwined with statistics as many statistics constructs are built around embedded mathematical concepts (Gattuso, 2006). For example, probability theory is a body of mathematical theory and mathematical theories underpin many practices in the analysis stage of statistical investigations (Wild et al., 2018). Mathematical tools are used in almost every statistics course, from the introductory level onwards. Clearly, mathematical aptitude and existing skills are useful in learning statistics and many quantitative studies confirm students' mathematical abilities as

[22] Terms used in everyday language, but some have specific meanings in statistics, for example, "significant" and "random" (Dunn, Carey, Richardson, & McDonald, 2016).
[23] Terms unique to the discipline such as "ANOVA" and "boxplot", Greek symbols such as μ and σ (Dunn et al., 2016).
[24] Terms from other disciplines that have different meaning in statistics, for example, the words "sample" and "regression" have different meanings in statistics and biomedicine (Dunn et al., 2016).
[25] For example, the word "estimate" means to make an estimation or sensible guess, whereas, in statistics, "estimate" means approximating a population quantity by a sample quantity (Dunn et al., 2016).

determinants of their success in statistics modules, as evidenced by Carmona et al. (2005), Gyuris et al. (2012), Johnson and Kuennen (2006), and Primi et al. (2016). In South Africa, Galagedera et al. (2000) and (Nolan, 2002) report similar findings.

A related challenge in the extant literature is that of teaching statistics to students from other disciplinary backgrounds, and the task this poses for statistics educators in their attempts to help students appreciate the value of learning statistics to their particular discipline, or for their future career. The focus of this research enquiry has been directed at the social sciences students. See, for example, Fisher and Brimblecombe (2014), (Hernandez, 2006) and (Deckard, 2017). In South Africa this issue is highlighted by North and Zewotir (2006) and Coetzee and Van der Merwe (2010). Students from other disciplines in general, and social sciences students in particular, have shown an aversion to studying statistics, and these attitudes impede on their learning in statistics (Wilhelm, 2007). This is corroborated by a South African study, where findings showed that "students' perceived academic and professional relevance of statistics relates to their statistics proficiency" with "interest, mathematics and statistics self-efficacy, enjoyment, worth, relevance and effort" identified as precursors to achievement on a statistics course (Ncube & Moroke, 2015, p. 231). Learning in an introductory statistics course may be perceived as being 'troublesome' to students majoring in other disciplines. This quality is also shared by introductory statistics educators, as this would entail reflection on disciplinary ways of thinking and doing, and introspection of their teaching instruction in order to decide on pedagogical best practices that would be most appropriate in imparting disciplinary knowledge to these reluctant students (Ben-Zvi & Garfield, 2004) of statistics.

In the extant literature, it is emphasised that academic understanding ought to centre on developing statistical modelers and thinkers within the disciplinary framework (Garfield et al., 2012). This would require a deep and reflective approach to learning, which involves a transformed way of thinking and entails leaving behind the prevalent mechanical (surface) approach to problem-solving in the discipline (Teran, 2007). An example that highlights this point is offered by Zewotir and North (2011). In determining the central tendency values of a data set, a student may choose to calculate any one of the following: mean, median, or mode. Each calculated value could potentially give different results, but the final answer should not be the focus of the exercise. The student should know the strength of each measure, and which measure would be the most appropriate to use in a particular context.[26]

This requirement identifies with “deep” and “surface” approaches to learning (Marton & Saljo, 1976), and may be identified by students’ intentions for understanding versus mimicry. Students adopting a deep approach to their learning in the discipline are active participants in the search for meaning, linking their existing knowledge and everyday experience, and integrating this new information into their personal understandings. By contrast, a surface learning approach involves a focus on and memorisation of parts that students believe that they may be questioned about. Although this approach may still allow some students to pass with reasonable grades, a deep approach to learning is still considered to be superior, as it is associated with higher quality student performance and student enjoyment (Ramsden, 2003).

The need for students to express their experiences and perceptions of learning and to articulate their validation of statistical concepts by apprehending what it means to be in possession of statistical knowledge lends itself to the phenomenographical approach to educational research, which represents a significant departure from the rest of the field of statistics education research.

The phenomenographical approach scrutinises “the individual meanings which students assign to a particular text, principle, idea, and so on” (Marton & Saljo, 1976, p. 4) in an attempt to understand students’ perceptions and/or conceptions of specific disciplinary topics and to identify qualitative differences in learning, and explore the sources of that variation. Investigations that explore and describe how students learn and understand statistics will enable statistics educators to develop pedagogical innovations that will enhance the student learning environment and guide students’ conceptions of statistics; consequently, perceptions of students’ own meta-learning capacity, which is, their

[26] For example, if a prospective home-owner wants to determine the average price of houses sold in her dream neighbourhood, she would gain greater insight into property value by calculating either the median or modal value of, for the sake of example, the houses sold in the neighbourhood in the past year. Calculating the mean could potentially produce an average value that might be affected by outliers, that is, the mean could result in an average value that may be skewed in the direction of the outlier.

awareness of themselves as learners, emerges as an important implication of this line of research.

The limited phenomenographic approaches that were used to draw insights from a more fine-grained look at students' conceptions of statistics and their understanding in the discipline (Gordon, 2004; Reid & Petocz, 2002) suggest that "[t]he activities and assessment that are used for learning need to place less emphasis on the acquisition of statistical techniques […] [r]ather they should emphasise the meaningfulness of what is uncovered using statistics, both in terms of the specific context and in terms of students' own lives" and that "curriculum needs to accommodate variation in student conceptions, … to explore the nature of statistical work and to […] demonstrate the applicability of students' [statistical] studies to their future work and professional roles. […] [T]he curriculum also needs to encourage [students] to be aware of their perception of their own place in the world, and to develop a critical appraisal of how statistics can help them in this endeavor[sic]" (Reid & Petocz, 2002, pp. 14, 15).

Ultimately, learning in statistics can be challenging, because it requires students to redefine and reinterpret terminology, construct new conceptions and reconstruct pre-existing misconceptions and realign their attitudes towards learning in the discipline. These largely discipline-related challenges are heightened by the immeasurable variation that exists between learners and their contexts. A full understanding of the challenges facing students of statistics needs to take into account far more than the principles and practices of the discipline. These challenges need to be identified and explained from the students' perspective.

2.3. Concluding comments

The review of the literature gives credence to the impression that students often find statistics difficult and links learning challenges to both cognitive and non-cognitive aspects of disciplinary learning. Arguably, contemplation of the difficulty of the discipline should involve research that explores and describes the inextricable, intertwining link between the cognitive and affective dimensions of learning. However, the literature reviewed above has largely been silent on this dynamic relationship between these dimensions of learning. Relatively little is known about the interactions between these dimensions of learning, particularly in South Africa, where research approaches have been almost exclusively quantitative. Some of the concerns highlighted in the international literature may be heightened (specifically, the mathematical preparedness and mathematical anxiety component to understanding in statistics), or experienced differently (for example, the implementation of and use of technology in statistics classrooms) in the South African context, where apart from a few indicative quantitative evidence, there are few published insights into the qualitative aspects of learning statistics in this country to be found.

Consideration of the literature as it pertains to students' success and progression in the discipline suggests that a solid grasp of disciplinary concepts requires a transformation in students' thinking if they are to master core concepts. This understanding of learning in the discipline resonates with the Threshold Concepts Framework (TCF) (Meyer & Land, 2003) to learning; which elaborates the idea of core disciplinary concepts as being "… 'conceptual gateways' or 'portals' that lead to a previously inaccessible, and initially perhaps 'troublesome' way of thinking about something" (Meyer & Land, 2005, p. 373). A defining feature of the threshold concepts view to learning is the emphasis it places on the affective, metacognitive, meta-learning and ontological aspects shifts that attends transformational understanding of disciplinary concepts. The threshold concepts framework forms the theoretical framing of this study, and is presented in more detail in the next chapter.

CHAPTER 3

APPLYING A THRESHOLD CONCEPTS FRAMEWORK TO LEARNING IN STATISTICS

3.1 Introduction

This chapter considers the threshold concepts theory to learning, which frames this study. The review of the major strands of research into teaching and learning statistics in higher education in Chapter 2 presented insight pertinent to the concerns about the quality of disciplinary learning that students ought to attain, and this has served as impetus for the adoption of a variety of pedagogical innovations in the introductory statistics classroom in recent years. These approaches have been broadly categorised in the literature as either having a cognitive or affective impact on student learning and is generally explained and analysed from the educator's perspective. The threshold concepts framework maintains a line of enquiry into understanding students' learning of disciplinary content, mainly from a student learning perspective but also generates debates around teaching approaches and curriculum content. The threshold concepts framework approach to teaching and learning remains largely unexplored in this country, and particularly in research into statistics education.

The threshold concepts framework was deemed relevant to the framing of this study for several reasons. Although the idea of threshold concepts emerged from research in economics education, this learning framework proved relevant with the features and accompanying transitions of disciplinary learning, as I understood them from my years of teaching an introductory statistics course. Adapting the approach to the statistics discipline, I was able to immediately engage with the approach despite my formal training in statistics and not in educational practice. The only drawback was the limited number of existing studies in statistics education that have used a threshold concepts framework orientation, on which I could draw and build. Its efficacy here lies in an acknowledgement of the effort required and emotional connotations to disciplinary learning. Additionally, threshold concepts-enquiry is distinctive with respect to its insistence that the cognitive and affective are entangled, where it queries the nature of this entanglement (Cousin, 2016). Thus, the threshold concepts framework accommodates the questions around learning in which I had developed interest. Additionally, it embraces relevant ideas from a range of learning theories, drawing on and continuously augmenting these to construct an illuminating view of the complexities of learning. Thus, this view to learning had the potential to yield insights beyond quantitative success factors or assessments and measuring instruments (predominant in the extant statistics education research literature) to generate a holistic and qualitative view of students' progression in disciplinary understanding.

Section 3.2 introduces the threshold concepts view of learning and its characteristic features. Section 3.3 provides a brief overview of the theoretical lineage of the threshold concepts framework, and notes its application to statistics education research and recent research directions. Section 3.4 outlines the main critiques of the approach. Finally, section 3.5 positions this study with regard to existing scholarship in statistics education and the threshold concepts framework, outlining key areas where it is hoped that this study may contribute to understanding students' learning in statistics.

3.2 A threshold concepts enquiry into learning

Threshold concepts theory was introduced by Meyer and Land (2003) based on their experiences in economics education. Their findings were part of a UK-wide research project entitled *Enhancing Teaching and Learning Environments in Undergraduate Courses*. Meyer and Land inspired fellow academics and initiated robust discourse, producing a whole new body of research.[27] The following presents their seminal description of a threshold concept:

> A threshold concept can be considered as akin to a portal, opening up a new and previously

[27] The Embedding Threshold Concepts (ETC) Project, implemented at several UK universities between 2004 and 2008, "established threshold concepts as an organising principle in research into undergraduate learning in economics" (Burchmore et al., 2007, p. 5). This project, hosted by Staffordshire University in collaboration with three other UK universities, ran from 2004-2008. The teaching materials are freely available for download from the project website at http://www.staffs.ac.uk/schools/business/iepr/etc/index.htm. A current online database listing threshold concepts-related research is maintained at http://www.ee.ucl.ac.uk/~mflanaga/thresholds.html. As of, October 2018, the site listed 74 completed PhD and Master's theses with the threshold concepts framework being discussed as a central theme across a variety of disciplines other than economics.

> inaccessible way of thinking about something […] a transformed way of understanding, or interpreting, or viewing something without which the learner cannot progress. […] [T]here may thus be a transformed internal view of subject matter, subject landscape, or even worldview. This transformation may be sudden or it may be protracted […] with the transition to understanding proving troublesome. Such a transformed view or landscape may represent how people "think" in a particular discipline, or how they perceive, apprehend or experience particular phenomena within that discipline (or more generally). It might, […], be argued, in a critical sense, that such transformed understanding leads to a privileged or dominant view and therefore a contestable way of understanding something (Meyer & Land, 2003, p. 1).

The threshold concepts approach to learning has established itself as an organising principle into research in undergraduate economics education (Burchmore, Irvine, & Carmichael, 2007), and has rapidly been recognised in the literature in a range of other disciplines.

The threshold concepts framework speaks to debates around issues of content as well as pedagogy in the international scholarship, offering a way to conceptualise and describe learning through its interrogation of the difficulties associated with learning new content. The framework offers some broad pedagogical principles and curriculum design considerations. It does not offer itself as a 'solution' to learning difficulties, but rather as a lens through which awareness of such may be illuminated. The threshold concepts theory to learning requires the educator to delve deeply into her discipline with the aim of determining the best way of teaching and learning it (Cousin, 2010). In this way, the theory has initiated discussions around how threshold concepts, the "jewels" in the discipline (Land, Cousin, Meyer, & Davies, 2006), come to be identified and prioritised in the first instance.

3.2.1 Identifying and characterising threshold concepts

Every discipline has a limited number of distinctive concepts that disciplinary experts identify as being threshold concepts. An understanding of these fundamental concepts is of paramount importance if a student is to advance in her learning and understanding of the discipline. Thus, a threshold concept maybe described as being a keystone of disciplinary wisdom that the student must master before the student can delve deeper into the disciplinary ways of thinking and doing.

Threshold concepts are likely to have several characteristics. The essence of a threshold concept is its transformative power on the learner. It brings on, in varying degrees, epistemic and ontological shifts in the learner (Meyer, Land, & Baillie, 2010). The evolution and development of the threshold concepts framework over the years (Land, Cousin, Meyer, et al., 2005; Meyer & Land, 2003, 2005) has characterised threshold concepts, in any discipline, as likely to have several characteristics, with a focus on inter-individual variation in recent years – students' individual encounters with a given threshold concept will vary in the degree to which they experience each feature below (Flanagan, 2018; Meyer & Land, 2006; Meyer, Land, & Davies, 2008):

- **Liminality –** internalisation of a threshold concept being likened to a journey or "rite of passage" within and beyond a liminal space.
- **Transformation –** a previously inaccessible way of thinking about something occurs; an epistemic shift.
- **Integration –** in the sense that previously occluded relationships between former disparately perceived aspects of the subject landscape are revealed. This revelation may be protracted or sudden in the sense of something 'clicking together'.
- **Reconstitution –** a shift in learner subjectivity, a transfiguration of self, of identity; an ontological shift.
- **Irreversibility –** once understood, the concept cannot become 'not-understood'.
- **Boundedness –** each concept does not generally explain the whole of the discipline, only a specific sub-domain, or related aspects.
- **Troublesomeness –** challenging, difficult to come to terms with, counter-intuitive, or requiring a suspension of disbelief.
- **Discourse –** crossing of a threshold will incorporate an enhanced and extended use of natural, symbolic or artificial language in a manner that characterises particular disciplinary discourses; how, for example, biologists, economists, historians,

lawyers or sociologists think (Baillie, Bowden, & Meyer, 2012, p. 229).

This set of likely characteristics is intended to highlight the essential characteristics of a threshold concept as experienced by individual students to varying degrees, and is not meant to be interpreted as a definitional checklist. However, in recent work, the “superordinate and non-negotiable” characteristic of a threshold concept is considered to be its transformational capacity (Land, 2016, p. 16).

3.2.2 Essential features of learning in the Threshold Concepts Framework

While threshold concepts may be defined within its disciplinary context, the approach, itself, transcends disciplines in its acknowledgement of the “universality of student experiences of difficulty in encounters with content in any – and all – of their respective fields” (Schwartzman, 2010, p. 22). Essential features of learning within a threshold concepts orientation (as informed by Schwartzman’s theoretical framing (2010)) are depicted in the schematic below and explained in the subsequent paragraphs.

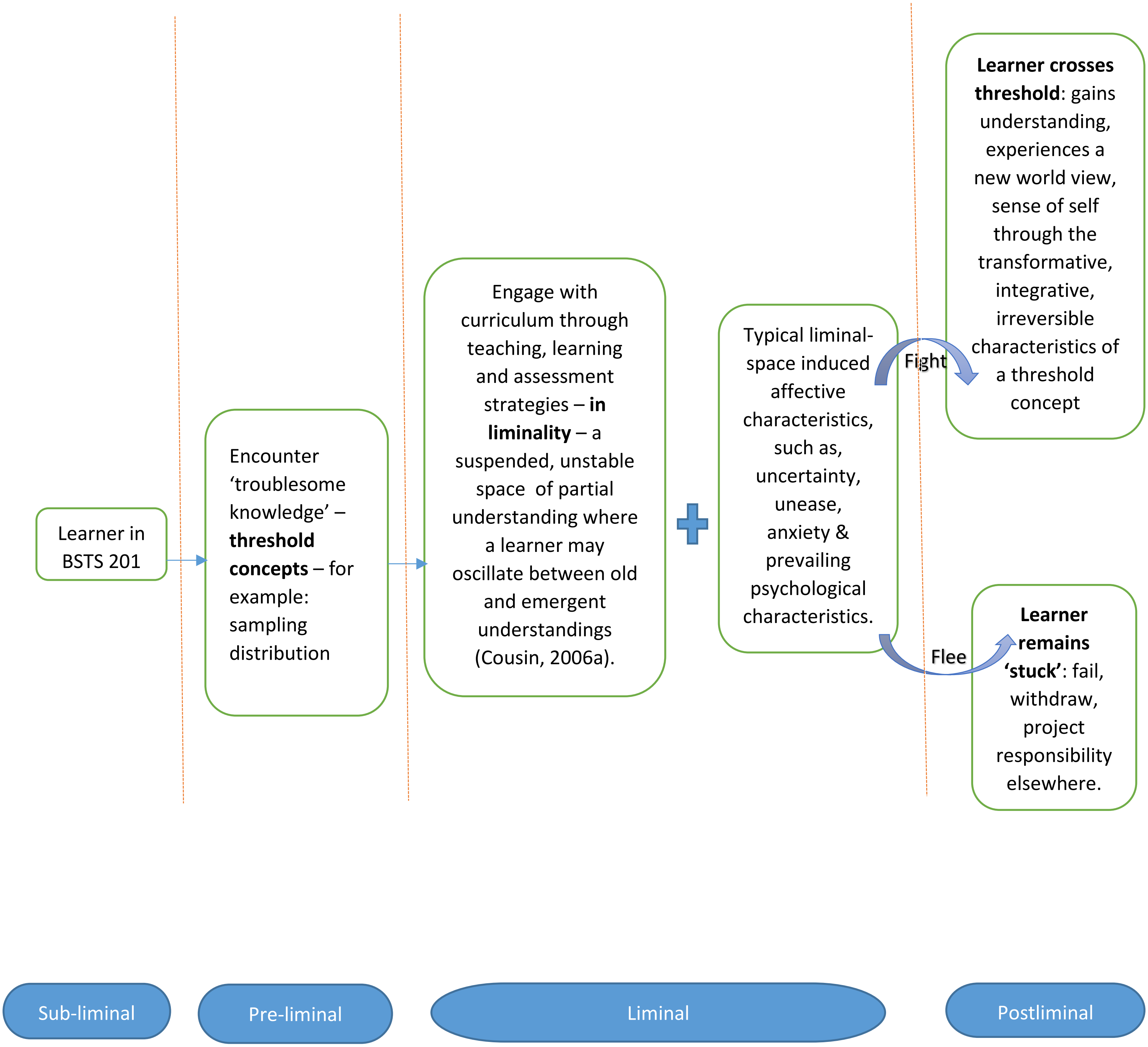

Figure 2. A threshold concepts view of learning

(Based on descriptions of learning in the Threshold Concepts Framework taken from Schwartzman (2010), Land, Meyer, and Baillie (2010))

Acquiring a threshold concept has been described as being akin to stepping through the portal to a “previously inaccessible way of thinking” (Meyer & Land, 2003, p. 1). However, this is not always a straightforward process for students. Some threshold concepts prove to be quite the challenge for students due to a variety of reasons. This may be attributable to having to let go of previously held beliefs and accepting new information, which constitutes a disconcerting space for students to be in, since it may require an integration of ideas and a transformation of their own prevailing understanding (Land, Cousin, & Meyer, 2005).

Learning is impacted by both affective and cognitive aspects, and the assimilation of new, troublesome knowledge can unsettle a learner (Rattray, 2016). This transition in the student’s understanding, that is, from a less sophisticated awareness to a fuller appreciation of a concept, takes time, and during this transformative phase, the student is said to be in a liminal space. In this space, learners may oscillate between old and new understandings and may get ‘stuck’(Meyer & Land, 2005).

Variations exist between learners’ experiences of being in the liminal state. Not all learners cross the threshold to obtain a deeper understanding of the subject, whereas others may struggle for varying periods of length before finally crossing the threshold and reaching the higher ground of deeper understanding of the concept. Variations between learners are not confined to the liminal space but are evident in all stages of the process, namely, the sub-liminal (tacit understanding developed in the absence of formal knowledge of the concept), pre-liminal (initial perceptions of the threshold concept), liminal (entering it, being in it and passing through (or not) it) and post-liminal (entering into new conceptual space) (Heading & Loughlin, 2017; Meyer et al., 2008; Nicola-Richmond, Pepin, Larkin, & Taylor, 2018).

Expounding further on the cognitive-affective dynamics of students’ learning in the liminal space, Cousin (2006a, p. 4) states:

> …it is important to temper the implicit suggestion in the idea of a threshold

> concept that the difficulty of its mastery inheres in the concept itself […], we need to be aware that this difficulty cannot be abstracted from the learner or the social context […], the idea of liminal spaces provides a useful metaphor to aid our understanding of the conceptual transformations students undergo, and the difficulties or anxieties that attend these transformations.

Ultimately, learning is a transformative process that goes beyond cognitive and affective shifts. Traversing the liminal space does not only bring about a conceptual or cognitive change, but also entails an ontological shift, or altered worldview, and the students' awareness of their meta-learning capacity. That is, their awareness of and control over themselves as learners (Biggs, 1985), is significant to the students' successful passage through the liminal space (Latreille, Meyer, & Ward, 2009). Thus, the liminal space may be conceptualised as a tunnel entering a dark and foreboding place, where the final outcome is uncertain (Land, Rattray, & Vivian, 2014).

These ontological shifts brought about by the threshold transformations are associated with both cognitive and affective changes in an individual, and it is vital that an educator considers the extent to which liminality might be experienced as both a cognitive and affective state that is more easily navigated by some students than others. In recent work, Rattray (2016) advances the idea that the four factors of Psychological Capital[28], namely self-efficacy, optimism, hope and resilience, might explain why some learners are able to pass through the liminal tunnel and acquire new conceptual framework, and others, despite having the intellectual capacity, are unable to make the transition. It is proposed that a learner, who believes that they are capable of understanding new ideas, who makes positive attributions in relation to their potential for success, who can monitor and re-align goals and pathways to attaining these goals, and who does not give up in spite of the difficulties they encounter with the new knowledge, is the type of learner that would successfully navigate the liminal space (Rattray, 2016, p. 73).

The importance and need for active student engagement with the conceptual material is noted above. Students should not only have a passive understanding of their discipline, but ought to be

[28] The concept Psychological Capital (PsyCap), pioneered by Fred Luthans (Luthans, 2002) , suggests growth in organisations should focus on workers' psychological rather than educational development. PsyCap has four pillars – Hope, Efficacy, Resilience and Optimism (HERO) – and has been linked to individuals' job and as well as life satisfaction.

able to engage with, and be critical of disciplinary concepts. In order for students to achieve critical engagement with disciplinary concepts Land, Cousin, and Meyer (2005) propose that: (i) educators be in tune with their sixth sense in order to determine students' current understanding of concepts and to detect signs of troublesomeness; (ii) consider the ordering of concepts taught in the discipline so that it is easily assimilated, and its integrative nature is discerned by students; (ii) teachers are encouraged to call upon their sixth sense, so to speak, that pick-up on students' current understanding that will ultimately impact on how future understanding is assimilated; and (iii) in the post-liminal state instructors are encouraged that on the excursive journey of learning, there are moments of recursion or reflection, where students are afforded a moment of pause to appreciate the interrelatedness of threshold concepts.

Discussion around the integration of threshold concepts with student learning and the curriculum abounds in the literature (Barradell & Kennedy-Jones, 2013; Cousin, 2007; Land, Cousin, & Meyer, 2005; Meyer & Land, 2006). The impact that research into threshold concepts has had on teaching and learning in the disciplines is illustrated in some of the curriculum change that have been advocated in the literature. Cousin (2007) refers to a "less is more" approach to curriculum design. The justification for this is that since, by definition, threshold concepts refers to the key fundamentals of a discipline, streamlining the curriculum as such, means providing better value for instructors and students as more time and resources are devoted to the learning of threshold concepts (Khan, 2014). Thus, threshold concepts framework holds with a student-focused approach to teaching. It requires educators to reflect on their discipline, and to ask four crucial questions: What should be taught? Why should it be taught? And, how and when should it be taught? (Barradell & Kennedy-Jones, 2013).

Educators are encouraged to identify and treat key areas of mastery in a curriculum as "jewels in the curriculum", to cultivate a "third ear" for listening out for persistent uncertainties and misunderstandings, to design activities to determine the students' position in the learning space - whilst demonstrating tolerance and the ability to persevere with students as they journey through the liminal space, and to take cognisance that mastery of a threshold concept is a journey of learning that often entails oscillation (recursion) across conceptual terrain (Cousin, 2006a, p. 5).

Onus is placed on the teacher to initiate curriculum inquiry to address the difficulties of the threshold concept in order to guide the learner through the liminal space. Thus, threshold concepts research offers a form of transactional inquiry, bringing together academics, students and educationalists to work together by delving deeper into their own discipline for the purpose of formulating the best pedagogical practice, and to focus on the difficulties of the subject, rather than on general education theories (Cousin, 2010).

3.3 Theoretical lineage and applications of the Threshold Concepts Framework

The Threshold Concepts Framework has a social constructivist orientation, placing learners' knowledge construction in a social context (Meyer & Timmermans, 2016). The framework prompts thinking and discussion about the mastery of disciplinary threshold concepts, whilst insisting that learning is as much about identity formation and disturbance as it is about cognition; this all the while weaving together insights from a range of learning theories and disciplines (Cousin, 2007; Rattray, 2014).

3.3.1 Theoretical lineage and leanings

In describing threshold concepts as the bedrock to attaining disciplinary mastery, the threshold concepts analytic framework to learning builds on the idea of learning for mastery initially proposed by Bloom (1968) – that is, to be deemed proficient in key disciplinary concepts, students need to display both the surface order levels of cognition exhibited by memorisation, understanding and application, as well as deep cognitive levels of analysis, evaluation, and creativity. Thus, the threshold concepts approach suggests that the student on the edge of understanding takes a surface approach to learning, whereas a student in the throes of acquiring mastery of a concept is likely to be taking a deep approach, following in the phenomenographic research tradition (Bhola & Parchoma, 2016; Marton & Saljo, 1976).

The transformative nature of threshold concepts implies that once a student has grasped the concept, her relation to the subject changes, representing a moment of deep learning, which in turn encourages even greater depth of learning. On the other hand, lack of mastery invites mimicry, which can be understood as a form of surface learning (Cousin, 2007). This view of a transformative learning journey also resonates with other learning perspectives, including Vosniadou's conceptual change process (2008), and Perry's views on changing epistemological beliefs (1970). These views parallels Talanquer's proposal of the terms conceptual threshold and crossing a conceptual threshold (2015). The former refers to the cognitive aspects that support the construction of a threshold concept, while the latter requires learners to "dismantle, set aside, coalesce, or separate existing assumptions, concepts, and ideas while building new ones", thus, portraying threshold concepts as complex cognitive constructs comprised of conceptual, epistemological, and ontological elements (Talanquer, 2015, p. 4).

Threshold concepts interrogation of sources of disciplinary difficulty links to Perkins's ideas of "troublesome knowledge" (2006) and, in terms of the threshold concepts framework's acknowledgement that letting go of an old world view and embracing new ideas is also troubling, the threshold concepts approach links to Dewey's observation that it is troublesome work to alter old beliefs (Dewey, 1986; Land & Rattray, 2017). In its focus on the liminal space as an unstable space in which the learner oscillates between old and emergent ideas, Meyer and Land (2003) borrow from anthropologist Turner's work on rites of passage (1969, cited in Cousin, 2007). Additionally, the metaphor of a liminal space has been likened to Vygotsky's (1978a) zone of proximal development (Cousin, 2008).

The role of discipline-specific orientation and context in the threshold concepts approach to learning, where learning includes participation processes of enculturation, links well with social learning theories and communities of practice (Cousin, 2007). Thus, threshold concepts can be said to echo aspects of "acquisition" and "participation" metaphors of learning (Sfard, 2009, cited in Goebel, 2017).

3.3.2 Scope and recent trends

Over the last decade, the threshold concepts analytic framework has "proved influential around the world as a powerful means of exploring and discussing the key points of transformation that students experience in their higher education courses and the 'troublesome knowledge' that these often present" (Perkins, 2010 , par 1). Early threshold concepts studies in diverse disciplines focused on identifying, interrogating and acquiring disciplinary threshold concepts (Flanagan, 2018). These early research activities have expanded and evolved to an extent that the latest volume of research into threshold concepts, Threshold Concepts in Practice (Land et al., 2016), the fourth volume in a tetralogy on threshold concepts discussing students experiences and curriculum interventions in a range of disciplines and professional practices and contexts, includes the doctoral research process (Keefer, 2013; Maistry, 2017).

A threshold concepts framework to teaching and learning has not been widely applied in statistics education research (Wills, 2017), where a majority of the statistical education literature on threshold concepts tends to focus on the identification of statistical threshold concepts (Bulmer et al., 2007; Dunne et al., 2003; Khan, 2014); with the list of statistical topics considered to be threshold concepts being: confidence intervals, randomness or variation, sampling distribution, the Central Limit Theorem, linear regression, Bayes' theorem, interval estimation, hypothesis testing, Analysis of Variance (ANOVA), the understanding of statistics and how it relates to understanding scientific articles, and identifying which tests to use for various data sets (Bulmer et al., 2007; Dunne et al., 2003; Norton, 2015).

Recent research suggests that there are many troublesome concepts in statistics that are not threshold, such as deriving estimators, and that there are three potential areas in statistics where threshold concepts may exist: (i) the nature of statistical inference and uncertainty; (ii) probability; and (iii) descriptive statistics (Wills, 2017). In statistics education research studies, application of the threshold concepts framework as an analytical tool to understanding students learning resulted in the promotion and adoption of various pedagogical and curricular reforms. For example, the use of online discussion boards generally enhanced medical statistics students learning of threshold concepts (MacDougall, 2010). Also advocated for was clear explanations and concise instructions on how to solve statistical problems, with a focus on the basics and opportunities to practice these (Bulmer et al., 2007). The general consensus was that the statistics curriculum is enriched by using visual, narrative and mathematical approaches with detailed examples, quizzes and exercises to assist learning by application (Thompson, 2008). In South Africa, the threshold concepts approach to learning remains largely unexplored in statistics higher education research and I was only able to find one research paper based on the identification of statistical threshold concepts by Dunne et al. (2003).

Recent trends in the application of threshold concepts has seen them being applied beyond the narrow confines of disciplinary conceptual focus to the liminal-esque space that is student-hood (Berg, Erichsen, & Hokstad, 2016). The transition into student hood, draws on one's "emotional capital" while attempting to master perceived "rules of engagement", and this may be especially difficult for non-traditional students, where context influences conceptual mastery, as is the case in South Africa (Goebel, 2017). Providing a supportive learning environment for students is critical (Cousin, 2014), and this view aligns with work relating to epistemological access in South Africa.

Although liminality (with its cognitive and affective connotations) is central to the threshold concepts view of learning, the focus has not generally been placed on students' experiences of learning threshold concepts within the liminal space and "quite what supports or facilitates this passage has not been clear" (Rattray, 2016, p. 71). Thus, an emergent focal area of research within the threshold concepts framework is a consideration of the psychological and affective aspects of student learning, in an attempt to understand how students cope with the demands of the journey through the liminal space (Land & Rattray, 2017; Rattray, 2014, 2016).

3.4 Critique of the Threshold Concepts Framework

As the threshold concepts approach garners support and endorsement in the education research literature, issues and concerns about the approach have been raised with revisions being offered (Tight, 2014).

3.4.1 Definitions, agent-relative properties and methodological concerns

Issues pertaining to the definition of threshold concepts arise from the claim that Meyer and Land have defined threshold concepts in the weakest possible terms (O'Donnell, 2010; Rowbottom, 2007). In their initial characterisation of a threshold concept, Meyer and Land attached qualifiers to their definition of a threshold concept as: "**likely to be**":

- transformative
- **probably** irreversible
- integrative

- **possibly often** (though not necessarily always) bounded
- **potentially** (though not necessarily) troublesome (Meyer & Land, 2006, pp. 7, 8)

Critics argue that the above qualifiers attached to these five features, commonly understood to be the definitive features of a threshold concept, seems to be a hedge against dismissing putative threshold concepts, as it is not clear how many or which features are required to designate a threshold concept (Wilkinson, 2014). It has also been highlighted that that the characteristics of a threshold concept may be experienced to varying degrees at various stages of the student's learning journey (O'Donnell, 2010), and the question raised as to how many students should share the specified experiences for a concept to be considered a threshold concept (O'Donnell, 2010; Rowbottom, 2007). Thus "a common interpretation of what a threshold concept is – and what makes it a threshold concept and for whom – needs to be established" (Barradell, 2013, p. 267).

Another criticism holds the view that threshold concepts have agent-relative properties, in terms of: (i) experiencing a threshold concept as being troublesome and/or transformative; and (ii) an instructor's opinion of what is worth knowing about a concept will affect the instructor's method of determining whether a student has mastered a concept (O'Donnell, 2010; Rowbottom, 2007; Wilkinson, 2014). It has been argued that the threshold concepts hypothesis does not take cognisance of the fact that the degree to which students experience the transformative/troublesome aspects of a threshold concept is an idiosyncratic experience. By not doing so, it denies the uniqueness of individual student's learning journeys (Wilkinson, 2014). Also, different instructors will have different views on how and what to assess about a threshold concept in order to determine whether a student has reached the post-liminal stage of understanding (Rowbottom, 2007).

In a related concern, the charge of hegemony has been levelled against threshold concepts enquiry (O'Donnell, 2010; Wilkinson, 2014). It is argued that the dominant school of thought within a discipline has the power to determine and define the threshold concepts for the discipline, and that the discipline will always be imbued with the educator's epistemological stance, which inducts students into a school of thought, as much as into the discipline (Cousin, 2008). A concern in the statistics discipline, with respect to the mathematisation of statistics (see Chapter 2) is echoed by Mearman (2013), with regard to threshold concepts in economics. Mearman (2013) argues that while threshold concepts are dynamic, and build intellectual capacity, if they are overly specific, they might narrow students' perspectives by locking them into particular modes of thought. In his view, excessive mathematisation in economics presents this danger.

Furthermore, it is asserted that the threshold concepts framework is akin to an organisation of a craft guild, where students are enculturated within the discipline by absorption of its thinking and practice. This is ostensibly a defensible model for training, but is inappropriate in education, as the dominant forces within a discipline could potentially act to protect the knowledge and practice of their craft, while resisting critique, innovation and change unless it comes from within their ranks (O'Donnell, 2010).

Threshold concepts theory has also been criticized for its purported reinforcing of stratification, and its resultant negative impact on inter-disciplinarity (O'Donnell, 2010). This raises the concern that this compartmentalisation approach to disciplinary learning and thinking stymies the development of critical thinking and innovation capable of straddling multiple disciplines.

In response to this line of criticism, in assuming that validity of the threshold concepts framework proceeds from its defining features, Townsend, Lu, Hofer, and Brunetti (2015) advise that one should interpret the hedging language used by Meyer and Land in their articulation of the criteria of threshold concepts not as exacting criteria but rather as a way of Meyer and Land saying: "just because a proposed threshold concept does not meet *x* criterion, doesn't necessarily mean it's not a threshold concept" (Townsend et al., 2015, para. 6).

In subsequent refinements to the original definition, (for example, Meyer et al., 2008) it has been emphasised that the likely features of threshold concepts would be experienced by students to varying degrees, and that these student experiences will be informed by a range of personal and contextual reasons. Land has identified epistemological and ontological transformations as the two non-negotiable features of threshold concepts (Quinlan et al., 2013), where, once a student has grasped the concepts, they will 'see' the world differently, and “their way of knowing (epistemology) and related ways of being in the world (ontologically) will change” (Quinlan et al., 2013, p. 2). Most critically, the threshold concepts framework offers a particular view on learning, and observing the degree to which an individual (or group) experiences the defining features of a threshold concept is part of the ongoing research.

Threshold concepts, as an emerging theory, actively engages with the aspects of variation experienced amongst students in the learning journey (Meyer et al., 2008), and acts as a catalyst in engaging educators in pedagogical and curriculum debates (Townsend et al., 2015). In doing so, “it forces us to consider the implications of asking students to look through our disciplinary lens” (Townsend et al., 2015 para. 17), thus refuting the claim of hegemony.

It is ironic that the threshold concepts view to learning, which has its origins in economics education research, and which has been adopted and adapted and so widely applied across a fecundity of disciplines, is itself being accused of stifling inter-disciplinary work. In fact, instances exist where threshold concepts framework has served as a catalytic agent, inspiring and initiating inter-disciplinarity research.[29] It may be argued that O’Donnell’s suggestion that “rather than training people to enter specialized [sic] communities of *x*’s, *y*’s and *z*’s, [threshold concepts orientation should rather] educate them to become members of a *broad community of rational, critical and creative thinkers* capable of understanding, improving and connecting disciplines” (2010, p. 9), has the potential to inspire further threshold concepts-related research into teachers’ epistemological stances towards teaching and learning in their respective disciplines. These findings may, in turn, impact on disciplinary pedagogical practices and curriculum design. All of this may have the desired effect of improving and enhancing disciplinary learning, and ultimately, even impact students’ personal lives, in a positive manner by enabling them to be a part of a “*broad community of rational, critical and creative thinkers”* (O'Donnell, 2010, p. 9).

[29] As of October, 2018 there were 61 articles available at https://www.ee.ucl.ac.uk/~mflanaga/thresholdsI.html#interd that were based on inter-disciplinarity and/or multi-disciplinarity studies inspired by the threshold concepts framework.

Methodological concerns with regards to the threshold concepts framework relates to a perceived lack of rigour, consensus on the methodology, and identification of disciplinary thresholds, and diversity in the methodological approaches used to date (Barradell, 2013; Quinlan et al., 2013). Although “conceptual and empirical work on threshold concepts has since developed and matured. […], the problem of identification [of threshold concepts] is beset with conceptual challenges that remain unresolved for researchers” (Barradell & Peseta, 2016, p. 62).

The relative scarcity of undergraduate student voices in the research findings, despite the centrality of understanding student learning in the threshold concepts framework and a ‘transactional curriculum’ orientation, has also been identified (Felton, 2016, as cited in Goebel, 2017).
Also, it has been proposed that the constituents in Cousin’s (2010) ‘transactional curriculum’ should include practicing professionals in the discussions around curriculum reform and renewal in the discipline “if the context and authenticity of practice is to be taken seriously for enhancing student learning” (Barradell & Peseta, 2016, p. 262).

3.4.2 Theoretical standing of Threshold Concepts Framework

Questions related to the nature, originality and usefulness of the threshold concepts framework has been raised – questioning whether the framework is a theory or a concept (Walker, 2013), whether it is a mere re-formulation of older ideas (Cousin, 2008), and potential links with complementary theories (Schwartzman, 2010), and whether a single framework is able to accommodate such a variety of disciplinary constructs (Tight, 2014).

The three major implications of the threshold concepts theory to learning (as summarised by Peter et al. (2014)) lies in its effectiveness in “re-envision[ing] teaching and learning at the tertiary level” by providing opportunities for educators to explore important disciplinary ideas and ways to thinking and practicing (WTP) within the discipline, in its highlighting of the unsettled understanding that students possess within the liminal space and the acknowledgement of the variation that exists between learners in their journeys towards understanding, and in its

cognisance of the interactions "between the epistemological (what is learnt and how) and ontological (changes in learner's identity) aspects of learning" (Peter et al., 2014, p. 3).
In her analysis of threshold concepts framework as a case of theory development in higher education research, Timmermans (2010, p. 16), concludes that:

> The value of an approach that acknowledges the existence and influence of the multiple layers of interacting (epistemological) contexts in which threshold concepts are embedded allows us […] to make them 'object'. Consequently, rather than being impervious to their influence, we may hold them to light, examine them, and question their influence in shaping our current and future ways of knowing and being.

In summary, despite the criticism levelled at threshold concepts framework, its fundamental principles and perspective of students' learning has not been repudiated.

3.5 Synthesis: Learning in statistics, threshold concepts, and the contributions of this study

Theoretical work in statistics has deepened our understanding of what learning in the discipline requires of a student. Studies conducted have used quantitative methods, in the main, to generate an extensive body of evidence of the methods that broadly support learning in statistics. Details gleaned from this body of scholarship matches the central idea of a liminal transition in learning and has, to varying degrees, highlighted the importance of pre-conceptions, conceptual change, troublesomeness, identity aspects and meta-learning capacity in disciplinary learning as aspects of learning that are emphasised in a Threshold Concepts Framework orientation.

Reflecting on the extant statistics education literature, guidelines informing best pedagogical practice in the discipline entailed the use of real-world application incorporating the use of real data, increased opportunities engendering active learning through cooperative learning exercises and the use of technology to foster deep approaches to learning. The threshold concepts framework approach agrees with these disciplinary pedagogical guidelines to learning in statistics (Bulmer et al., 2007; MacDougall, 2010). In South Africa, statistics education research has focused predominantly on quantitative studies of performance determinants and (to a much lesser extent) on teaching innovations (de Wet, 1998; Galagedera, 1998; Galagedera et al., 2000). However, becoming proficient in disciplinary ways of thinking and doing is a dynamic process, requiring the complete enculturation of the student into the discipline – this involves interaction of the student with the nature of the discipline, teaching approaches, course content and broader contextual features. Given the idiosyncrasies of individual learner journeys and the notoriety of statistics as being difficult amongst students, learners' emotions are bound to play a significant role in their learning journey. The significant absence of extant studies in the statistics education literature focused on an entanglement of student learning and self-identity is lamentable.

In contrast to this gross neglect in statistics education literature, the Threshold Concepts Framework approach offers an encapsulation of the two strands of the 'DNA' that characterises statistical learning, viz. the cognitive and the affective. The threshold concepts framework to learning offers a holistic view of learning initially identifying sources of difficulty, then interrogating cognitive and affective elements to assist students in crossing the liminal space, and finally describing the epistemological and ontological metamorphosis of the learner. While this learning perspective is well-established in research into learning internationally, it has not been deeply explored in statistics as a discipline. In South Africa there appears to have only been a study conducted by Dunne et al. (2003) on identifying threshold concepts in statistics.

In this study, I set out to explore how (and why) statistics students learn in a threshold concepts-enriched tutorial programme. In using a threshold concepts orientation here, I hoped to address both conceptual and contextual gaps in the extant statistics literature. The study focuses on processes and experiences of students' learning, and indicates possible ways to support and facilitate learning transitions and sheds further light on the less understood, liminal aspects of statistics disciplinary learning in terms of threshold concepts theory.

Reflecting on Chapter 2, the threshold concepts view to learning speaks to current debates in statistics higher education research arising from concerns with the quality of learning and calls for more student-centeredness to foster deep approaches and active learning. Threshold concepts orientation also reconciles the apparent poles of cognitive and affective aspects of learning by highlighting their united impact on student's learning within the liminal space (Rattray, 2014, 2016).

Attempts at augmentation of the threshold concepts framework includes a proposed framework for the design of university curricula in the form of the Threshold Capability Integrated Theoretical Framework (TCITF) (Baillie et al., 2012). The TCITF is an amalgamation of Threshold Concepts Framework and Capability Theory[30] (Bowden, 2004). Capability Theory draws upon phenomenography and variation theory,[31] and is concerned with the development of knowledge capability (Baillie et al., 2012). The thinking behind linking the two approaches is the dynamic progression from understanding threshold concepts to developing threshold capabilities, the ability to use threshold concepts in context, to knowledge capability (for example, enabling a student to think and practice as a statistician). For example, in statistics, understanding confidence intervals is considered to be a threshold concept (Khan, 2014), but being able to discern the implications of altering the sample size, say, on the confidence interval, requires the student to have threshold capabilities.

The TCITF offers a new perspective on disciplinary learning, wherein the emphasis is placed on preparing and equipping students to apply their understanding to new, previously unseen situations, thus enabling students to achieve a longer-term professional goal of gaining knowledge capability (Land, 2014). The TCITF contributions to knowledge acquisition is achieved through: (i) the capability to handle previously unseen situations, where a common requirement in professional life is developed through multiple experiences of dealing with new situations, and (ii) discernment of key aspects is assisted by experiencing variation, i.e. experiencing a range of situations in which the key aspects vary (Bowden and Marten, as cited in Baillie et al., 2012).

The essential elements of the learning process within a TCITF orientation to the statistics discipline is represented in the schematic below and explained in the subsequent paragraph.

[30] Capabilities Theory or Capabilities Approach was introduced as an approach in welfare economics (Sen, 1979). The core characteristic of this approach is a focus on what people are effectively able to do and be – in other words, their capabilities (Robeyns, 2003).

[31] The Variation Theory of Learning (Marton, 2015; Marton & Tsui, 2004) arises out of the phenomenographic research approach. Through pedagogical designs, students are introduced to variations in the illustrations of the critical aspects of a disciplinary concept, skill or practice. This variation is seen as an expansion in awareness of the different aspects of disciplinary concepts, and of the relationships between those aspects (Akerlind, 2015).

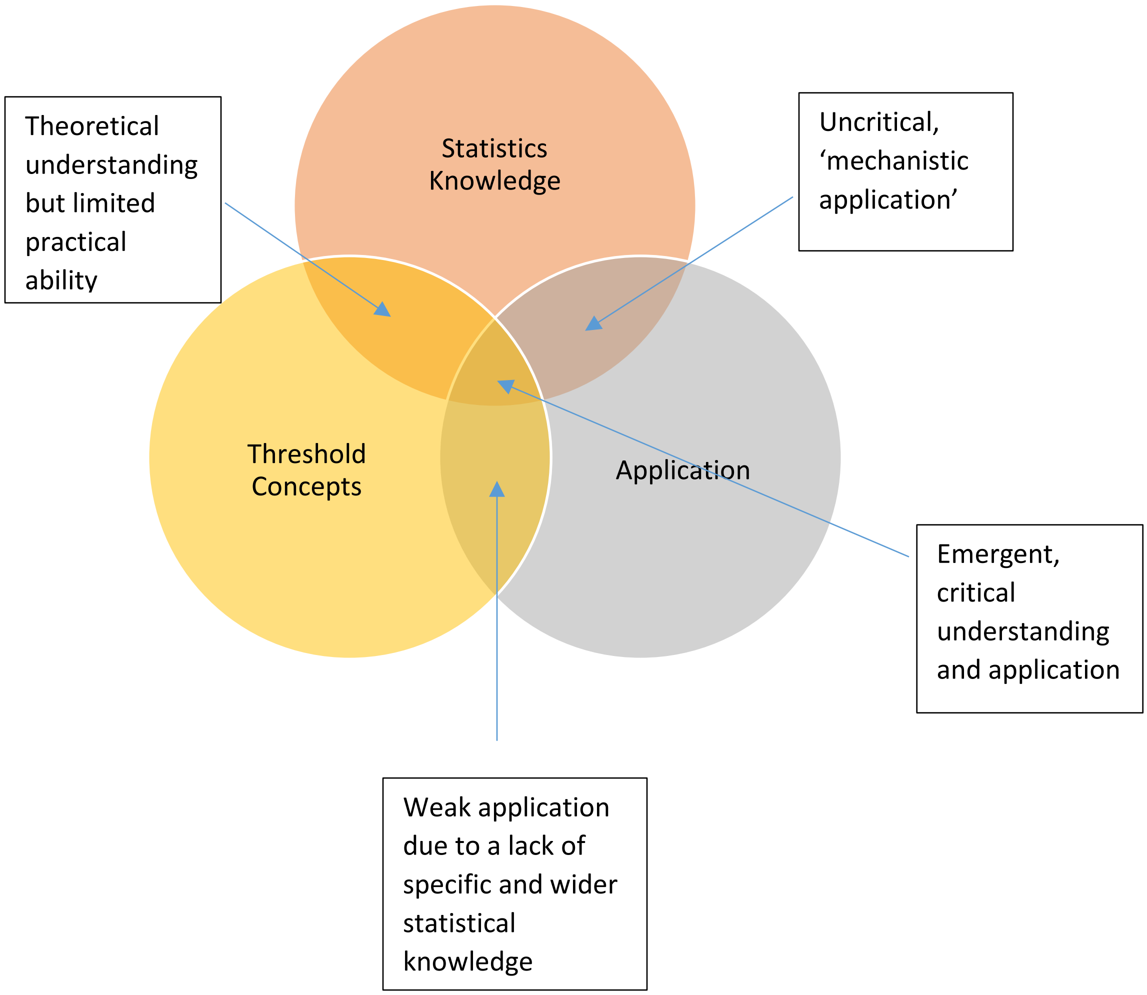

Figure 3. A TCITF view of learning

(Based on an amalgamation of the descriptions of a TCITF and Threhold Concepts Framework view of learning taken from Baillie et al. (2012); HEReflections (2015))

This model positions disciplinary knowledge as the over-arching framework for a curriculum. Threshold concepts are the building blocks that support disciplinary knowledge (Meyer et al., 2010). Use of threshold concepts allows students to move deeper within their discipline to either specialise within coherent, particular spheres in their discipline or outwards towards a wider field of study. If disciplinary knowledge and threshold concepts are engaged with alone, then there is a deficit in the applied/practical use of the emerging learning. It is at the intersection of the three dimensions of disciplinary knowledge, concepts, and application, where we strive for learners to be. The journey to this level is a personal one for each student with different contexts, interests and applications driving learning (HEReflections, 2015).

The threshold concepts framework has been characterised as a “transactional curriculum inquiry”, in the sense that it is neither teacher-centred nor student-centred, but rather, a collaboration between subject specialists, researchers and learners (Cousin, 2008). Thus, in a threshold concepts view to learning, the pedagogical innovations and curriculum re-designs carried out by disciplinary teachers are inspired and motivated by their learners. In an attempt to bring this vast and expanding body of research knowledge to the threshold concepts community of scholars, the Integrated Threshold Concept Knowledge (ITCK) has been proposed (Meyer & Timmermans, 2016). The ITCK attempts to translate threshold concepts findings in a theoretically sound and actionable form in an unifying approach extending across disciplines, while “remaining non-prescriptive and adaptive to the various contexts in which threshold concept research and practice occur” (Meyer & Timmermans, 2016, p. 25). ITCK is described as being “socio-empirically constructed knowledge” constituted by different ‘types of knowledge’ (Meyer & Timmermans, 2016, p. 25), arising from: (i) the critical features of threshold concepts; (ii) learner variations with respect to the cognitive, affective and ontological aspects of experiencing threshold concepts in the liminal state; and (iii) pedagogical responses to engendering threshold concept crossing.

It is within these two broadly specified frameworks, that of the TCITF and ITCK, that the findings of this study fit. Firstly, the exploration of how (and why) statistics students learn in a threshold concepts-enriched tutorial programme in this study context will shed light on the following critical curriculum design features of the TCITF:

- The kinds of learning experiences and combinations thereof, which would best assist the learner to develop interim threshold capabilities, and ultimately build on, to develop the capability to handle an unknown future after graduation?
- How can the learning environment be best arranged to provide access to those optimal capability development experiences?
- How can the differing needs of individual students be catered for?
- What, specifically, is the role of teachers in supporting such learning by students?

(Baillie et al., 2012, p. 237).

Secondly, by foregrounding the students' voices to answer the research questions, this study's approach is also quite rare in statistics education research, which is almost exclusively from the perspective of the educator. Within threshold concepts scholarship, questions of student learning are central to the framework, and using student voice-data is increasingly recognised as an effective way of exploring cognitive, affective, and identity-related dimensions of learning. My research approach aims to elicit, deep, rich qualitative descriptions of the learning process in the participants' voices, and was thus appropriate for capturing the details of cognitive, affective or ontological aspects of students' encounters with learning statistics in threshold concepts-enriched tutorials and navigation of the liminal space of learning. The considerations made possible by such a close reading of statistics students' learning may suggest ways in which the learning process may be supported or facilitated, which ultimately have implications for pedagogic and curricular responses such as those enumerated above in the ITCK.

This work also addresses a clear contextual gap in South Africa, where research in statistics higher education encompasses a narrower range of approaches and issues than those in evidence in the international literature, where little qualitative or conceptual enquiry has been undertaken, and an understanding of how students learn in statistics in South African higher education remains superficial. Furthermore, the setting of the case study within an introductory statistics course context could potentially generate possible insights into learners' progress in crossing inter-disciplinary thresholds.

CHAPTER 4

RESEARCH METHODOLOGY: THE THRESHOLD CONCEPTS–ENRICHED TUTORIAL PROGRAMME AND INTERACTIVE QUALITATIVE ANALYSIS

4.1 Introduction

The previous two chapters reviewed the extant literature on teaching and learning in statistics and discussed the theory of threshold concepts that frames this study. This chapter is a description of the research approach that I followed in my quest to understand how and why students' learn statistics in the way that the do. Sections 4.2 and 4.3 consider the relevance of a qualitative, interpretive approach and a case study research design and the reasons for using this approach in this study. In section 4.3, I also discuss the research site and the selection process for participants in the study. Section 4.4 explains the threshold concepts-enriched tutorial programme in which the students participated. In section 4.5, I describe the methodology of Interactive Qualitative Analysis (IQA) (Northcutt & McCoy, 2004) used to generate and analyse data. Issues of rigour and ethics are considered in sections 4.6 and 4.7, respectively. I offer some methodological musings in section 4.8 and concluding comments in section 4.9.

4.2 Qualitative Research

Qualitative research aims at generating a deep understanding of a specific phenomenon under study by weaving together an "explicit rendering of the structure, order and broad patterns found among a group of participants" (Munigal, 2017, p. 52). Qualitative researchers focus on the socially constructed nature of reality and how social experience is created and given meaning (Merriam, 2009). This research offers a holistic perspective of the phenomenon by understanding that the phenomenon is a complex system of dynamic inter-dependencies and that these complex, multi-layered systems often cannot be reduced to simplistic systems due to the phenomenon being subjected to a multitude of idiosyncratic interpretations and perspectives (Labaree, 2009). Thus, in the interest of authenticity, qualitative research entails an interpretive, naturalistic approach - the phenomenon is observed in its natural setting and interpreted using “thick descriptions representing the complexity of situations” (Cohen, Manion, & Morrison, 2011, p. 17), in the words of those individuals who are part of the phenomenon. Thus, this research approach makes meaning of the phenomenon from the standpoint of the individuals who are active participants in it (Cohen et al., 2011; Denzin & Lincoln, 2011).

This study situates itself within the interpretivist paradigm, as the study seeks to understand how (and why) students’ learn in statistics, through gaining insight into their backgrounds, beliefs and experiences (Schwartz-Shea & Yanow, 2012), and imbues the following defining characteristics of a qualitative, interpretivist approach (Thanh & Thanh, 2015):

(i) studies are carried out in a natural setting, where this research into students’ learning in statistics took place in the students’ natural setting of a tutorial classroom;

(ii) research questions are designed to explore, interpret, or understand the social context and participants are selected non-randomly based on their knowledge of the phenomenon, where the student participants in this study were selected in a non-random method. using purposive sampling method to sample the students that I thought possessed vital answers to the research questions;

(iii) the researcher should be in close contact with the participants, where as the researcher, I played an active role in acquainting myself with the participants and the social context in which they live through the threshold concepts enriched tutorial programmes, my facilitation of the focus groups and conducting of the individual interviews;

(iv) research hypotheses are made after data collection and modified as new data is collected, where hypotheses for this study were formed after the data was gathered and analysed and verified by means of data triangulation; and

(v) research results should be reported in narrative style, where the results of this research was reported using rich, detailed narratives.

4.3 A qualitative case study research design

The qualitative case study research design is congruent with the principles of social constructivism, in terms of which truth is seen as relative and dependent on one's perspective, meaning is individually created, and reality is socially constructed (Baxter & Jack, 2008). This perspective clearly resonates with the current study as the threshold concepts framework, which frames the study, rests within a social constructivist model (Land, Meyer, & Smith, 2008), where the role of social context is entwined with knowledge construction around how (and why) students learn in statistics. The nature of the data as rich, deep, contextualised descriptions satisfies the requirements of the critical questions, which seek a deep understanding of students' learning in a particular context. Thus, it was clear that the study would be best served by a case study research design. Given the importance of the role of context in this study, it was clear that the systematic and investigative research approach offered by a case study would be most suitable (Rule & John, 2011). Additionally, case studies are deemed appropriate research designs for answering how (and why) research questions about a contemporary issue over which the researcher has no control. Case study enquiry also copes with a technically distinctive situation in which the study has many variables of interest arising from the complexity and context of the phenomenon, requiring the convergence of multiple sources of evidence in a triangulating fashion, and building on previously developed theoretical propositions to guide data collection and analysis (Yin, 2014).

Case study research designs may be classified as intrinsic, instrumental or collective (Stake, 1995). Types of case study research designs include exploratory, explanatory, and descriptive (Yin, 2014). This study resonates with the categories of intrinsic and instrumental as proposed by Stake (1995) since this study investigates a particular group (students studying statistics) within a particular context (statistics students' learning in a threshold concepts-enriched tutorial programme) and, since greater insight into the theoretical underpinnings (threshold concepts framework to learning) of the phenomenon is being examined. This study most closely matches Yin's (2014) "explanatory category", as it seeks to determine how (and why) events occur and the variables that may influence particular outcomes (Hancock & Algozzine, 2011). Thus, case study research is richly descriptive, because it is grounded in deep and varied sources of information.

The defining appeal of the case study research design for this study is its holistic approach, where the case study design considers the interrelationship between the phenomenon and its context allowing the researcher to gain insight into the idiosyncrasy and complexity of a phenomenon (Verschuren, 2003; Yazan, 2015).

The criticism that is often levelled against case studies is its limited generalisability (Flyvbjerg, 2006; Rule & John, 2011). However, the goal of a qualitative study is to understand the phenomenon under investigation from the emic perspective ((Hancock & Algozzine, 2011), that is, from the participants' perspective and not the researcher's perspective, by converging data from multiple sources, the case study research design is "generally more illustrative than comparative or predictive […] seeks to identify themes or categories of behaviour and events rather than to document similarities and differences or to test hypotheses" (Hancock & Algozzine, 2011, p. 16). Thus, notwithstanding the particularities of the study, this research may have wider implications or resonance with the broader literature. The rationale for this study was not to generalise beyond the case, but to better understand the phenomenon in context in order to effect real and applicable action in the future.

4.3.1. Site and context of research

The study was conducted at the Durban University of Technology (DUT), in Durban, South Africa. DUT was formed in 2002 following a merger between Technikon Natal and ML Sultan Technikon when it was initially known as the Durban Institute of Technology. The university has a diverse student and staff population and offers qualifications in a wide range of academic and technical disciplines on five campus sites. The study was based in the Business Statistics II (BSTS 201) module on DUT's ML Sultan campus. BSTS 201 is a compulsory, one semester offering (in the 2^{nd} semester only) to students in their third year of study in the Cost and Management Accounting programme. The group is split into two classes, with approximately 100 students in each class. I teach the A Group, and my colleague taught the B Group. Groupings are made according to surnames, with students with surnames A to Mn in Group A and the remaining students fall into Group B. Teaching for both groups take the form of three weekly lectures and one weekly tutorial period.

BSTS 201 is an introductory statistics module, where the concepts and principles it encompasses, the tools and techniques it provides can be seen as the cornerstone of a statistical way of thinking and of analysing real-world phenomena. Business Calculations I (BCAL 101) is a 1st year pre-requisite module for BSTS 201. In BCAL 101, the students would have already successfully encountered topics in descriptive statistics, that is, techniques used for the summation, condensation and presentation of data. BSTS 201 is a more advanced statistics module with a focus on inferential statistics, involving techniques used for making inferences about a population by using data drawn from sample(s) of that same population. BSTS 201 is comparable in terms of topic coverage to equivalent introductory statistics course globally, and is intended to give students an appreciation of the vital role of the subject of statistics in empirical research and to teach students on how to apply statistical techniques to empirical research in their specialist field. This course required a deep approach to learning as the emphasis in class, in tests and exams was placed on understanding the reasoning by calculations, the assumptions under which various statistical tests are valid and the correct interpretation of results. Thus, BSTS 201, a module that I have taught for several years and am familiar with the content, and know which areas students find particularly troublesome, was deemed to be an appropriate module in which to investigate students' learning of disciplinary threshold concepts.

4.3.2. Study participants and the selection process

Participants were sampled from the BSTS 201 class. At an information session during the first week of the start of the semester, I explained to the two groups of the BSTS 201 class what participation in the study would require of them, namely regular attendance at tutorials, which I (as the researcher/lecturer) would facilitate, completion of the tutorial assignments, weekly writings in their reflective journals, participation in the online discussion board that would be created for the tutorial group; participation in the IQA focus groups; in-depth interviews conducted towards the end of the module; maintenance of reflective learning journals; permission to use their written reflections (from their learning journals and online discussion board); and audio-taped focus group session and individual interviews for research purposes.

I had anticipated that there would be sufficient volunteers to select a sample because from experience with this module, many students would take-up opportunities perceived as potentially beneficial to their performance in the module. The sampling technique used was a purposive sampling method, as I purposefully chose to draw the sample of participants based on characteristics of interest to the study (Cohen et al., 2011). The sample is not intended to make statistical inferences from the sample to the population (Silverman, 2014). Instead it is a collection of participants chosen for their "typicality" or possession of a particular characteristic of interest (Cohen et al., 2011) – being learners of statistics – that will best enable me to answer my research questions (Rule & John, 2011).

I aimed to have a sample size of 20, because these participants would comprise the tutorial group through the semester, as well as the IQA focus group conducted near the end of the module. A class of size 20 is deemed to be appropriate for small-group teaching by Bargate (2012), and in addition, a group size of 20 complies with Northcutt and McCoy (2004) recommendation of having 12-20 participants in a focus group. Altogether, 32 students volunteered to participate in the study, I decided to allow all 32 students to participate, to accommodate those students whose attendance at the tutorials might eventually wane. At the first meeting, 19 students attended. Over the course of the semester (which comprised seven tutorials), this number of 19 participants remained more or less constant, of whom 17 participated in the focus group sessions and interviews.

The participants were all Black African[32] students. I did not ask the students to provide me with details of their home language as I felt that if language is a barrier in the successful learning of statistics that this would emerge in the focus groups or individual interviews. I purposefully did not ask students to provide me with details of their academic records, as I did not want any participant to feel that they would be prejudiced against by having me know their academic record. I wanted all participants to enter into this tutorial programme feeling a sense of mutual equanimity and I wanted my knowledge of them to grow and develop over the course of the tutorial, and my insights to be gleaned from reading their reflective writings and online chats, interactions in the tutorial class, as well as through observations.

4.4 The threshold concepts-enriched tutorial programme

To enable me to examine students' learning in statistics, I designed a tutorial programme informed by a threshold concepts orientation, which ran alongside mainstream lectures for most of the

[32] The term used by Statistics South Africa in their official demographic statistics releases in reference to Black people of African origin (Statistics South Africa, 2019).

semester. These tutorial sessions allowed me to use active, cooperative learning activities involving the use of real data, which was not practical to implement in the mainstream classroom setting, but which established in theoretical and empirical research as conducive to learning (see chapter on Literature Review). The programme comprised three aspects, viz. weekly tutorials, written reflections in a learning journal, and an online discussion board for the tutorial group participants. Opportunities for students to reflect on the process of learning statistics were built into the programme through all three of these components. Through my facilitation of the tutorials, my reading of and responses to their written reflections, as well as interaction with participants on the group chat, I was able to engage closely with the participants over the semester, and I believe that the relationship I formed with the group facilitated subsequent processes of data generation.

4.4.1 Tutorial format and activities

The weekly 60 minute sessions focused on specific threshold concepts embedded in topics which form part of the BSTS 201 module content.[33] I attempted to align the timing of topics or concept coverage in the tutorials broadly with the mainstream lectures so that the relevance of these additional sessions would be clear to the participants, and also to help reinforce the ideas and concepts covered in the lectures.

In the tutorial sessions, I strove to create a semi-structured, relaxed environment where students could interact comfortably with each other to discuss the tasks and to share and develop their statistics knowledge, while ensuring that focus did not shift from the task at hand. I tried to create a well-balanced ecosystem in these tutorial sessions wherein the participants and I could share a mutualistic relationship (Cohen et al., 2011). I anticipated that the tutorial programme would help student participants to deepen their understanding of concepts covered in BSTS 201 by engaging with additional material and applying statistical concepts to relevant real-world problems. Beyond these immediate module-related academic benefits, I expected them to gain from working with peers in a structured way, in a small-class context and a relaxed environment. The benefits to me consisted not only in access to information and insights for the purposes of the study, but also in the opportunity to develop my teaching practice, informed by a growing understanding of how

[33] Attached to Appendix 5.

students learn this content.

At the beginning of each session, I handed out printed copies detailing the session's activity. I facilitated this by outlining the activity and the task to be carried out and assisted in assigning students to small groups of three to five members. This was to ensure that people did not sit repeatedly with their friends, and that all students would get to interact with each other over the semester. Surprisingly, students were amenable to this idea, using it as an opportunity to expand their social network. The bulk of the tutorial session was taken-up by small group activity and discussion. I did not re-teach the material, but facilitated in either clarifying a point or helping to steer in the right direction.

Each tutorial was structured around an exercise focused on a real-world or everyday application of specific statistical threshold concepts. The tasks often involved data collection, extensive group discussion, and a written component. Further reflection was given post-exercise in the tutorial, and/or later in their reflective writing. The tasks were drawn from the textbooks *Essentials of Statistics* (5th ed.) by Triola (2015) and *Introductory Statistics Global Edition* (10th ed.) by Weiss (2017). The activities were designed for a cooperative pedagogic approach and where appropriate, I adapted them slightly, to reflect a South African context. This made the tasks relatable and facilitated ease of understanding. The activities were amenable to the introductory level of the syllabus and the exercises were intended to guide students through their understanding and application of statistical conceptual knowledge. At the end of each tutorial session, I handed out solutions to the exercises so that students could refer to this to check against their own workings. In this way, potential misunderstandings/misinterpretations were unmasked and re-learned. The tasks and solutions were also uploaded on the online classroom for the tutorial group.

The design of the tutorial exercises were intended to encourage active learning using a variety of engaging and relatable topics. Each exercise embeds threshold concepts in the case or example that students are guided to analyse. Given the view of active learning as being good disciplinary pedagogical practice – a bridge that links theoretical and practical know-how (Carlson & Winquist, 2011) - the exercises did not focus solely on one concept each but the aim instead was to draw the students' attention to the interconnectedness of these concepts as a way of developing their understanding of the disciplinary framework of thinking and doing (Davies & Mangan, 2006).

Attendance was voluntary, and attendance numbers ranged from a maximum number of 21 students to as few as six students. On average, the tutorials were consistently attended by a core group of between 15 to 20 students, who stayed the course and participated in the focus group sessions and individual interviews at the end of the semester. Where the tutorial exercise called for written answers to tasks, I did not collect these for assessment purposes. I did not censure students who missed sessions, thus attendance and participation relied on the motivation and good will of the students in the group, and to a great extent (I suspect) students' belief in the value of the tutorial sessions to their overall learning in the course.

4.4.2. Writings in reflective learning journals

Each week, as a form of personal reflection on their learning, I asked the participants to write a reflection on their learning experiences in statistics in their learning journals (which I had handed to them at the commencement of the tutorial programme). I hoped that this activity would have intrinsic value for the students, in the sense that while writing they would think about the learning process, they may recognise how they learn thus enabling them to participate more actively in their own learning, organise their thoughts and reduce stress (Bargate, 2012; Ersozlu & Kazu, 2011; Ward & Meyer, 2010). Reflective journals provide a starting point for learning as it provides an opportunity for students to write down their observations and experiences whilst centering students in the learning process by enabling students to integrate life experiences with their understanding of a topic (Boud, 2002; Moon, 2006).

The use of reflective learning journals in this study had three distinct advantages for me as the researcher – it served as a pedagogical tool, it was used as an aid in teaching instruction, and was instrumental in the development of relationships with my student participants (O'Connell & Dyement, 2011). The reflective journals opened up a dialogue between myself and the students whereby I was able to respond directly to the learning needs of individual students. By reading through the students' reflective writings, I was privy to an additional source of evidence regarding students' understanding of a concept, because these journal entries offered insight into the transformative, integrative nature of the disciplinary concepts and possible shifts in identity which learning threshold concepts entails (Davies & Mangan, 2006). The reflective writing journals assisted me in cultivating a bond with these students, as I got to know students as individuals and their individual particularities of engagement with the subject matter through my feedback to them. These positive aspects of reflective writing are also evidenced in the extant literature. Denton (2018) introduced writing in a reflective learning journal to psychology students in his introductory statistics course with positive effects on students' learning experience in the course.

Participants in this study wrote their reflections long-hand. I suggested questions or prompts (Moon, 2004) for each week's reflections,[34] which encompassed both tutorial and content-specific responses and more general insights. I asked participants to submit their written reflections to me on the Monday (during the tutorial), which I then read and responded to and returned to students on the Wednesday for them to have ample time to write their reflections before the next tutorial session. Most students submitted on time, but given the small number, I was able to read and write individual responses to each submission every week. I believe the individual comments I wrote in response to each submission underscored the value I placed on their reflections, and encouraged many of the participants to reflect more deeply on their learning. A positive response from me sometimes produced positive feelings in students, which was heightened by students making public the positive exchange between themselves and me. I think that other students, witnessing this good rapport between myself and some students, encouraged them to trust me, and the rate of submissions increased over the course of the tutorial programme, with some students handing in a few week's worth of submissions a batch at a time. Most reflections were limited to a few lines, whilst a few offered more detailed responses. Submissions were scanned and copies made for analysis. Since completion of the reflections was not compulsory and had no impact on assessment, I was reliant on participants' goodwill, and interest. I expressed my gratitude for their submissions and frequently emphasised their importance to my research, reminding the participants weekly to submit their reflections and accepting late submissions gratefully.

The reflective journals also provided an additional source of qualitative evidence for the study. The journal entries supplemented the data collected from the IQA focus groups and individual interview data and served as a source of triangulation for the IQA findings gathered, thereby enhancing confidence in the focus group and interview findings (Cohen et al., 2011; Guba, 1981).

[34] Attached to Appendix 6.

4.3.3 WhatsApp group in lieu of the online discussion board

I initially created an online Blackboard classroom for the tutorial group, which featured a discussion board. MacDougall (2010) asserts that the use of a discussion board can offer several advantages in the teaching of statistics. It provides an opportunity to encourage participation from less confident students, where students evolve into tutors as they offer advice to their peers and thus engage in a deeper form of learning. In this way the instructor is alerted to new and/or ongoing troublesome concepts, characterised by the frequency with which these issues may be raised by individual students, thus leading to an enhanced learning experience for future students. Land, Cousin, and Meyer (2005) further endorse the use of discussion boards by pointing out that when students are within the post-liminal space, a discussion board offers a space for students to contemplate and reflect on the nature and interconnectedness of the concepts that they have learned.

I uploaded all the tutorial session activities and their respective solutions onto this classroom at the end of each tutorial session. I hoped that even if a student missed the tutorial, that they would still have access to the activity and the solution. My intention in creating the Blackboard classroom was that I hoped that students would make use of the discussion board to interact with each other about the module and/or discuss their experiences of working in the tutorial programme, and use it as another medium of communication to discuss all of their statistics-related issues. I also planned on using the discussion thread messages to supplement my IQA data and offer an additional lens through which to look at the research questions. I attempted to initiate a discussion thread by posting a message asking the students to discuss any concerns that they might be experiencing with the course. This was relatively unsuccessful. The feedback that I received in reflective journals and individual interviews as to why students were reluctant to use this medium of communication pointed to various factors. These findings are discussed in further detail in Chapter 8.

Once I sensed that students were not eager to use this method of communication, I decided to create a WhatsApp group chat for the participants in the tutorial programme. I thought that this would be another means of fostering a social constructivist environment for learning in statistics (Amry, 2014; Naidoo & Kopung, 2016), and I hoped that the inclusion of images in the students' postings of messages would have a positive effect on their learning (Cetinkaya, 2017). This socially constructed environment came alive when a class test or exam was imminent. Students assisted each other by posting past year question papers, asking each other for worked-out solutions to questions, and generally posting positive messages of support and motivation to one another. I also used this medium to post reminders of the tutorial sessions and date and venue for the focus group sessions and individual interviews. The WhatsApp group messages were downloaded from my mobile phone, and scanned. These served as an additional source of data triangulation, further enriching my IQA data. An exhaustive search of contemporary literature did not reveal any studies in the statistics education literature that incorporated the use of WhatsApp messaging as a pedagogical tool.

4.5. Data generation and analysis

I sourced data from the two phases of IQA, namely focus group sessions and in-depth interviews. I used IQA protocols to generate, analyse and interpret the data from my study. I supplemented this data source with the writings from the participants' reflective learning journals and their posted messages on the WhatsApp group chat.

4.5.1. Interactive Qualitative Analysis (IQA)

In Chapter 2 I have shown that for the most part, that quantitative studies have dominated research undertaken into the cognitive and affective aspects of students' learning in statistics. In order to examine the current research questions as to how (and why) students learn statistics in the way(s) that they do, I chose to use the qualitative research design IQA, developed by Northcutt and McCoy (2004). It was chosen due to its systematic, rigorous, accountable framework to analyse qualitative data (Tabane & Human-Vogel, 2010). Winston (2011) describes IQA as a systematic, protocol-driven research method that combines the quantitative rigour of data analysis with the qualitative depth of descriptive interviews. The method involves generating data through two phases – conducting a focus group session with participants and semi-structured individual interviews of participants. In the first phase, the focus group session, participants write down their thoughts, feelings, reflections, and experiences of the phenomenon under study, which they then classify according to various themes called "affinities'. The participants then suggest a system of influence that exists between these affinities which results in a unified Systems Influence Diagram (SID). The SID is a graphical presentation of the phenomenon under study. The IQA method is congruent with a social constructivist approach to data generation and analysis (Bargate, 2012), as it lends itself to the precept that knowledge (of the phenomenon) is socially constructed from human experiences. The participants construct their own meaning of reality from their experiences of interacting with the phenomenon in context and in its refutation of traditional qualitative norms of enquiry that casts the role of the researcher as the expert. IQA stands out, entrusting participants with data generation, analysis and interpretation. Thus the researcher's role is purely facilitative, greatly limiting the potential for skewed power relations and bias often hazardous issues in qualitative research (Goebel, 2017). Thus, the IQA methodology is compatible with the research approach of this study, which adopts an interpretivist/constructivist approach of knowledge creation through human experiences (Andrews, 2012).

In order to understand the workings of the system (phenomenon), IQA methodology attempts to provide clarity on the various elements (affinities) that constitute the system and how these elements influence and/or inter-relate with one another in this dynamic system (Goebel, 2017; Northcutt & McCoy, 2004). The concept of affinities is akin to cogs turning a wheel - a minor but necessary component in the workings of the system.

IQA is a novel method, which, as far as I can determine, has not been used in the extant statistics education research literature. In South Africa, IQA has been applied in the fields of educational psychology (Tabane, 2009; Tabane & Human-Vogel, 2010). In a context similar to that of the current study, in students' learning of economic threshold concepts, Goebel (2017) draws a comparison with the IQA methodology and the "transactional curriculum inquiry" feature of the threshold concepts framework. This is done since in IQA methodology, researcher and students work together iteratively to explore the dynamics of the phenomenon, which is similar to the collective efforts of academics, students and curriculum developers in threshold concepts research (Cousin, 2010). Issues of trustworthiness, dependability and confirmability are significantly reduced in the IQA methodology (Tabane, 2009), as the participants are solely responsible for generating, analysing, and interpreting the data. This aspect will be discussed further in section 4.6.

4.5.2. IQA ideology

In this section, the philosophical assumptions of IQA as they inform this study's method and design are described. The epistemological and ontological stance of IQA is captioned as the "Beliefs and Values Redux" of IQA and is presented as a series of points by Northcutt and McCoy (2004, pp. 16-17), which are elaborated on below.

Ontological Perspective

Northcutt & McCoy note that "IQA presumes that knowledge and power are largely dependent, that power influences which knowledge is determined to be relevant and irrelevant, important and unimportant" (Northcutt & McCoy, 2004, p. 16). One of the IQA criteria for constituent (participant)[35] selection is the degree of power that the constituency has over the phenomenon. This assumption is reflected in this study by selecting constituents from among the participants in the threshold concepts-enriched tutorial group to participate in the IQA focus group. Since these students were inextricably linked to the phenomenon under study, namely experience of learning statistics in a threshold concepts-enriched tutorial programme, they had the power and knowledge to reflect on their experiences of learning statistics.

"IQA presumes that the observer and the observed are dependent (or […] interdependent)" (Northcutt & McCoy, 2004, p. 16). Qualitative research norms, according to IQA methodology, hold that data collection and analysis are separate and distinct processes, where only the researcher is capable of interpreting the data. IQA methods involves the participants in generating, analysing and interpreting the data while the researcher's role is that of facilitator. In this study, the participants generated data by reflecting on their experiences of learning statistics in a threshold concepts-enriched tutorial programme during the focus group sessions and in the follow-up semi-structured individual interviews. Participants analysed the data by grouping their reflections/thoughts/experiences into various themes (affinities). Participants interpreted this data by suggesting a system of influence between the affinities. A SID is the final, visual representation

[35] Northcutt and McCoy (2004) favour the term 'constituent' to reflect the "knowledge and power" relationship. Whilst noting the aptness of this term, I have chosen to use the word "participant" interchangeably with "constituent", because it reflects students' participation in the tutorial programme over the semester and the focus group and individual interviews.

of the phenomenon under study “prepared according to the rigorous and replicable rules for the purpose of achieving complexity, simplicity, comprehensiveness and interpretability” (Northcutt & McCoy, 2004, p. 41).

Northcutt & McCoy argue that “The object of research in IQA is clearly reality in consciousness” (Northcutt & McCoy, 2004, p. 16). The second criterion of IQA for constituent selection is that of distance from (or closeness to) the phenomenon. The participants in the tutorial programme were chosen because they were closest to the phenomenon, and therefore had the experience and authority to represent and dissect their reality of learning statistics in the threshold concepts-enriched tutorial programme. Their group realities were initially socially constructed and expressed in the focus group sessions followed by an elaboration on their individual realities in the individual interviews.

Epistemological Perspective

Northcutt & McCoy state that “IQA insists that both deduction and induction are necessary to the investigation of meaning” (Northcutt & McCoy, 2004, p. 16). During the focus group session, participants were required to categorise the generated data into categories of meaning (affinities) using induction, then refine and define these affinities using both induction and deduction and then, finally, participants deductively identify relationships of influence among the affinities. According to Northcutt & McCoy, “These three stages of data production/analysis – correspond to the three formal classes of analysis of coding: emergent, axial and theoretical” (Northcutt & McCoy, 2004, p. 16).

Northcutt & McCoy note that “IQA contends that decontextualized [sic] descriptions are useful and possible as long as they are backed up or grounded by highly contextualised ones, and as long as the process by which the text was decontextualized [sic] is public, accessible and accountable” (Northcutt & McCoy, 2004, p. 17). I have endeavoured to provide the reader with the broader context within which my study situates itself by weaving my study into the expansive quilt of statistics education research and threshold concepts view of learning (Northcutt & McCoy, 2004). IQA allows the constituents to weave together an interpretive quilt of their reality of experience of the phenomenon (Bargate, 2012).

Northcutt & McCoy further argue that "IQA is clearly favourable to theory, both from the point of view of inducing theory and of testing it" (Northcutt & McCoy, 2004, p. 17). The SID - being the final product of IQA – is a visual representation of a mind-map of the group reality of the phenomenon under study, rather than a model imposed by previous research findings or theorists (Northcutt & McCoy, 2004). The mental model produced by the participants in this study is their theory of their conscious reality of their lived experiences of learning statistics in a threshold concepts-enriched tutorial programme (Northcutt & McCoy, 2004). My study findings situates the study in the broader statistics education research, where it takes a threshold concepts view of learning. I will discuss the emergent findings in relation to the extant literature in Chapter 8.

The principles of IQA certainly support constructs such as credibility, transferability, and dependability, while highlighting the concepts of validity and reliability through public, accessible, and accountable procedures. Issues pertaining to the rigour of this study will be discussed in section 4.6.

4.5.3. IQA methodology in action

The first phase of the IQA process entails the selection of constituents to participate in the focus group session that results in the generation of a visual representation of the dynamics of the phenomenon. The second phase of the IQA process involves the conducting of semi-structured individual interviews with the constituents. The aim of these interviews is to further probe individual meanings of the affinities generated in the focus group session and provide an opportunity for constituents to theorise and rationalise their understanding about the relationship between affinities. The main processes of IQA will be outlined here in general terms. Details of the implementation of the focus group and application of IQA protocols for the study are reported in Chapter 5.

4.5.3.1. Identifying constituents (participants)

The first phase of IQA is the creation of the focus group. The task of the focus group participants is to represent their reality of the phenomenon in terms of its components of meaning and to propose their hypotheses of the relationships amongst these components (Zimmerman, 2006). This is in harmony with the guiding principle of social constructivism, namely that meaning-making is socially constructed. IQA's criteria for the selection of constituents are: (i) extent of power over the phenomenon; and (ii) distance from or the extent to which the constituent experienced the phenomenon (Northcutt & McCoy, 2004). In keeping with these criteria, the constituents for this study's focus group were 17 participants, who voluntarily participated in the semester-long threshold concepts-enriched tutorial programme. These participants shared a collective, close experience of the phenomenon.

4.5.3.2. The IQA focus group: A collective reality

Focus groups are considered a key data collection method in qualitative research (Ritchie, Lewis, Nicholls, & Ormston, 2013). Northcutt and McCoy (2004) recommend a 12-20 member participation in the focus group and the IQA prescribed format does not centre on verbal discussion, so as to reduce the possibility of bias being introduced by domineering personalities during the coding phase. The IQA focus group data collection techniques assists participants "in articulating perceived relationships among these experiences to produce a theory in perception or a conceptual map" (Northcutt & McCoy, 2004, p. 81). In this study, the participants in the focus group generated responses to issue statements that would capture the essence of and shed light on the participants' experiences of learning statistics in a threshold concepts-enriched tutorial programme. My role as researcher was strictly facilitative – guiding the group through the IQA procedures – being conscious of not imposing an interpretation of the emergent data or influencing data generation with my perceptions of the phenomenon of students' learning experiences of statistics. In the following paragraphs I offer an outline of the IQA focus group procedure as it relates to this study.

Generating and naming affinities

At the commencement of the session, I presented the participants with index cards and issue statements.[36] The issue statements were designed to probe and elicit answers to the research questions. The first task for the focus group participants is silent brainstorming. Northcutt and McCoy (2004) suggest using guided imagery to help participants relax and clear their minds for the session. A silent brainstorming session ensues, allowing participants to engage with the issue statements. Participants record all of their responses to individual problem statements on index cards, writing one thought/experience per card using words, phrases, sentences or imagery. After the brainstorming – approximately 45 minutes – the index cards were randomly taped along a wall.

The clarification of meaning stage follows: as the facilitator, I read each card out loud to achieve clarity and consensus on the meaning of the card, which lays the foundation for constructing a shared reality in the group (Goebel, 2017). Next, in the stage known as inductive coding (Northcutt & McCoy, 2004), participants are requested to silently organise the cards into groups of meaning or themes which will be known as affinities. The next stage is axial coding, a deductive process, that requires the participants (as a group) to decide on a name to give to each cluster of responses (affinity naming) and to sort any cards that may be miscategorised into the appropriate group. This entire session took approximately four hours to complete. Although IQA calls for a single focus group session, in this study I had to schedule two sessions, five days apart, which allowed me to write-up the affinity meanings. A consolidated description of the meaning of the affinity, grounded in specific responses or examples. This was done after the first session, for the group to check and confirm at the second session.

Identifying relationships among factors

This process entails theoretical coding and was conducted in the second focus group session. After the participants checked and confirmed the description of the affinities that I prepared, they were asked to analyse the nature of the relationships of influence between each of the affinities recorded in a matrix called an Affinity Relationship Table (ART). For any pair of affinities, (A and B), participants are to decide whether: A influences B (A → B), B influences A (A← B) or no

[36] Attached to Appendix 7.

relationship of influence exists. Participants were also asked to provide a specific example, in everyday language, or as an “if … then” hypothesis, to indicate how they see the directionality.

Constructing the Inter-relationship Diagram (IRD)

This activity is called theoretical coding, and creates an extended reality for the group through further discourse. The goal of this stage is “to identify the skeleton of a ‘theory in perception’” (Northcutt & McCoy, 2004, p. 48).

Constructing the Systems Influence Diagram (SID)

IQA protocols prescribe certain steps proceeding from the IRD to produce the SID. My use of these steps, culminating in the mind-map of the participants’ experiences of learning statistics in a threshold concepts-enriched tutorial programme is detailed in Chapter 5. The SID is a visual mind-map of the “theory in perception”, “grounded in the specific experiences and logic of the participants” (Northcutt & McCoy, 2004, p. 48).

4.5.3.3. IQA interviews – individual meaning-making

The second phase of IQA entails conducting semi-structured individual interviews, which serve a two-fold purpose:

1. axial interview is an open-ended design to capture rich descriptions of the affinities from the participants and the interviewer (researcher) probes the participant’s meaning of the affinities; and
2. the structured, theoretical interview design probes participant’s meanings of relationships between affinities.

(Northcutt & McCoy, 2004).

The interview protocol is only drafted after the focus group and ART phase, since participants are expected to elaborate on their interpretation of the meaning of the affinities and the relationships between them. Whereas the focus group dealt with the generation of data that was socially constructed, representing the participants' shared experience of the reality presented by the issue statements (Northcutt & McCoy, 2004), the individual interview stage creates an opportunity to explore "individual differences in meanings vis-à-vis the issue" (Northcutt & McCoy, 2004, p. 238), and the composite interview mind-maps (the outcome of the individual interview stage) serves as a source of data triangulation in the sense that if the participant "is representative of the constituency from which the group SID was derived, then the composite of all such interviews should be similar to the focus group SID" (Northcutt & McCoy, 2004, p. 238).

The advantages of conducting individual interviews, as envisaged by the IQA process outlined above, may be somewhat tempered by the possibility of bias creeping into the interview process. Bias arises from skewed power relations between the interviewer and participants (Creswell, 2013). Since I was the participants' lecturer, some participants may have felt inclined to provide answers to garner favour. To mitigate this possibility, I reminded them of the purpose of the interview in relation to generating data for the study, and emphasised that the integrity of the study rested on honest feedback. I also feel that during the duration of the tutorial programme, a less formal, trusting relationship developed between the participants and myself. This helped to put the participants at ease in the interview and they were able to answer questions openly and honestly. Also, since the structure of the interview was built around the affinities, which the participants as a group generated, this helped to give participants a sense of power and control over the content of the interview.

I used the ART generated by the participants to develop an interview protocol.[37] I conducted individual interviews with 17 students, who attended the tutorial programme, handed-in reflective diaries, participated in the WhatsApp group chat, and in the focus group sessions. Each interview followed a similar pattern, in which I asked the participant to reflect on their personal meaning of the affinity in turn, and on the relationship of influence amongst the affinities. I tried to put participants at ease by maintaining a conversational tone. All interviews were audio-recorded and transcribed verbatim by a professional transcription service provider, who was not acquainted with the study or knew the students. I checked the transcripts upon completion.

[37] Attached to Appendix 10.

4.5.3.4 Data analysis

As described above, in the focus group stage, initial analysis and interpretation is merged with data generation. My use of IQA protocols to arrive at the SID as the culmination of the focus group activity, is explained with reference to the specifics of the study in Chapter 5. This section will explain my use of IQA protocol to analyse individual interviews. This is a process I also adopted to analysing participants' reflective writings and WhatsApp messages.

I examined the interview transcripts, reflections and WhatsApp messages, searching for "specific examples of discourse that illustrate or allude to an affinity" (Northcutt & McCoy, 2004, p. 315) in accordance with IQA guidelines for combining axial data (examples of the range of meanings of affinities). In coding the reflective writings and WhatsApp messages, I was able to accommodate the thematic threads from each data source within the affinities.

The result of this axial coding was a composite table per affinity (with identifiers to help me distinguish participant, data source and transcript line). From the composite table, I identified recurrent themes (Bargate, 2012; Goebel, 2017) reflected in sub-groups of quotes within each affinity. I followed the same process for theoretical coding (producing the relationship between affinities), for which I used the examples provided by the participants in their ARTs, in addition to the interview transcripts, reflections, and WhatsApp messages to compile quotes regarding the directions of influence for the affinity relationships. The composite quotes describing the sub-affinities making-up each affinity, and the relationships of influence among affinities, form the *bricoleur* (Northcutt & McCoy, 2004), or the interpretive quilt of meaning weaved by the IQA process (Bargate, 2012), and will be discussed in detail in chapters 5-7.

4.5.3.5 IQA protocol for representation and interpretation of results

Together, the IQA processes of: (i) focus group; and (ii) semi-structured individual interviews, enabled the generation of socially constructed answers to the study's research questions. The affinities (the elements of meaning of the phenomenon) and their perceived cause-and-effect interactions is grounded in the thick, rich descriptions in the words of the participants. Each affinity is presented as comprising several sub-affinities, which in turn are each described by a composite quote, woven together from multiple individual quotes. The relationships of influence among affinities are rendered in the same way.

In this manner, IQA methodology attempts to reveal “truth” as constructed by an individual or group by deliberately incorporating concepts from the three important understandings of the meaning or theories of truth: correspondence theory of truth (CTT), coherence theory of truth (CoTT), and constructive theory of truth (CsTT) (Northcutt & McCoy, 2004, pp. 340-342).

The CTT interprets truth as correspondence with facts or reality, as described through participant experiences. In this study, findings correspond with participants’ lived reality of their experiences in learning statistics in the threshold concepts-enriched tutorial programme, as observed through the data sources (Bargate, 2012; Goebel, 2017).

The CoTT sees truth as being consistent with other true statements. CoTT has three criteria:

- Structural coherence: coherence between “elements” and “relationships” that make-up a meaningful structure. In this study, this interpretation of truth would be reflected among the affinities and affinity relationships.
- Referential coherence – the study fits into a larger system with other studies, such as broader theoretical perspectives in this case; and
- Dramatic coherence – where the characters are relatable and resonate with our own experience. This may be construed as participants’ individual meanings/interpretations of affinities and relationships of influence amongst affinities.

The constructivist theory of truth conveys the value of truth as being “useful’ or “pragmatic” and that the “real” truth of a proposition “lies in its potential for solving a problem” (Northcutt & McCoy, 2004, p. 342). My study findings offer vivid descriptions of the phenomenon in the form of insights into students learning in statistics – with implications for practical interventions in the statistics classroom and potential for further research.

4.6. Rigour

Rigour, in qualitative research terms, is similar to the criteria of validity and reliability used to evaluate positivist research, are methods employed to establish trust and confidence in the findings of a research study (Thomas & Magilvy, 2011).

Within a constructivist-interpretive paradigm such as this research study, the use of criteria credibility, transferability, dependability and confirmability are advocated over the positivist research criteria of validity and reliability (Denzin & Lincoln, 2011).

In their classic work on naturalistic (interpretive) enquiry, Lincoln and Guba (1985), were the first to address rigour in their model of trustworthiness of qualitative research. Guba contends that trustworthiness is the principal criterion for judging the value of research (Goebel, 2017). This model addresses four components of trustworthiness, viz. truth-value (credibility), applicability (transferability), consistency (dependability), and neutrality (confirmability).

In this study, the research methodology of IQA and data triangulation assisted in upholding the trustworthiness of the study. The respective roles that they played is elaborated upon below.

IQA methodology supports the "constructs such as credibility, transferability, and dependability, while highlighting the concepts of validity and reliability" (Northcutt & McCoy, 2004, p. 17). IQA has built-in features promoting rigour in both data generation and analysis (Bargate, 2012; Tabane, 2010). These features are evident in the design of the research. The research design is: (i) public and non-idiosyncratic; (ii) replicable within reasonable bounds; and (iii) not dependent (especially for analysis) on the nature of the elements themselves (Northcutt & McCoy, 2004). In IQA research design, the issues commonly associated with qualitative research, such as researcher bias, reflexivity or trustworthiness is eliminated, by having a transparent audit trail of the steps followed according to rigorous, reliable and replicable rules (Bargate, 2012, p. 73).

Triangulation refers to the use of multiple perspectives, methods, or sources of data, and is another means of enhancing confidence in research findings (Baxter & Jack, 2008; Guba, 1981). When the same phenomenon is observed from multiple data sources, this can enable a fuller explanation, assist the researcher in generating reliable evidence, and contribute to credibility and confirmability (Cohen et al., 2011). In my study, the two phases of the IQA (focus groups and interviews) were supplemented by the analysis of reflective writing and the participants' contributions to the WhatsApp group to give additional perspectives on students' learning.

The four criteria suggested by Guba (1981) are thus directly addressed in this study by the design principles of IQA. In addition, I employed many of the strategies suggested in the literature (data triangulation) as means of promoting the trustworthiness of the research, as elaborated here.

Credibility is similar to internal validity in quantitative research (Thomas & Magilvy, 2011). As stated by Krefting (1991, p. 218),"A qualitative study is considered credible when it presents an accurate description or interpretation of human experience that people who also share the same experience would immediately recognise." Credibility is established through reflexivity, member checking and peer debriefing or peer examination (Thomas & Magilvy, 2011). IQA promotes credibility as it involves member checking, and member debriefing. Participants of the focus group, from whom the data are generated and who constructs the affinities or themes, are interviewed to ensure that the researcher's interpretations of the affinities are recognised by the participants as being accurate representations of their experiences of reality. In addition, prolonged and varied time spent with the participants over the semester in the scheduled tutorial periods, WhatsApp chats and interview techniques and the transcription of these interviews, reflective musings and WhatsApp chats that are used to write the final report in the words of the participants, will strengthen the credibility of the study. A range of data sources will be available (two phases of the IQA process, focus groups and interviews, analysis of reflective writing and WhatsApp group chats) to observe the phenomenon which will contribute to credibility (Guba, 1981).

Transferability is equivalent to external validity or generalisability in quantitative research and is the ability to transfer research findings or methods from one group to another (Thomas & Magilvy, 2011). It "determines the extent to which the findings of a particular inquiry have applicability in other contexts or with other subjects/participants" (Lincoln & Guba, 1985, p. 290). One strategy to establish transferability is to provide a dense description of the population by providing descriptions of demographics and geographic boundaries of the study (Thomas & Magilvy, 2011).

My aim was to craft detailed descriptions of the data, as well as context, so that the idea of "reader-determines transferability" is upheld (Rule and John, 2011, p. 105). By providing rich descriptions of subject and context, the researcher enables the reader to determine the level of transferability of her study. Goebel (2017, p. 85) recommends a deductive explanation to the notion of applicability. She asserts that the requirement of applicability may be met if (i) two or more case studies support the same theory, and if (ii) one can compare the empirical results of one's case study to previously developed theory. In light of this perspective, this study was informed by the theory of threshold concepts and I have been able to draw comparisons with related findings to students' learning in statistics in other contexts, within and outside the threshold concepts framework.

Dependability relates to reliability in quantitative terms, and occurs when the reader is able to follow the decision trail used by the reader (Thomas & Magilvy, 2011). An audit trail was achieved, by describing the purpose of the study, and by discussing how and why the participants were selected for the study. Descriptions of data collection, condensation and analysis and a discussion and presentation of the research findings all assist in maintaining an audit trail. IQA largely circumvents issues of dependability, because the participants generate, analyse and interpret their data within a predetermined protocol. IQA creates an audit trail for each stage of data collection and analysis. Another strategy that may be used to establish dependability is to conduct a step-by-step repetition of the study to see if the results may be similar (Thomas & Magilvy, 2011). The set of IQA protocols promote replicability: adhering to the procedures, different researchers with the same set of focus group data should arrive at the same Systems Influence Diagram representing the phenomenon, regardless of their individual bias and interpretation of the data (Bargate, 2012).

Confirmability is achieved when credibility, transferability and dependability have been achieved (Thomas & Magilvy, 2011). The triangulation of multiple data sources, as explained above, also aided in achieving confirmability in this study. In addition, the qualitative research must be reflective, requiring a self-critical researcher, who is able to reflect on her study and be able to reveal whether one's preconceptions or biases affected the study in any way (Guba, 1981). I have kept a reflective journal, where I recorded personal feelings, concerns and insights. I made these notes immediately after each focus group and individual interview and I made a conscious effort to follow, rather than lead, the direction of the interviews by asking the participants for clarification of affinities. Further reflections on my role in the research is offered in section 4.8.

4.7. Strategies to address ethical and methodological issues

In educational research, ethical and methodological considerations are particularly pertinent when the study involves an inherent power differential between the researcher (lecturer) and the participants (students) (Ferguson, Yonge, & Myrick, 2004). I addressed the concerns associated with the various stages of this study as follows.

Institutional ethical review

Institutional review boards are charged with the responsibility of ensuring that the proposed research judiciously protects the confidentiality of participants and minimises harm to them (Ferguson et al., 2004).

Since the study involved students in a module of the Faculty of Accounting and Informatics at DUT, before its inception I wrote to the director of research as the 'gatekeeper' of the research site, explaining the purpose of my research and requesting permission to proceed[38]. After obtaining her written approval[39], I applied to the UKZN Ethics Committee and received ethical clearance to conduct the study[40].

Recruitment and voluntary informed consent

Participants freely chose to take part in the study: I called for interested volunteers from the class at large after explaining what the programme would entail. In the first tutorial session, all participants completed an Informed Consent Form[41] confirming their agreement to take part in the study. They were informed in writing and (repeatedly) verbally by me that they were free to withdraw from the study at any time, without any negative consequences. I also made it clear that the data collected would only be used for the purposes of this research.

[38] Attached to Appendix 1
[39] Attached to Appendix 2
[40] Attached to Appendix 3
[41] Attached to Appendix 4

Confidentiality and anonymity

Respect for the privacy of participants is important (Creswell, 2013). I expected that the potentially sensitive or personal nature of the information revealed would require that I ensured confidentiality of the data and participants in the tutorials, focus groups, interviews, reflective journals and WhatsApp messages, as well as in the data analysis and writing up of the thesis. Although the nature of the composite quotes characteristic of IQA representation does not call for individual attributions, there may be other occasions where individual participants would receive mention. I proposed to provide anonymity by using letters or numbers (e.g. 'Student X') when necessary in writing up the results. I conducted all of the interviews myself. As required in terms of the University of KwaZulu-Natal's (UKZN's) ethics policy, I kept all confidential documents in a safe place while working on the study. On completion, data will remain in the custody of the School of Education for five years, after which it will be destroyed to preclude unauthorised use.

Dual agency of researcher/lecturer

Researchers who recruit student participants in their study are said to have double agency as they might experience conflicting loyalties as teacher and researcher (Ferguson et al., 2004). The use of IQA mitigated possible concerns around ownership, authority, representation, and positionality. Data generation and analytical processes belonged to the participants, who grouped their responses, named the affinities, and described causal relationships among them. The representations that emerged can thus be regarded as capturing the legitimate voice of the participants (Northcutt & McCoy, 2004).

I sought to establish an understanding from the outset that the tutorial programme should be mutually beneficial to the participants and to me. I explained my study purpose, the importance of their participation, and conveyed my appreciation for their involvement. I told the group frequently that I was open to feedback, critiques or suggestions from them at any time, so that we could ensure they found the tutorials beneficial. To counter perceptions that the group of students participating in this study might receive unfair advantages over the rest of the class, I uploaded all of the tutorial exercises and feedback to the course website, where they were accessible to all

BSTS 201 students. I did not receive any complaints from mainstream students or have any reason to believe there was a sense of preferential treatment of the participants.

An overarching principle of research is that it should be mutually beneficial to the participants and researcher (Cohen et al., 2011; Creswell, 2013). I anticipated that the tutorial programme would help student participants to deepen their understanding of concepts covered in BSTS 201, by engaging with additional material and applying statistical concepts to relevant real-world problems. Beyond these immediate module-related academic benefits, I expected them to gain from working with peers in a structured way, in a small-class context, as well as through the social media platform of the WhatsApp group chat, in a relaxed environment. I also hoped that through reflection they would enhance their metacognitive skills, bringing benefits beyond the BSTS 201 module. The benefits to me consisted not only in access to information and insights that would allow completion of my research, but also in the opportunity to develop my teaching practice informed by a growing understanding of how students learn this content.

4.8 Methodological reflections

This section offers some brief reflections on my use of the tutorial programme as a vehicle for studying learning, on IQA as I applied it, and on my role and involvement in both.

As described in section 4.4.1, the structure of the tutorial programme allowed me to use cooperative learning and small-group discussion, which were not feasible in the mainstream group. This approach demanded intense involvement from me in preparation for as well as facilitation during the sessions. I found teaching in this way rewarding and energising, but knew that the programme was very much a one-off experience that could not feasibly be replicated for the class of a few hundred students within current budget and timetable constraints.

In offering the tutorials, I was constrained by the mainstream course arrangements alongside which the tutorials ran. BSTS 201 is offered to a few hundred students on two campuses, with common content and assessments, several lecturers and a course coordinator. I did not have leeway to depart from the pre-existing syllabus or to redesign assessments to align with the pedagogical approach in the tutorials.

Assessment relies heavily on multiple-choice questions, and there is little room to redesign these in line with a threshold concepts orientation. This may have meant that the potential impact of the threshold concepts-enriched tutorial programme was not fully realised, as participants' learning continued to be driven largely by prevailing assessment approaches (Biggs, 1996). Concerns about assessment arose in individual reflections during the group and reflective writing, and are discussed in later chapters.

I was fortunate to have access to most of the tutorial exercises I used in a suitable format (Triola, 2015; Weiss, 2017), and was able to map appropriate activities to what I perceived to be the typically troublesome, transformative elements of the BSTS 201 curriculum, using only minor adjustments such as the conversion of metric measurements in the examples to the metric system used in this country. Being able to use these activities, which were closely aligned with the threshold concepts theory, not only facilitated the development of the programme but also increased my confidence in the approach. This was borne out by the participants' responses. The ways in which concepts were presented in the tutorial exercises allowed for a different take on the mainstream lectured material, as well as offering the chance to complete or resolve partial or inaccurate prior understandings.

I had to revise my initial plan to use purposive sampling to select participants from volunteers from the class. As it happened, the number of volunteers was only slightly higher than my intended sample, so I invited all of them to take part in the programme. In effect, the participants therefore self-selected. Over the course of the semester, a few stopped attending tutorials, compounding the element of self-selection of those who remained to take part in the IQA processes. While the lack of attention to representivity is not a major concern since the intention is not statistical generalisability, I am aware that there may have been different insights into learning in statistics from those who did not select themselves into the tutorial programme, or who opted out before the end, which will remain uncaptured.

I planned to have the content covered in the tutorial activities keep pace with the content taught in the mainstream lectures. However, participants that were from the other half of the class taught by another lecturer were sometimes behind in the sections covered in the tutorial programme. As such, I had to repeat the tutorial activity the following tutorial session, so that the other participants could benefit from doing an activity based on content that they have already been acquainted with during the lecture periods. Nonetheless, those students who were already familiar with the content were given the opportunity to play the role of tutor and help the other students to understand the new content. (This aspect of learning is discussed further in later chapters). As such, the repetition of a tutorial activity along with other external (out of my control) factors[42] placed constraints on the number of tutorial periods that I was able to hold over the semester, and limited the span of content that I had planned to cover during the duration of the tutorial programme. Thus, the tutorial activities that I designed for the discussion of the statistical topics of hypothesis testing and Chi-squared tests, were not attempted in the tutorial sessions. As a result, insight into learning these topics will remain uncaptured.

My use of IQA revealed some limitations and possible hazards, as well as the advantages noted in describing the approach in section 4.7. Many of my concerns relate to the pivotal role of the focus group, on which the rest of the approach may be seen to depend. First, the communal nature of the focus group, and its emphasis on group reality, seem to reflect an assumption that there exists a single, albeit complex, group reality that can be satisfactorily captured in the SID. The IQA guidelines (Northcutt & McCoy, 2004) do not offer steps to follow if participants cannot reach complete agreement before time and energy run out. In the focus groups, my observations suggested that the participants reached consensus relatively smoothly, and I did not have to respond to this type of dilemma. A concern remains, however, that in seeking consensus, the focus group processes might simply be masking conflict and attaining compromise — the appearance of agreement. The silent nature of brainstorming and clustering in IQA, while offering advantages, may not reveal unresolved conflicts of meaning among participants.

The interviews may address some of the concerns around consensus and silence, by offering an opportunity to explore individual variations in the meaning of affinities. However, the interviews are themselves bounded and structured by the affinities, which inform the interview protocol and therefore largely determine the issues to be discussed. Thus, while the grounded, participant-driven nature of affinities (and their interrelationships as depicted in the SID) is one of IQA's key strengths, this may be a double-edged sword: once confirmed, the affinities are set, and the researcher and readers are called on to trust that they are a fair representation of the participants' reality. While Northcutt and McCoy (2004) point out that the interviews can act as a check of the affinities and influences, they do

[42] Tutorial periods were missed due to the following external factors: two test weeks held during the semester (wherein students do not attend lectures or tutorials), public holiday (Heritage Day), third-term holidays, localised flooding in October 2017 which caused damage to lecture venues, and one tutorial activity had to be repeated so that students attending from the other group could keep pace with the tutorial activity. As a result, at least six tutorial periods were lost during the semester.

not offer comment on the possibility that the affinities and system produced by the focus group in the first place may be flawed. Again, this underlines the critical importance of the execution and functioning of the focus group.

Although IQA calls for a single focus group session, in this study I had scheduled two sessions, five days apart, which allowed me to write up the affinity meanings (as described in 4.5.3) after the first session, for the group to check and confirm at the second. Their agreement would subsequently affect the SID, the interviews, and ultimately the findings of the study. In short, IQA protocol is not self-driving: the focus group phase needs careful planning and management, because all of the phases that follow hang on the credibility of the affinities. Practical considerations should not be overlooked, given the importance of this phase. I found the focus group sessions to be more time-consuming than I had anticipated, and at times logistically challenging, with 17 participants ranging back and forth along the array of cards attached to a wall. Allowing for two consecutive sessions might be an advisable adjustment to the IQA prescriptions, although it also increases the demands made on participants.

I believe the willingness of the participants in this study to commit so much of their time to the focus group sessions, subsequent individual interviews, and reflective writing, was due to several factors, including: the relationship I had established with the group over the semester; their relationships with one another, their understanding and support of the purpose of the research; an appreciation of having their views heard; and last, but certainly not least, the general improvement in understanding of content knowledge that they experienced in their working through of the tutorial activities. The level of commitment of the participants was essential to obtaining the depth of data which was generated in these phases of IQA.

The written reflections I requested of participants were an addition to standard IQA practice, which I hoped might offset some of the concerns around silence or conflict noted above, as a less focused and more private medium, reflective writing, might be a channel for insights students would not mention in the focus groups or interviews. My confidence in the affinities was increased when I found that the reflective writing could be accounted for within those categories of meaning. This modification to IQA may also have enhanced the quality of the data by predisposing the participants to think more widely or introspectively during the focus group phase, since they would have reflected regularly on their learning over the preceding weeks. A consideration of issues of representation in IQA highlights similar concerns to those mentioned in the preceding paragraphs. Section 4.5.3 describes IQA's reliance on composite quotes, woven together from individual sources to sound like a single voice, to elaborate the affinities. This practice presents a trade-off, where, while a holistic and nuanced picture is created for the group, individual voices are not reflected or tracked in these aggregated quotes.

The WhatsApp group chat that replaced the online discussion board as a medium of communication between myself and the study participants (see section 4.3.3), revealed conversation threads that were congruent with the elements that characterised the affinities. In particular, the elements of teamwork, cooperation and see-sawing emotions associated with disciplinary learning (to be elaborated upon in Chapters 6 and 8), were clearly evident when students helped each other with questions posted from past exam papers on the group chat. The range of emojis[43] used to convey participants' experiences' of studying statistics or their gratitude towards their fellow colleagues for their assistance was enlightening. Thus the WhatsApp group chat served as a source of data triangulation through which I could confirm and further increase my confidence in this study's findings.

IQA is about privileging student voices and minimising research influence. However, from my experience, the method as it stands already requires significant researcher engagement in deeper analysis and representation. While IQA is intended to be exactly replicable, this applies to the extent that different researchers presented with the same set of affinities and interrelationships would arrive at the same SID representing participants' views of the phenomenon. Faced with an abundance of qualitative descriptions from the interview transcripts and reflective writing, I had to exercise my judgement, drawing on my own experience and understandings to select and compile composite quotes capturing the range of meanings participants ascribed to the affinities and their influences on each other. I am aware that in this sense my tracks as researcher are all over the data, and it seems disingenuous to suggest that the process of representation and interpretation in IQA is neutral, objective, or unequivocal beyond the production of the SID. Given this, I believe the occasional departure from protocol does not detract from the advantages of IQA as I have used it, but if transparently and reflexively undertaken, may serve to offset some drawbacks or shed light on some blind spots.

[43] A digital icon used to express an idea or an emotion (Wikipedia, 2019).

I reflected on my multiple roles as lecturer/tutor/researcher in Chapter 1. The different perspectives on students' learning these roles afforded me assisted me in further analysing and interpreting participants' descriptions of their learning. In a qualitative enquiry such as this, the researcher is a key research instrument (Creswell, 2013). I was aware of my own investment in the tutorial programme, and in the students' learning. Teaching, as I experienced it in the tutorial programme, was an exciting and rewarding process. I came to know every participant and witnessed some of their learning struggles and successes at close range. Given that 'objectivity', in the sense of my being detached and disinterested in the participants and the course of their learning, was not possible, a supportive stance seemed appropriate.

Clearly I was not an objective outsider as just described. To some extent, the participants seemed to have constructed me as an insider, for instance, assigning mentions of me to the Tut Group, Journey of Understanding and Personal Journey affinities. For my part, beyond the distinct differences (in status, age, race) between the participants and myself, I empathised with them as students learning a new, sometimes troublesome discipline that might demand that they tolerate uncertainty, let go of old understandings, and reconstitute their identities, because this resonated with my concurrent experience in reading for a PhD. At the same time, obvious and undeniable power differentials remained in my role as their lecturer (and eventual examiner). Using IQA as a research approach helped to reconcile these positions, and mitigated my own discomfort around the split roles I occupied. By casting the participants as the experts on their own learning, IQA remained consistent with the dismantled authority relationships which characterised the cooperative learning pedagogy of the tutorials.

4.9 Concluding comments

This chapter has described the research design and methodology I used in seeking to enhance understanding of the processes and experiences of students' learning in statistics: a case study within a qualitative, interpretive paradigm, involving participants in a threshold concepts-enriched tutorial programme. The chosen approach of Interactive Qualitative Analysis was explained. I also considered issues of rigour, and the ethical considerations affecting this study, before offering some reflections on the methodology, and on my role in the research. Chapter 5 provides detailed description of the application of IQA in the focus group sessions, and presents the SID, which represents the group's view of their learning in the threshold concepts-enriched tutorial programme.

CHAPTER 5

AFFINITIES, RELATIONSHIPS OF INFLUENCE AND SYSTEM DIAGRAMS:

THE FOCUS GROUP'S 'THEORY IN PERCEPTION'

5.1 Introduction

In this chapter I will describe how the first phase of IQA methodology, outlined in Chapter 4, was applied to arrive at a system representation of students' reflections on their experiences of learning statistics in a threshold concepts-enriched tutorial programme. Section 5.2.1 describes how data was generated by the focus group participants and explains the application of inductive, deductive and axial coding to identify thematic categories of meaning (affinities) representing participants' learning. Section 5.2.2 elucidates the theoretical coding process by which participants recorded their views on the relationships of influence among these affinities, and the IQA procedures I followed to capture a composite representation of these affinity interrelationships for the group as a whole. The visual representation of the affinity relationships in the form of a SID is developed in section 5.2.3 with a brief interpretation of the SID offered in section 5.2.4. Section 5.3 provides concluding comments for the chapter. The affinities and interrelationships developed in this chapter laid the foundation for the second-phase of IQA in the form of semi-structured individual interviews. The detailed descriptions of the affinities and their interrelationships that participants gave in the interview phase are presented in chapters 6 and 7.

5.2 The IQA process

Northcutt and McCoy (2004, p. 43) assert that "the purpose of an IQA study is to allow a group to create its own 'interpretive quilt'" wherein "The quilt is represented as a system of patches (affinities) held together by stitches (relationships among affinities)" (2004, p. 43). IQA is anchored in the social construction of phenomena, and advocates that those closest to the phenomenon of interest should be directly involved in data collection and analysis so as to limit the "erosion of original data by researcher 'tracks' and enhances the ability of replication by other researchers" (Smith, 2005, pp. 481, 482). Systems theory is linked to the development of IQA methodology, thus imparting a sense of the structure of quantitative analysis to the qualitative data by producing a graphical representation and interpretation of the system.

The IQA protocol of focus group interviews analysis and representation were described in Chapter 4. The aim of the focus group phase (the subject of this chapter) is to identify affinities and the relationships of influence that exists among them. These components of meaning of the phenomenon are captured in a systems influence diagram, with further clarity and variations of meaning attained through individual reflections elicited in the interview phase. In this study, the focus group sessions were intended to generate the groups' unified perception of their reality of learning statistics in a threshold concepts-enriched tutorial programme.

5.2.1 System elements: Focus groups and affinity generation

As stated in Chapter 4, selection of participants for the focus group should be based on the criteria of power over (experience of) and proximity to the phenomenon (Northcutt & McCoy, 2004). Northcutt and McCoy (2004, p. 87) also suggest that the focus group should comprise 12-20 constituents who are information rich with knowledge of and experience of the phenomenon; have the ability to translate their reflections on the issue statements into words; have the time, patience and inclination to participate in the focus group; share commonalities of distance and power vis-à-vis the phenomenon; and adhere to group-work etiquette, respect for other members and not too timid to contribute to the collective effort. Having studied BSTS 201 and participated in the threshold concepts-enriched tutorial programme over the semester, it was self-evident that the students who participated in the tutorial programme should constitute the focus group. They held the knowledge about the phenomenon of their experiences of learning statistics in a threshold concepts-enriched tutorial programme, because of their proximity to and power over the phenomenon.

The participants' written reflections had already given me some insight into their learning in the discipline so they were clearly capable of articulating their learning experience and offering further insight. I scheduled the focus group sessions in the last couple of weeks of the semester, five days apart. Both sessions were scheduled before midday (so that participants were alert and focused and we could take a lunch-break and continue the session thereafter) in a time slot when I knew that they were available. I gave them advance notice of the focus group sessions and provided lunch. After a semester-long interaction in the tutorial sessions, participants were familiar with each other and were relaxed and respectful of one another in the group. This allowed for a smooth running of the focus group sessions. The first session lasted almost four hours (including a 45 minute lunch break) and the follow-up session lasted approximately $2\frac{1}{2}$ hours. Both sessions were attended by 17 of the regular tutorial group participants.

5.2.1.1 Brainstorming

Guided by the advice offered by Northcutt and McCoy (2004), I began the first focus group with a warm-up exercise using guided imagery to help participants relax, clear their minds, and reflect on their learning in BSTS 201 and the threshold concepts-enriched tutorial programme during the course of the semester. Thereafter, I handed out issue statements to the participants, which I read out aloud, and which were designed to generate responses to the research questions. I encouraged students to let their thoughts flow freely and to be open and honest in their reflections of learning in statistics.

The participants then engaged in approximately 30 minutes of silent brainstorming, during which they recorded all their individual, spontaneous responses on index cards, writing one thought or experience per card using words, phrases, sentences or drawings. Once it was apparent that most participants had captured all their responses on index cards, these were collected and randomly affixed to the wall. In all, 217 responses were generated.[44]

5.2.1.2 Clarification of response meanings

The next step in the group process is clarification of the understanding of each individual response in order to “eliminate any ambiguity and vagueness associated with the meaning of the words or

[44] Attached to Appendix 8.

phrases" (Northcutt & McCoy, 2004, p. 94). This also aids in creating a "socially constructed, shared meaning" of each response cars within the group (Northcutt & McCoy, 2004, p. 94). The author of each response is anonymous, so any participant may offer clarification or interpretation of a response. Thus, ownership of the responses generated is shared by the group. I read out each and every response with very few response cards requiring clarification. This phase took approximately 50 minutes to complete and was audio recorded.

5.2.1.3 Inductive and deductive stages of axial coding: Clustering, refining and clarification of affinities

Axial coding "refines, re-organises, and describes the range of meaning of each affinity within the context of the others" (Northcutt & McCoy, 2004, p. 98). The inductive coding phase of IQA requires the focus group participants to review the response cards and then to cluster the responses into groups with a similar thematic thread weaving through them (these themes would later become the IQA affinities). The group members abided by the IQA requirement of silence for this activity to ensure equitable participation in the process by participants. This was a lengthy process, with students moving along the length of the wall, sorting and shifting cards until all were satisfied with the thematic classification of the cards. The response cards were organically organised by the group into four groupings.

In the deductive stage of axial coding, the participants engage in naming, re-organising, clarifying and refining the evolving affinity and any sub-affinities emergent within each cluster. Northcutt and McCoy (2004, p. 99) characterise a well-defined affinity as: (i) not being a person, place or physical thing, but rather describes constructs or characteristics of meaning; (ii) it is homogeneous – describes one construct rather than a mixture; (iii) it is easily named or defined – implying homogeneity; (iv) range of meaning within the definition; (v) it has context (relationship to other things. But affinity names should not depend on definitions that point to other affinities within the system.

I facilitated this process by guiding the participants through the naming process for each affinity. I wrote the affinity names onto coloured cards which were affixed above each cluster. While reviewing the response cards with reference to the newly named affinities, miscategorised cards were reassigned to the appropriate affinity by the participants. This phase was audio recorded. It was an impressive sight indeed to see the response cards ranged across the wall in their assigned affinities. Participants were so excited about the work that they accomplished during this session that they took photographs of the wall of responses and proudly shared these on the WhatsApp group.

The four affinities were identified as:

- Tut Group
- Journey of Understanding
- Emotions
- Personal Journey

Up until this point, the session had taken approximately four hours. I decided to call a halt to the session as students had other commitments. We agreed to meet for a second session the following week to review the affinity write-ups and to complete the ART.

5.2.1.4 Affinity write-up

My next task was to use the participant data (the response cards and discussion that occurred during the focus group session) to capture the meaning of each affinity. The description of each affinity should be "grounded in the text through reference to specific quotes or examples" and provide in-depth coverage of the range of data included (Northcutt & McCoy, 2004, p. 100). The affinity write-up should include the following basic elements: (i) detail; (ii) contrast – what the affinity is not; (iii) comparison – how it is different from other affinities; and (iv) richness – elaboration and examples.

Bearing these guidelines in mind, I drafted the affinity write-ups. Participants' data was richly descriptive and detailed and I was able to write-up thick descriptions for each affinity. At the second scheduled focus group session attended by 17 participants, I read through the write-ups for each affinity (from hand-outs that I prepared for the group). The group constituents confirmed that the meanings I had captured of each affinity were accurate reflections of their shared understanding and experience.

The affinities were used to draw-up the ART, which in turn was used to develop the protocol for the semi-structured individual interviews that made-up the second data generation phase of IQA and are the subject of chapters 6-7. The affinity write-ups as confirmed by the participants provided thick, detailed reflections of their experience with the phenomenon under study and are provided below.

TUT GROUP

This affinity was informed by the constructs that characterised the threshold concepts enriched-tutorial programme in which the students voluntarily participated. The participants identified the tut group as an essential conduit to their understanding in the BSTS 201 module.

Specifically, the teaching methods/instruments used in the tut sessions was viewed by the students as being beneficial to their grasping of statistical concepts. The teaching methods that the students credited for their improved understanding in statistics were: collaboration (group work); the use of real data to solve real world problems; writing in reflective journals; and being provided with the detailed solution after each tut activity.

These were reflected in many responses referring to the teaching methods used in the tut programme: *"Joining the tut sessions was a really good move because we were put into groups where we all had to work together and it is sometimes easy to understand something when you hear someone explain it clearly to you, and how they think it should be done plus it was always fun too"* […] *"The feeling I had joining this group was that it would make Statistics easier for me cause more heads will be joined together in finding solutions than just me alone"* […] *"Working in groups, having the ability to voice your opinion either through writing or just by talking"* **and** *"The learning in this tut programme has real[ly] changed the way I viewed statistical concepts because we in the group help each other and by linking the statistic with the real world was interesting and I enjoyed it"* […] *"Reason for joining this group as because I wanted to learn more about stats and how its used in the outside world"* […] *"In the tut sessions* *we were given questions to ask and then the solutions of the tasks to see where you went wrong"* **and** *"I liked the idea of having a journal so we'd get feedback from some of the thing I didn't understand in class. Also to give my point of view on or after the activity"* **and** *"Our first meeting and activity as a group at first was intimidating, but reflective journals was good on what I thought and enjoy, but as time goes on, I enjoyed the group and felt at home."*

This affinity also reflected the students' positive response to easy access of the instructor during the tut period: *"I also had a chance to get help from the lecturer if I didn't understand a concept in class"* […] *"This group teaches me something that I didn't thought I will ever do. Speaking with a lecturer. YO! YO! I am a very shy person. I never thought that I will ever ask a lecturer a question but now. Hey ☺"* ***and*** *"Now talking about the tut session as a whole, I had fun with it and our tutor/lecturer not sure what to call her !!!"*

The overwhelming consensus on participation in the tut group was: *"This tut group helped me understand the new knowledge about statistics because of the activities that we did together"* **and** *"I feel great about the tut group, it has helped me a lot and I have no regrets of joining it, it has been an awesome experience in learning" and "If I were to rate the tut I would say 11/10 ☺ If it were a hotel I would say it's a 6 star hotel lol!!"*

JOURNEY OF UNDERSTANDING

This affinity encompasses students' progression of understanding of statistical concepts. It documents their journey in the learning process from moments of "stuckness" to triumphant moments of realisation or insight and perseverance with the module that helped them across this spectrum of understanding. This particular affinity resonates strongly with the principles of the Threshold Concepts Framework to learning, alluding to cognitive and affective factors essential to one's successful journey across disciplinary thresholds.

Many students' responses detailed their personal dedication and commitment towards their attempt to understanding the subject that helped to make their journey of understanding a successful one: *"The negative emotions in my learning, I deal with it by giving the learning the time to try and practice more and also seeking help from others"* **or** *"Pretty much statistics is not an easy module it needs time and commitment. But through hard work and dedication it becomes easier and even fun especially during tut sessions"* **and** *"When I struggled to understand something the tut came in handy as I would either ask our lecturer or tut group mates which made things even easier for me than to go over hours trying to figure something on my own"* **and** *"My knowledge of my own learning did change by being in this tut group because I learnt new things and found ways to understand stats by even using everyday problems".*

Students also noted specific statistical concepts that caused impasse: *"I thought binomial distribution was hard coz I wasn't getting the answers everyone was getting only to find its coz I wasn't I don't know what do when P(X<1) or P(X>1) after I understand it was smooth sailing"* **[…]** *"Probability is the one topic that got me stucked like no other. Tjoh it was just too much I guess."*

Students noting specific moments of insight as follows: *"I realised how important statistics is by learning some aspects of it, I was tempted to say to myself , "Oh Stats SA uses these things were learn to make some statements and predictions"* **and** *"AHHA!!! P and q are constant * I never noticed that until I got it in the group tut"* **and** *"After taking time and re-doing what was done in the class, it all made sense as I understood the purpose and use of regression, then I felt little bit relieved."*

Some students described their journey of understanding as starting off rocky but ending on a happy note: *"Pretty much statistics is not an easy module it needs time and commitment. But through hard work and dedication it becomes easier and even fun especially during tut sessions"* **[…]** *"Negative thoughts into positive thoughts – improvement"* […] *"Everything was still very fuzzy especially during simple linear regression and sampling distribution but the tut sessions really did help together with hard work".*

Students credited their participation in the tut group as being a pivotal element in their journey of understanding: *"It* **[tut group]** *did change the way I learnt as there were people who you would discuss the content with and it made it easier to understand. It made it more fun. ☺"* […] *"I understood my own learning after I attend this tut group"* […] *"When I struggled to understand something the tut came in handy as I would either ask our lecturer or tut group mates which made things even easier for me than to go over hours trying to figure something on my own"* […] *"My knowledge of my own learning did change by being in this tut group because I learnt new things and found ways to understand stats by even using everyday problems".*

Students felt that mathematics is a key component in one's successful understanding of statistics: *"It took me time to adjust to Business Statistics cause I'm used to straight mathematics which is what we did in BCAL but with stats it seemed different"* […] *"Just a bit but its still calculations at the end of the day. So you still see statistics and remember high school with pure maths"* […] *"The way I overcome my stuckness was that since I did maths in high school and figured I did get through statistics in maths I should apply same knowledge I got, especially in probability."*

The overarching sentiment shared by the students is that their journey of understanding statistics has been a positive one: *"By learning at home, in class and in the tut I came to understand the new knowledge taught in Business Statistics because I could solve my problems faster and get ready for my tests better"* **and** *"I have come to an understanding that I can relate what I am learning into reality."*

One student responded: *"I do not want to lie learning statistics this semester was stressful."*

EMOTIONS

This affinity represents the range of emotions students experienced while learning BSTS 201 and participating in the tut group.

Some mentioned their initial feelings of fear: *"The moment I saw that I will be taking Business Statistics this semester, I trembled, frightened and scared since I heard rumours people saying the worst is yet to come. Stats gonna show us flames"* […] *"My initial thought about statistics was that it was very difficult, I had a skeptical view, wasn't even sure if I will pass the module."*

Many students expressed positive feelings for the tutorial sessions, saying: *"My feelings of learning statistics changed from feeling bored to excited about learning statistics because of the tut and seeing how it is applied in real life circumstances"* […] *"Best decision ever"* […] *"It has been an amazing experience"* […] *"Figuring out how to calculate an equation is the most AWESOME feeling".* ***Sketches of smiley faces and hearts reflected these positive emotions:*** *"Fun and informative (my experience ☺)"* […] *"Right now I'm ☺ happy"* […] *"I ♥ statistics now yipeee".* ***As well as:*** *"In over all I'm very happy and I think I have fallen in love with this module as it changed the way I see the world as a whole."*

Even test results brought out some positive emotions: *"80% → test one – 90% → test two – (picture of balloons with A's written in them) → exam (final)" and "Second test was actually fun and exciting ... ☺ wish I wrote all my tests like that".*

Some students experienced positive emotions after mastering new concepts: *" Figuring out how to calculate an equation is the most AWESOME feeling".*

However, there was one negative response in the form of: *"☹".*

PERSONAL JOURNEY

This affinity refers to the personal outcomes or life lessons that students gained by learning in BSTS 201 and the threshold concepts-enriched tutorial programme.

Responses reflected personal growth or development: *"Learning statistics did change the way I thought about the world. Yes it did. I never thought that they are people who are not from your family who could help you to do better each an***[d]*** every day. Who can help you reach your goal"* […] *"I just believe in myself and now I am still does"* […] *"Learning statistics has helped me to see myself at large, it made me believe that there are changes for me to become a better person in future. It made me believe there is a 95% for me to leave a mark in this world"* […] *"The one thing I learnt from this tut group and statistics 201 is that you can achieve anything you set your mind to"* […] *"You can achieve anything if you put your mind into it"* […] *"School life hasn't been easy but the journey has taught me perseverance and not to be afraid to aim high and work very hard to achieve and to reach full potential"* […] *"In spite of being terrified by people about how difficult business Statistics is, I said to myself 'I will fight, I am not a loser, everything has got its limitations'. I had a hope that I will overcome any unforeseen obstacles in Business stats"* […] *"I have learned to be persistent"* […] *"What I learned is that if I set goals for myself, I put in the effort and I work tirelessly I will achieve what I want to achieve and I'll succeed in whatever I put my mind to."*

Also participating in the tutorial group and interacting with their peers and lecturer grew students' confidence in their abilities: *"My own learning and thought processes actually improved by being part of this tut programme"* […] *"My group working skills have improved because most of the time the experiments we did in the tut required us to work in groups"* […] *"The way I dealt with challenges was that if I get stuck, Mrs. Ananth is here to simplify things so I would seek help in the tut session. Then that helped take the negative thoughts I had about stats being hard away"* […] *"In this tut programme I learnt to work with my peers which is something I was not used to as I preferred studying/working on my own before"* […] *"Mrs. Ananth's positivity and constant patience has helped me deal with negative emotions/challenges."*

Students also credited their participation in the tutorial programme for overcoming their aversion to working with mathematics: *"The more classes I attended, the more I started to have interest in mathematics"* […] *"Learning stats for the first time this semester felt like here we go again, what is maths doing now. We never became friends with maths. But look at me now. Who knew I would get 70% on stats. Lol!!"* […] *"I used to think DUT never loved us coz this maths but you can actually use it wherever you go, so it's all good."*

Students' perception of learning, in general, improved: *"I have a better opinion about learning as a whole and how stats can be useful in our daily lives"* […] *"Being the inquisitive person I am I have learned that I enjoy statistics a lot, because I always want to question the knowledge I am given. I've also learned that maths is not so bad if you practice"* **and** *"My background and my personality affected me in my learning journey by understanding certain things on how did they come about it, but after learning the statistics it made me really eliminate certain things in my personality."*

The affinities described above may be considered as the system building blocks or components of the group's shared reality of their experiences of learning statistics and participating in the threshold concepts-enriched tutorial programme. These affinities were used to draw-up the ART, the next task that students had to complete in the follow-up focus group session. Participants had to fill in the ART to explain how they perceive these affinities to relate to each other. This task is completed through a deductive process, according to IQA protocol.

5.2.2 Theoretical coding: System relationships of influence

In the theoretical coding phase of IQA, participants use Affinity Relationship Tables (ARTs) to determine the nature of the relationship between all possible pairs of affinities. In the focus group for this study, I used independent, detailed ARTs, because each participant (17 altogether) is required to write a statement that reflects their experiences and that supports the cause and effect relationship recorded for the affinity pair. Independent coding is time consuming, but it is advocated for, as it is thought to yield quality, rich data (Northcutt & McCoy, 2004).

5.2.2.1 Detailed ART completion

I had pre-printed ARTs[45] on which group members worked individually. For each affinity pair, participants decided on the direction of influence (if any) and provided a justification of their indicated relationship. The four affinities generated results in 12 affinity pair relationships[46] to consider. All the participants completed their ARTs in the session.

The completed ARTs were used to complete the IRD (explained below). The examples of relationships of influence that participants provided were used to supplement interview transcripts and reflections in compiling quotes illustrating the direction of influence for the affinity relationships, as described in Chapter 4.

5.2.2.2 Composite group analysis of relationships of influence: Pareto principle

I analysed the ARTs at a group level to create a composite IRD – a matrix of all the perceived relationships in the system (Northcutt & McCoy, 2004); aggregating the responses for each relationship pair in the completed ARTs from 17 participants.

IQA adopts the Pareto principle [47] to statistically determine which of the inter-relationships ought to be included in the IRD. The Pareto principle or 80/20 rule observes that 20% of the variables in a system will account for 80% of the total variation in outcomes in the system (Northcutt & McCoy, 2004, p. 156).

Northcutt and McCoy (2004) encourage a parsimonious[48] representation of the system, where the optimal number of relationships to be included in the model of the system is also "the fewest

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[45] Attached to Appendix 10.
[46] 12 permutations of 4 affinities taken pairwise as the order of the relationship is as yet unknown (eg. $A \rightarrow B$ is as likely as $A \leftarrow B$).
[47] Named after Economist Vilfredo Pareto who developed the concept in the context of the distribution of income and wealth among the Italian population.
[48] The Law of Parsimony or Occam's Razor advocates that an explanation of a natural phenomenon should be portrayed with economical descriptions reflecting simple but evocative models.

number of relationships […] that represents the greatest amount of variation (for the sake of comprehensiveness and richness)" (Northcutt & McCoy, 2004, p. 156).

In applying this principle, I followed the steps prescribed by IQA. The process and its outcomes are displayed in Table 1 below.

Table 1: Affinities in descending order of frequency with Pareto and Power analysis

	Affinity pair relationship	frequency	Cumulative frequency	Cumulative % relationships	Cumulative % frequency	Power
1	**1 → 2**	**17**	**17**	**8.33**	**17.00**	**8.67**
2	**1 → 4**	**15**	**32**	**16.67**	**32.00**	**15.33**
3	**1 → 3**	**14**	**46**	**25.00**	**46.00**	**21.00**
4	**2 → 3**	**12**	**58**	**33.33**	**58.00**	**24.67**
5	**2 → 4**	**12**	**70**	**41.67**	**70.00**	**28.33**
6	**3 ← 4**	**11**	**81**	**50.00**	**81.00**	**31.00**
7	**2 ← 3**	**6**	**87**	**58.33**	**87.00**	**28.67**
8	**3 → 4**	**6**	**93**	**66.67**	**93.00**	**26.33**
9	**2 ← 4**	**4**	**97**	**75.00**	**97.00**	**22.00**
10	**1 ← 3**	**2**	**99**	**83.33**	**99.00**	**15.67**
11	**1 ← 4**	**1**	**100**	**91.67**	**100.00**	**8.33**
12	**1 ← 2**	**0**	**100**	**100.00**	**100.00**	**0.00**

The first step is to conduct a frequency tally. I counted the 'votes' for each of the 12 affinity pair relationships, recording them in an Excel spreadsheet. In total, the participants cast 100 votes for relationships of influence. No participant voted for "no relationship" between any of the affinity pairs. I sorted the relationships in descending order of votes (frequency) and then calculated the cumulative frequency (columns 1-4 in Table 1).

As each additional affinity pair is considered, the cumulative percentage of total possible relationships is calculated (column 5). Each additional relationship adds $^{1}/_{12}$ or 8.33% of the total (thus the first three relationships, cumulatively, accounts for 25% or $^{3}/_{12}$ of all possible relationships, while all 12 relationships account for 100%. The sixth column shows the cumulative percentage of frequency, i.e. of votes cast (based on the total of 100 votes) for the successive affinity pairs. Thus the first relationship drew 17 of the 100 votes or 17%; the first four relationships accounted for 58% or $^{58}/_{100}$ votes. In other words, the entries in this column reflect how much of the total variation in the system (= 100 votes) is accounted for by the cumulative relationship pairs. The final column, Power, is calculated as a cumulative percentage frequency less cumulative percentage relationships.

IQA analysis applies the MinMax[49] criterion in deciding which relationships should be included in the group IRD. "The decision involves optimising a trade-off between two criteria: The composite should account for maximising variation in the system (cumulative percentage based upon frequency) while minimising the number of relationships in the interest of parsimony (cumulative percentage based on relations" (Northcutt & McCoy, 2004, p. 158). In line with the Pareto principle, in this study, although the proportions are not exactly $^{80}/_{20}$, it is still clear from Table 1 that a relatively smaller proportion of the relationships account for most of the variation. Six relationships (50% of the total) account for 81% of the variation in the system. Power reaches a maximum value (highlighted in red in Table 1) at six relationships, which accounts for 81% of the variation in the system, therefore six relationships (highlighted in blue in Table 1) would be a justifiable choice for inclusion in the group IRD because it is the optimal number in the sense of the MinMax criterion.

Included in Appendix 9 is a graph that offers an alternative way of illustrating the MinMax criterion.

[49] MinMax is a statistics decision rule used in game theory to minimise loss in the face of a maximum loss scenario. In IQA, it is used to determine the minimum number of relationships needed to be analysed that accounts for the maximum variation in the system.

5.2.2.3 The group composite Interrelationship Diagram (IRD)

During the process of "rationalizing [sic] the system" (Northcutt & McCoy, 2004, p. 170), the first step is to display a summary of the optimal number of perceived relationships in the system in the form of a matrix called the Inter-relationship Diagram (IRD). The IRD is created by placing arrows into the table, thus showing the direction of influence (cause or effect) in an affinity pair relationship. Arrows point only left or up and each relationship is recorded twice in the IRD. For example, in Table 2, in row 1, the up arrow in column 2 indicates that affinity 1 (Tut Group) influences affinity 2 (Journey of Understanding). The same relationship is captured in the second entry for that affinity pair, in row 2 where the left arrow in the column 1 shows that affinity is influenced by affinity 1. In both instances, the arrows point away from 1 toward 2 (in a typical IRD constructed according to IQA protocol, the affinity names are omitted. But I have included the names purely for explanatory purposes). The six relationship pairs identified for inclusion using the MinMax criterion is recorded in Table 2 below.

Table 2: The Inter-relationship Diagram (IRD)

		1	2	3	4	Out	In	Δ
Tut Group	1		↑	↑	↑	3	0	3
Journey of Understanding	2	←		↑	↑	2	1	1
Emotions	3	←	←		←	0	3	-3
Personal Journey	4	←	←	↑		1	2	-1

The arrows for each row are then tallied. (↑) are counted as Outs and (←) arrows as Ins. The Outs minus the Ins determine the value of Δ (delta). The table is then sorted in descending order of delta. Table 3 appears below.

Table 3: Tabular IRD sorted in descending order of Δ

		1	2	3	4	Out	In	Δ
Tut Group	1		↑	↑	↑	3	0	3
Journey of Understanding	2	←		↑	↑	2	1	1
Personal Journey	4	←	←	↑		1	2	-1
Emotions	3	←	←		←	0	3	-3

The value of delta is used to designate the relative position of an affinity within the system. With reference to this study, affinities with positive Δ's: Tut Group, Journey of Understanding are relative drivers or causes in the system while those with negative Δ's: Emotions, Personal Journey are relative outcomes or effects in the system. These relative positions may be classified further. A driver that has many 'out' arrows and no 'in' arrows may be called a Primary driver (Tut Group). Northcutt & McCoy advise that "Primary driver has a high positive delta and is a major cause that affects many other affinities but is not affected by others" (Northcutt & McCoy, 2004, p. 173). A secondary driver is distinguished as having more 'outs' than 'ins' (Journey of Understanding). It has a relative cause or influence on affinities in the system. The Primary outcome is characterised by a high negative delta resulting from many 'ins' but no 'outs' (Emotions). Thus, the Primary outcome is a significant outcome that is affected by many of the affinities in the system. A Secondary outcome reveals a relative effect and is identified as having more 'ins' than 'outs' (Personal Journey). Often, affinities may have equal numbers of 'ins' and 'outs' – these affinities are referred to as circulators or pivots in the final representation of the system. In this study, there were no affinities that fit this description thus there is no circulator/pivot in this system.

The tentative assignment of affinities in the system is shown in Table 4 below.

Table 4: Focus group: Tentative SID assignment

Affinity		**Assignment**
1	Tut group	Primary driver
2	Journey of Understanding	Secondary driver
4	Personal Journey	Secondary outcome
3	Emotions	Primary outcome

5.2.3 Focus group: System Influence Diagram (SID)

The information presented in the IRD is graphically represented in the form of the SID. The SID is a graphical presentation of the entire system of influences and outcomes – a visual system of affinities and relationships among them (Northcutt & McCoy, 2004).

5.2.3.1 The Cluttered SID

In developing the SID, all the affinities are arranged according to the tentative SID assignment table in topological zones: Primary drivers to the left and primary outcomes to the right. Secondary drivers and secondary outcomes should be placed in-between the primaries. In zones that contain more than one affinity, these affinities should be placed vertically in descending order of delta. Arrows are then drawn, as connections between each affinity pair, in the direction of the relationship as represented in the IRD. This version of the SID is referred to as the cluttered SID as it is "saturated" with each link present in the IRD (Northcutt & McCoy, 2004, p. 176).

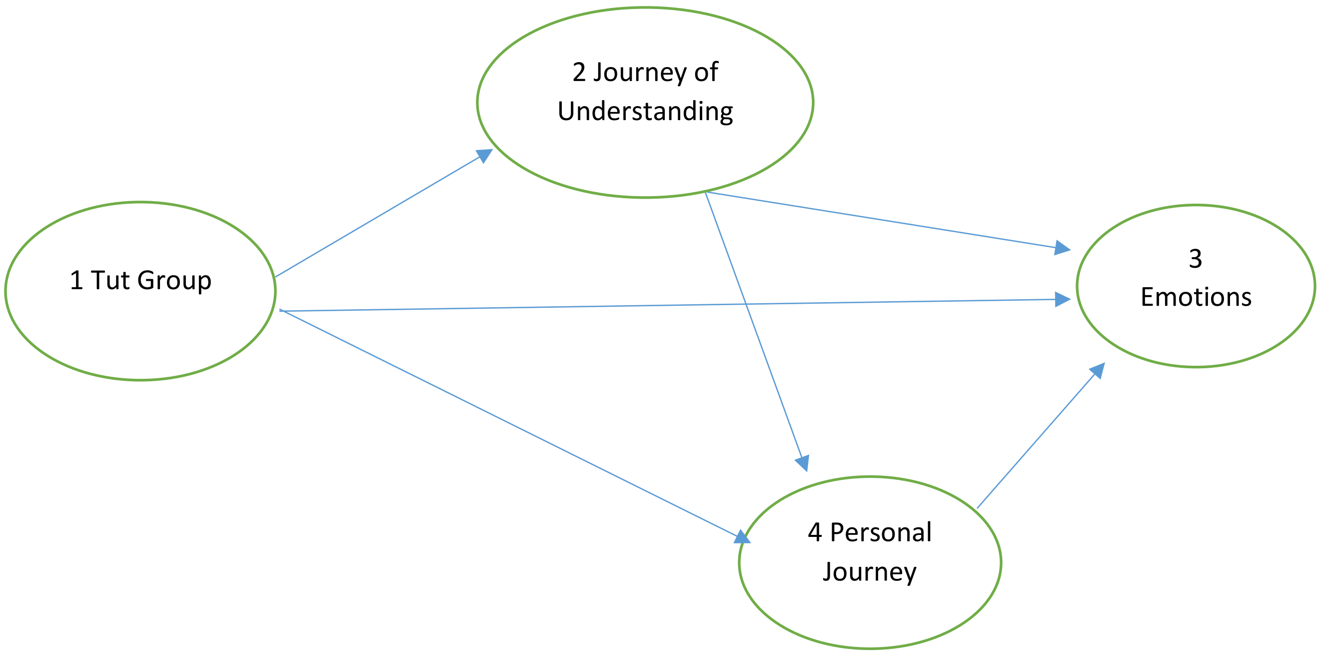


Figure 4: Cluttered SID

Figure 4 shows the cluttered SID which is a vivid representation of the system dynamics. The cluttered SID is the visual culmination of the findings from the focus group.

5.2.3.2 Uncluttered SID

The cluttered SID serves the purpose of offering a comprehensive and rich description of the system but lacks in the objective of parsimony of an SID (Northcutt & McCoy, 2004). In other words, the detailed comprehensiveness of the cluttered SID, saturated with the many links, can dilute the explanatory power of the SID as the system becomes "boggled down by the details of the relationships" (Northcutt & McCoy, 2004, p. 176). To reconcile the "richness-parsimony dialectic" of the SID (Northcutt & McCoy, 2004, p. 176), IQA proposes the removal of redundant links, i.e. remove direct links which instead can be facilitated by mediating affinities. Redundant links are removed by considering affinities at the extreme left (highest Δ) and the extreme right (lowest Δ). If there are alternate paths between the two deltas other than the direct link, then that direct link can be removed. To illustrate the point, in the cluttered SID for this study, link $1 \rightarrow 3$ would be considered redundant, because $1 \rightarrow 2$ and $2 \rightarrow 3$, thus the direct $1 \rightarrow 3$ link can be removed.

By eliminating the redundant links from the cluttered SID, the system is said to be “rationalized [sic]” (Northcutt & McCoy, 2004, p. 178), thus yielding the uncluttered SID: “a simpler, more interpretable mental model – one that has optimum explanatory power” (Northcutt & McCoy, 2004, p. 177).

The uncluttered SID representing the participants’ experiences of learning statistics in a threshold concepts-enriched tutorial programme is presented below.

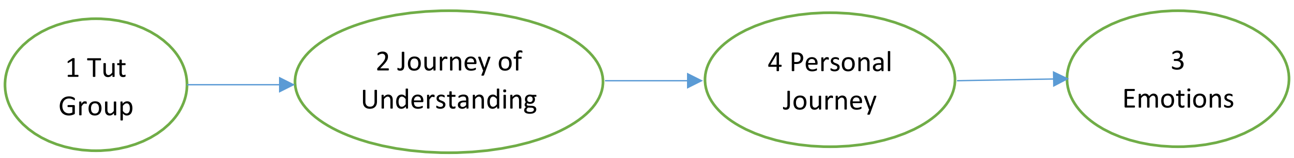


Figure 5: Uncluttered SID

Due to its simplicity, the uncluttered SID, paradoxically has the most explanatory power offering a visual composite mind map or mental model of the participants experiences in its rationalised form (Northcutt & McCoy, 2004, pp. 147, 183). The visual representation may be expressed through language as follows: the dynamics of participating in the Tut Group drove participants’ learning in statistics by influencing their Journey of Understanding in the discipline. Their disciplinary Journey of Understanding brought about a shift in the way students think about statistics and in the way they think about learning in general. This shift in thinking about learning impacted on students’ Personal Journey, which culminated in an influence on their emotions.

5.2.4 Feedback loops, zooming and naming

A feedback loop comprises a system of at least three affinities, wherein each affinity influences the other either directly or indirectly. For example, considering an arbitrary system, the links ($A \rightarrow B$; $B \rightarrow C$; $C \rightarrow A$) comprises a feedback loop in which each of the three affinities, A, B and C influence each other. Thus, in a feedback loop, the distinction between drivers and outcomes is blurred. A, B and C have individual, independent meanings, but through their interconnectedness they have a collective meaning as a dynamic set of affinities.

Zooming refers to naming feedback loops with a name that succinctly captures the essence of the individual components comprising the feedback loop. By zooming out, simpler views of the SID are constructed. Northcutt and McCoy (2004, p. 337) explain that "zooming is actually just another form of affinity analysis conducted by the investigator for interpretive purposes."

In this study, the SID featured no feedback loops. The uncluttered SID features a simple though evocative linear system with no branching. However, the sequential interaction of Tut Group, Journey of Understanding and Personal Journey evokes connotations of a spiritual journey or pilgrimage of sorts. Spiritual in the sense that participation in the Tut Group impacted on students' understanding in the discipline (journey of the mind), which ultimately had bearing on students' personal journey of self-discovery (spiritual journey). This pilgrimage captures the essence of a mind-soul connection, where students initially embarked on a cognitive journey of the mind by participating in a threshold concepts-enriched Tut Group (a pedagogical tool) and ending in a Personal Journey of enlightenment and self-reflexivity. Thus, I decided to name the sequential interaction between Tut Group, Journey of Understanding; and Personal Journey: a Pedagogical Pilgrimage.

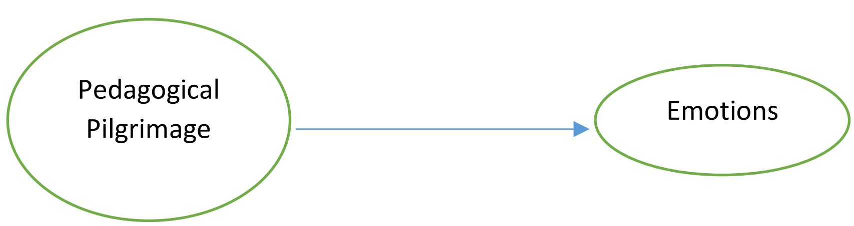


Figure 6: Telephoto view of SID

This minimised linear view of the system cannot be simplified further and comprises only two elements, "the bare minimum for a system" (Northcutt & McCoy, 2004, p. 337). Students' pedagogical pilgrimage ultimately impacts on their emotions.

The SID will be referred to repeatedly through the remaining chapters as I represent and discuss the findings in subsequent phases of IQA.

5.3 Concluding comments

This chapter featured the process and outcomes of the focus group phase as applied to my study. The participants generated responses to issue statements related to their learning of statistics in a threshold concepts-enriched tutorial programme. Participants thematically categorised these responses to construct and name affinities. I used these responses to complete the affinity write-ups, which participants verified as being an accurate reflection of their shared meaning of the affinities. Their views on the relationships between affinities were recorded in ARTs, which I used to compile the IRD. The construction of the SID based on the IRD, represents a visual mind map of the system as perceived by the participants. The multiply linked cluttered SID was rationalised to yield the uncluttered SID. From this I was able to present a verbal summary of the participants' views of their shared reality. The uncluttered SID was further minimised to yield the simplest, telescopic version of the SID, in terms of which the students' pedagogical pilgrimage drives the Emotions affinity.

The SID arrived at thorough consensus during the focus group phase of IQA presents the group's reality of the phenomenon under study as a 'theory in perception'. The in-depth individual interviews that followed the focus group sessions offers fine-grained analysis and variation at an individual level of the affinities and their relationships of influence. These descriptions are the subject of chapters 6 and 7, where the SID and its components are drawn on in representing and discussing emergent findings.

INDIVIDUAL REALITIES: REFLECTIONS ON A SHARED LEARNING EXPERIENCE

INTRODUCTION TO CHAPTERS 6 AND 7

The focus group sessions described in Chapter 5 provided insight into students' experiences of learning statistics in a threshold concepts-enriched tutorial programme that they had participated in over the semester. Data gathered during these focus group sessions were in the form of individual written responses to issues statements that reflected their experiences of learning statistics. These responses were grouped into clusters of meaning (affinities) for which consensus amongst the group participants was sought and achieved in order to create, refine, and name the affinities. Individual ARTs were then completed by the participants and the culmination of these responses was a visual representation of the group reality in the form of the SID. The SID offers a structured mind-map of the system's components and is the initial step towards understanding students' experiences of learning in the discipline. The completed ARTs, reflective responses generated during the first focus group session, participants' reflective writings and individual interviews all present data at the same level of analysis at an individual level. These individually generated sources of data will be used to offer a composite, fine-grained analysis of the affinities and the relationships of influence that emerged from the focus group stage of IQA. This description and presentation of individual realities will be the subject of the next two chapters.

The description of each affinity and influences amongst them in the following two chapters is based almost exclusively on participant's depictions of their individual realities of their shared experience of learning statistics, expressed in their own words. This promotes transparency and credibility of the research findings as it allows the reader "to examine the data along with the researcher and to draw their own conclusions about the study" (Northcutt & McCoy, 2004, p. 302). The IQA guidelines for presenting these results as well as my departures from IQA protocol for presenting the findings for this study are outlined in the following section. The chapters that follow present the composite affinity descriptions and the relationships of influence emanating from each affinity. Chapter 6 considers each of the four affinities, separately, and presents a composite description of each affinity. Chapter 7 describes the relationships of influence emanating from each affinity.

IQA system description rules

The IQA rules for presentation of the study findings limits researcher interpretation and opinion of the results to a bare minimum. The possibility of researcher bias creeping into the study findings is eliminated, thus adding credibility to the data and it also provides the reader with an audit trail for the study's findings and conclusions (Northcutt & McCoy, 2004). In arriving at this stage of the study, I followed the steps reported in detail in Chapter 4, coding the transcripts of the 17 individual semi-structured interviews, the students' reflective writings and individual responses conceived during the brainstorming segment of the first focus group session. I assembled axial quotes for each affinity and organised these into sub-groups containing quotes that address a common theme describing the affinity. I have interpreted these sub-groups as being the fundamentals of the affinity. In the same way, in addition to the theoretical coding completed by the participants in their ARTs, I compiled quotes regarding the directions of influence for the affinity relationships from the ARTs, interviews, reflective writings and individual written responses from the first focus group session.

In line with IQA custom, all the composite axial affinity descriptions in terms of their fundamentals is presented first (in Chapter 6) before proceeding to the description of relations of influence amongst the affinities (in Chapter 7) (Northcutt & McCoy, 2004). I departed slightly from IQA guidelines by augmenting the IQA-standard interview data with the inclusion of extracts from participants' reflective writings and individual focus group responses. I also found that some participant musings arising from their reflective writings and response cards clearly alluded to a specific affinity and as such, could be accommodated within the various fundamentals comprising the relevant affinity. Additionally, extracting pertinent information from various sources of data served as triangulation of the study results, thereby enhancing the credibility of the study findings. In another slight departure from IQA guidelines, after each sub-affinity composite quote I also added a summary paragraph to highlight the main features of the sub-affinity.

Northcutt & McCoy (2004, pp. 314-315) state that "Because IQA is designed to describe the perceptions of the phenomenon or the lived reality of the group, it makes sense to describe the affinity purely in the words of the group". According to IQA "Rules of Evidence and Juicy Quotes" (Northcutt & McCoy, 2004, pp. 316-322), the composite description of affinities based on participants' quotes should proceed as follows:

- The researcher provides a description of the affinity by making an opening statement which provides an overview of the affinity, the researcher's understanding of the affinity, highlighting its salient features, the evidence for which will be presented later in the form of the participants' composite quotes.
- The description of the sub-affinity begins with a statement in bold which captures the essence of the sub-affinity in the voice of the participant. This sentence is repeated later as part of the composite quote.
- The second sentence interprets the sub-affinity in the voice of the researcher and contains a key noun or phrase that is italicised.
- The remaining paragraph – indented and italicised – consists of multiple quotes in the voice of the participants, selected by the researcher and minimally redacted to read as one voice.

A similar format is used in describing the influences of each affinity (Chapter 7). These sections begin with an individual affinity with arrows showing all of the relationships of influence stemming from that particular affinity and that were included for analysis in terms of the Pareto protocol (Chapter 5). The numbers on the arrows indicate the order in which the six relationships in total are documented. Thus, chapters 6 and 7 deals exclusively with the presentation and description of individual realities.

CHAPTER 6

INDIVIDUAL REALITIES WOVEN IN THE WORDS OF THE CONSTITUENTS:

THE COMPOSITE AFFINITY DESCRIPTIONS

6.1 Introduction

The composite affinity descriptions in this chapter give a more detailed view of each affinity and its fundamentals. The quotes that make-up the affinity descriptions are composited from multiple quotes taken from individual participants, lightly edited where necessary (for instance to correct spelling in written sources or grammatical errors from verbal sources for ease of reading), and the quotes are woven together to read as the experiences of a single participant. Thus, each composite affinity description is comprised of individual participants' realities, in the process revealing the variations that exist between individual realities of the shared learning experience. In the following section, each of the four affinities is considered separately and are described in terms of their constituent fundamentals. The affinities are considered in descending order of delta, corresponding to a left-to-right reading of the SID, from drivers to outcomes in the system. Sections 6.2, 6.3, 6.4 and 6.5 focuses on the affinities: Tut Group, Journey of Understanding, Personal Journey and Emotions, respectively, providing composite quotes which illuminates each of the fundamentals that constitutes the respective affinity.

6.2 Tut Group

Tut Group emerged as a primary driver in the system that constituted the focus group's experiences of learning statistics in a threshold concepts-enriched tutorial programme over the semester. Tut Group encompasses all the qualities and attributes related to student's participation and interaction in the semester-long threshold concepts-enriched tutorial programme that students saw as being influential on their learning statistics. Tut Group, a name that the participants chose for this affinity, is a colloquial reference to the tutorial programme, which conveys a sense of the familiarity and camaraderie that participants developed towards their peers and lecturer over the course of their participation in the programme. The participants did not view the tutorial programme as a formal, regulatory academic programme, but rather, as a non-formal, convivial gathering, where learning was facilitated and friendships developed. In the system, Tut Group is a colossal force driving the other affinities and fundamentally intrinsic in their constitutions.

My analysis of participants' reflections on Tut Group yielded nine sub-affinities (fundamentals) that captured the essence of students' meanings for Tut Group:

- it was interesting and made me want to come for more;
- the most difficult module in DUT;
- we in the group help each other;
- linking statistics with the real world;
- I found with enough practice it all made sense;
- yes, I do have a working grasp of the statistical concepts;
- joining the tut sessions was a really good move; and
- as time goes on, I enjoyed the group and felt at home.

6.2.1 Fundamentals of Tut Group

Opening Statement: Students' participation in the tut (tutorial) group (programme) was a key force in their understanding in the discipline, enhancing students' experiences through group work, classroom activities and instructor style. Tut Group is a major component (primary driver) in a system that is largely seen as a transformative and unique experience. The small class size, keeping of reflective journals and frequent writing in them and being handed detailed solutions to each tutorial activity were also critical components of the Tut Group, which enriched students' experiences of learning statistics.

6.2.1.1 It was interesting and made me want to come for more. For many students, joining the tutorial programme was an opportunity to be able to *understand statistics better*.

My initial feelings towards Business Statistics were of fear, doubt and anxiety; that it's a complex module as it requires high cognitive thinking and intelligent students. I feared the worst might happen since I've heard of how difficult it is to pass the course. Doubt was lingering in my mind if I was going to be part of the statistics of those who don't make it. But then again, I was eager to take on the module as I'm always eager to learn new things. I joined the tutorial programme in the hopes of improving my understanding of the course, to acquire more knowledge about statistics and also get better marks. This tutorial will help me understand more and find other ways to understand statistics. I'm absolutely excited about what it has in store for me; I get to improve my knowledge in terms of statistics. I knew it will be beneficial to me, I'll have a better understanding of the work. The tut showed a lot of interesting factors about Business Statistics and it therefore made me want to be part of the programme. All in all the first tut session has helped me a bit in overcoming my fear towards Business Statistics; it was interesting and made me want to come for more as I thought it would teach me more. The tut sessions so far have been an eye opening experience; attending these tutorials helped me see how much of the work we do in class I really understand. At times I think I've locked it down and when we are doing the tut activities I realized that I haven't really locked it down like I thought I did. It is very easy to fail statistics and in seeing that, I knew that joining the tut sessions would really be of help because it is where you get a clear understanding of statistics and all the topics we had to cover, of what to do and how to do it. I wanted to improve and change my thoughts (negative) about some of the topics covered in statistics.

Fear, doubt and anxiety about learning the new discipline of statistics was the driving force for students wanting to participate in the tutorial programme. The tutorial sessions were viewed as a unique experience that did, to some extent, help alleviate students' fears of the subject. The tutorial activities served as a barometer for gauging student understanding of content. If students were able to understand the tutorial activity then they were reassured that they understood the concept. If not, they knew that they had to work at their understanding.

6.2.1.2 The most difficult module in DUT. Students anticipated problems with the mathematical content of the course in terms of not having done a high level of mathematics in high school and being intimidated by *scary formulae.* Joining the tutorial programme helped in alleviating their fear of mathematics.

> *When I was doing my first year, I heard people/other students who were doing 3rd year and BTechs[50] talking about this module. Honestly, they didn't speak nicely about it. They were always saying that it is the most difficult module in DUT especially if you are doing it without any background of pure maths (if you didn't do it in high school). I kept that in my mind. The work that is covered is completely new, it's something I haven't done in my school career and I'll battle with it. But I was always telling myself that I would be able to do it. Here comes the day of registration, it appears on my proof of registration, this thought comes back into my mind. It was like it has been put on repeat, because I couldn't stop thinking about it. I was never good at maths in high school, but good in accounting. Like most students I didn't have the best experience with maths in high school. Despite my dedication to the subject it just didn't love me back. So I thought that may be history will repeat itself. I did Math Literacy by the way, that is the main reason I want to attend the tutorial. My challenges in Business Statistics is that it got so many formulae that I find it difficult to understand. The challenge might be learning and understanding them; it's kinda tricky. When I heard about this tut, I joined it, and now everything has changed. This group taught me not to listen to other people. When I joined the tut group, I found it beneficial, because I also had a better view about maths in general, and how we can use maths in real life, cause I never saw the correlation between the two. I just thought that maths is just made for us to have a hard time, but then I saw that we can actually use it for real life problems.*

The Business Statistics 201 course is infamous amongst the 3rd year Cost and Management Accounting students for its underlying mathematical content. Students were scared about this because either they did not enjoy mathematics or they did not do a sufficiently high level of

[50] Bachelor of Technology – a post-graduate degree equivalent to an Honours degree at traditional universities.

mathematics at high school. By joining the tutorial group, they were introduced to activities that applied the mathematics to real world phenomena. The practicality of the mathematics that they were learning helped cultivate an appreciation for the subject amongst the students.

6.2.1.3 We in the group help each other. Students credited the opportunity afforded in the tutorial sessions of working in groups as helping them *improve their statistics knowledge.*

> *The tut group, the way I saw it was a way that could help me understand more of the content of the module, in the way I'd interact with people and they'll be able to explain everything to me and it will stick, because the more people explain to you as compared to you doing something on your own, it becomes easier. I always enjoy working in groups, because it's part of the reason why I have been able to succeed throughout my academic career. Taking part in the tutorials applying the 5 P's (Proper Planning Prevents Poor Performance) and working in groups was the best idea ever, because we get to see things from other people's point of view, and breakdown the information so that it's easier to understand. I get a chance to consult with other students in the group, and they help me, or rather we help each other better understand what we are working with. I get to help other students which is also beneficial to me because I get more assurance about my problems with stats and understanding. It made me understand the work more than if I did it alone. Today I was working with a new group from Group B, and I'm from Group A. It was kind of challenging working with them since they are still behind with the topic that we did today. But it was good working with them because I had to do a lot of explaining, which helped me discover what I did not understand in class, and couldn't respond to them. Most of the time, group work is the best compared to individual work, and you get more information and easy ways to tackle the question. If you are not sure of something or you can't handle a particular thing, group members always give you a hand. What I like about this tutorial, if there is something that I don't understand it enables me to ask from my class mates. Today we handled the exercise very well, everyone was participating making sure we get correct answers. Group work was amazing, fortunately I worked with people who seek for answers, 'un-lazy'; when there is a problem you faced regarding business statistics you just ask for help from your*

tut group members using communicating channels provided in the tut session; it was really comfortable for me; that really helped me to learn the work. The learning in this tut programme has really changed the way I viewed statistical concepts because we in the group help each other. This tut group helped me understand the new knowledge about statistics because of the activities that we did together. I think it helps working in groups than individuals when practicing business statistics; I learned that I am not as good as I thought in solving problems alone, but with group work I'm even more productive and excel. With the help of this group, I did better; I gel with everyone and they assist me to better understand statistics; I had a chance to tackle exercises by myself or with a peer and that really helped me to learn the work. I also enjoy the fact that we get to know each other. Why this didn't happen when I was doing my first year? I didn't think I will be able to study with a group of people. My personal attributes, skills and knowledge for this tut programme, was being able to communicate with other students when needing help and also gain much knowledge from the students in the group on how to tackle questions in the statistical way.

The structured format of the group activities developed students understanding in statistics. Students were able to seek guidance from their peers whilst at the same time get a sense of their own understanding by trying to explain a concept to the group. This group work facilitated students communicative skills and imparted a sense of confidence at being able to impart knowledge to their peers. Students' meta-learning perception improved as they came to the conclusion that learning in a group is more beneficial than trying to struggle through understanding a concept on one's own and that they really do enjoy collaborative learning.

6.2.1.4 Linking statistics with the real world. The realistic component of the tutorial activities, collection and analysis of real data to help resolve practical real-world problems and the application of statistical concepts to real-world phenomena helped to improve students' understanding in the discipline by allowing them to *see the bigger picture*.

Reason for joining this group is because I wanted to learn more about stats and how it's used in the outside world and apply it in real life situations. Tut programme helped to give me more understanding when we do activities, since we were doing practical examples. So whatever we did in class, when you come to the tut group, we put it into practice and we understand more of the concepts that we did. Collecting real data and applying the data to the real world was really amazing; was superb!!! The first activity we did, where we were measuring height and shoe sizes was very interesting, as I found it to be practical and was a real life example. The tut programme has been very interesting, especially when it comes to real life experiment and by linking statistics with the real world; helped to give me more understanding when we do activities. When real life situations were used, it made me understand how I can apply theory into the real world and actually solve problems or make mathematical assumptions. I would also try to use my own real life experiments to try and understand the work better and it did help me understand the work. Learning in this tut programme has changed the way I view statistical concepts; to see how real life statistics is implemented and finding out that all the methods really do work. For example, the storm that happened a few days ago, it is confirmed that damages are 30 million of which I believe that Statistics South Africa had to confirm that. Now I can relate as to where Statistics South Africa obtain such information to come to some conclusions and predictions. I think economists also use this information in their predictions/forecasts. I enjoy this course as it is very practical to the real world and it enhances me with useful information.

The application of statistical concepts to real world problems impacted students' understanding in the discipline. In seeing how statistics is used in the real world, students' perceptions on the utility of statistical concepts improved, and they were also able to explain how statistics is obtained and disseminated in related disciplines.

6.2.1.5 I found with enough practice, it all made sense. Students viewed the tutorial sessions as an extra statistics class wherein the activities in the tutorial programme served as extra practice of the application of concepts learned in class and in test preparation. These extra lessons positively impacted on students' learning, making them believers of the age-old adage: *practice makes perfect* ☺

> *Business Statistics will challenge me, as it seems like a module that needs to be practiced in order to do it well; to master Business Statistics you need a lot of practice. I deal with challenges by doing more practice on what is challenging me. The tut sessions have been good and productive for me as it gave me more exercises to practice with, and I would regard this tut programme as extra lessons, which provided useful information, 'cause whatever I couldn't figure out in class, the activities would come in handy and assist me. What I liked about the extra class is that we get an opportunity to understand the work better, we get a chance to tackle the activities by ourselves that's when you see where you lack and where you understand. The tut programme helped me get more practice in the work since in class we would only do the example in the book. I feel very happy about this tut because it helped me to understand better what I missed during the lecture. It enables us to practice more and also in our own time as we are given extra activities to do at home. The examples that we were given to try out were do-able, even I managed, I must say this tut seems to have been a good move for me as I am gaining from it; doing my exercises helped me to understand stats. Tut sessions would really be of help, because it is where you get a clear understanding of statistics and all the topics we had to cover, of what to do and how to do it. The time consumed by the tut was worth it, as every tut was progressive and very helpful in learning. The aspect which I find difficult was understanding the topics, but as time progress and engaging with the group for business statistics tut, it really helped me a lot to overcome my difficulties and help me improve my marks. In the tut group we were provided with activities that helped us a lot when we studied for the test, because I found with enough practice it all made sense. The study preparation for Test 1 was good and the tut we are doing really helped me a lot; my preparation for Test 2 was a bit stressful, but the tut sessions helped me a lot, because we did activities that helped me when I was studying. I have my own skills, which I have developed in this tut programme, that helped me in doing better on my tests; I prepared for the test with the help of my friends/group mates. We worked really hard and we collected past year papers. It worked out really well, as we all achieved excellent results.*

> *My feeling about this tut is I am very happy, it helped me score more in my tests. The tut has been of great help to me and my studying; I was surprised at the mark I got for test two, I did not expect it. I was very glad I passed, made me start preparing for the exam even earlier.*

Students realised that to be successful in statistics, volume, and variety is key. In the sense that students should work through as many examples as possible that explores the concept in various ways. The activities in the tutorial sessions gave students this variety of extra practice, which honed their statistical skills enabling them to perform well in tests.

6.2.1.6 Yes, I do have a working grasp of the statistical concepts. Participation in the tutorial programme heightened students' working knowledge and appreciation of the various statistical topics leading students' to be of the opinion that *stats is also for dummies (not just the smart ones)*.

> *Probability distributions are intriguing. Sometimes tackling probability questions on your own can prove to be a bit tricky, especially if you don't know which method to apply to which question. Today's session about probability distributions was very interesting, as I got to learn and understand the chapter more, my understanding has been broadened and I can now prepare and do activities with much better knowledge and ease. I had fun in this tut, as we came up with different results. The probability of having different results. The probability of having different outcomes is always different. Statistics taught me that every time I am doing something, I should know that there are possible chances. Either it happens or not, either it comes out good or bad, etc. It made me understand it more, and I would use it when I am at home or with friends, or writing a test or exam. It has helped me understand, each chapter that we do, better. It enables us to ask for help and be answered/helped where we don't have a clear understanding. Today's tut was a bit challenging. Binomial distribution is what I am finding hard, though I look forward to continuing the tutorial next week. Today I had some difficulties with determining whether we are looking for X or Z, but the tut helped me. Probability distributions and modelling was good, I am learning every day we have the programme.*

> *Yes, I do have a working grasp of the statistical concepts especially sampling distribution, non-sampling distribution, sampling with replacement and sampling without replacement. Without the tut group, I wouldn't have learned that we can use stats to predict future occurrences in real life, known that stats is also for dummies (not just the smart ones).*

The tutorial activities were pivotal in students' understanding of particularly troublesome topics (for example, probability and the binomial distribution). Students' initially struggled with these topics when they were introduced in class, but through the format of the tutorial activities, such as structured peer collaboration in solving real world problems, they managed to attain a working grasp of the concepts.

6.2.1.8 Joining the tut sessions was a really good move. Learning in the tutorial programme had a transformational effect on students in terms of learning in the discipline and on a personal level allowing them to *see things differently*.

> *Being part of this group at first, it was intimidating, but as time progressed* […] *I felt at home and relaxed and enjoyed being part of it. ☺ I wish all modules could be the same because this really improved my learning and it gave me hope. It has shown me that I can do things that other people think I won't be able to do with the help of this group. I did better. Why this didn't happen when I was doing my first year? I don't regret my decision on joining the tut group. Before I used to stress about five modules, but now I only stress about four modules. I was afraid to join the tut group, because I thought I won't get what I want. But hey ☺ I get more than what I expected. I would like to convey my gratitude for this opportunity to have this tutorial programme as it makes me willing to learn more in statistics and it gives me confidence towards my studying. Joining the tut sessions was a really good move; happy with each tut. Through all the tuts, hard work and commitment, I now see things differently. Being part of this tut did not change me*

that much or made me see the world differently at large, but it has taught me how to tackle challenges differently from a different aspect and perspectives. I have an increased hunger to learn ever since I joined this group. More hunger for knowledge. Well, to be honest, I would advise anyone doing stats to join the tut, as it may help them to improve their statistics knowledge. Tut group = knowledge, friends, constructive. I enjoy doing statistics now, unbelievable but true. The tut grouped has been very helpful for me as I've developed the love for statistics. Learning of BSTS 201 and this tut programme is the best thing ☺

If I were to rate the tut I would say 11/10 ☺ If it were a hotel I would say it's a 6 star hotel lol!! I would rather miss my birthday party than miss the tut.

Students' experiences in the tutorial programme impacted on their personal lives. Their participation in the tutorial programme, in the form of collaboration with friends (old and new), increased their metacognitive perceptions with students asserting that through hardwork and commitment their goals may be achieved. Their metalearning capacity was also heightened in terms of having an increased confidence towards studying in general.

6.2.1.9 As time goes on, I enjoyed the group and felt at home. Students' commended the lecturer's instructional style of conducting the tutorial sessions and highlighted the small class size, the use of reflective journals and being handed the solutions to activities as being constructive to their learning in statistics *making things even more easier*.

Now talking about the tut session as a whole, I had fun with it and our tutor/lecturer. Having the ability to voice your opinion either through writing or just by talking and with the help of our lecturer who made everything manageable for us. The tut group is, I feel like, it's there to help us students. Because sometimes it's very difficult to ask the lecturer for help, especially in a big class. So I feel like having a tut group helps us to understand the work better and some students are shy to ask for help in a big class. So having a tut group, it helps us to understand better, it's there to benefit us as students and I feel like the tut group should have a different approach than a lecture. In the tut *sessions we were given questions to [answer] and then the solutions of the tasks to see where you went wrong. I was also happy when I saw the solution and discovered that I was on the right track. I also had a chance to get help from the lecturer if I didn't understand a concept in class. This group teaches me something that I didn't think I will ever do. Speaking with a lecturer. YO! YO! I am a very shy person. I never thought that I will ever ask a lecturer a question but now. Hey ☺. Our first meeting and activity as a group at first was intimidating, but reflective journals was good on* [voicing] *what I thought and enjoy, but as time goes on, I enjoyed the group and felt at home. I liked the idea of having a journal so we'd get feedback from some of the things I didn't understand in class. Also to give my point of view on or after the activity.*

Our lecturer is very helpful, welcoming, kind and easy to approach, making things even more easier and comfortable because we don't fear to ask or answer any questions. Questions that are hard to ask in class are easier to ask in the tut session because there is a small amount of students. It is a pleasure to be taught by someone who has so much of experience. You have made us succeed in our module ☺ I am grateful to you Mrs. Ananth. I feel like I owe you. Thank you so much.

The format of the tutorial sessions being so different from their usual large classroom setting of small group collaboration, writing in reflective journals and receiving the solution to the activities proved to be beneficial to the students since the small class setting was not intimidating to students, and allowed the more reserved student to seek help from peers and the lecturer. Students appreciated the opportunity to voice their thoughts and concerns in the reflective journals and to receive feedback from the lecturer. Being handed the solutions to the activities allowed students to reflect on the work done during the tutorial session and a guideline to reference when studying. Students also credited the lecturer's *helpful, welcoming, kind and easy approach* as a contributing factor in their understanding in statistics.

6.2.1.10 Synopsis: Fundamentals of Tut Group

This composite set of complex interactions that constitute Tut Group may be summarised as follows. Initially, students volunteered to participate in the threshold concepts-enriched tutorial programme, because statistics was notoriously difficult. Students felt that by joining the tutorial programme they would gain a better understanding of statistics. Fear of the underlying mathematical concepts in the discipline was also a driving force for students wanting to be a part of the tutorial sessions. Spurred on by these initial fears, students' found that once they were a part of the tutorial group, what they had hoped to gain from the sessions was achieved. As they worked together, friendships were made and students began to see each other as resources in their learning journey. Reality based tutorial exercises helped them construct a deeper understanding of statistical concepts and these additional exercises augmented their classroom learning. The small group interactions with peers and lecturer created a protected, friendly and supportive space and served to bolster students' self-confidence and impressions of their own abilities thus enhancing their metacognitive and meta-learning perceptions. Students recognised that their learning in statistics in the tutorial group was significantly impacted by small group peer and lecturer interactions, reality based problem solving and constant practice and that hearsay and fear of mathematics are surmountable challenges.

The next section describes the fundamentals comprising the affinity Journey of Understanding.

6.3 Journey of Understanding

In this section, participants understanding of the Journey of Understanding is elaborated. This affinity was described as a secondary driver in the SID that described students' learning and that emerged during the focus group sessions. The Journey of Understanding may be viewed as an expedition that the students' embarked on with the final destination being an attainment of understanding in the discipline. By analysing students' interview transcripts, reflective writings and responses to focus group issue statements, I identified the following sub-affinities:

- **I just could not understand what and why I am calculating;**
- **The practicality of probability and statistics as a whole;**
- **STUCKNESS → into → AHA;**
- **AHHA!!! P and q are constant * I never noticed that until I got it in the group tut; and**
- **When I understood statistics my world became so much better ☺**

Each is described further in the following section, which again relies on composite quotes to reflect students' meanings of the affinity.

6.3.1 Fundamentals of the Journey of Understanding

Opening Statement: A secondary driver in the system, this affinity details students' journey of understanding in the discipline. It describes the journey's terrain as comprising deflating moments of 'stuckness' and elevating 'AHA' moments. Various factors impacted on students' journey of understanding – personal attributes, participation in the tutorial programme and lecturer attributes. The general timbre of this affinity is positive and uplifting, imbued with the essence of students' marvel at their achievement of understanding in the course.

6.3.1.1 I just could not understand what and why I am calculating. Students recounted the statistical concepts that posed the most amount of challenges to their learning in the discipline with the module being succinctly described as *complex*. The use of mathematical symbols (including, but not limited to, Greek and Roman letters) to denote various disciplinary concepts proved confusing and their being incorporated into various formulae proved troublesome to students' understanding, echoing students' aversion towards mathematics acquired from high school. Specific statistical topics, with probability and probability distributions being frequently mentioned, also served as stumbling blocks in their understanding in the discipline.

> *My journey of understanding was hard at first, I must say, because of all of the concepts and everything about stats. There are so many symbols to use and the terminology. Sometimes, there are questions that I didn't know how to answer, like which formula to use. I didn't know what formulas to use for each example given to us. They seem to be very alike/similar so it gave me difficulties in understanding which one belongs to this and which one belongs to that. I just could not understand what and why I am calculating. But it's still calculations at the end of the day. So you still see statistics and remember high school with pure maths. I understand the working concepts of most but hated having a lot of info to study or understand about the type of samples. The other*

> *way I overcome my areas of stuckness was that since we are asked in a MCQ way, I would simply work around the given answers till one satisfies the question, especially in calculations. I do not want to lie learning statistics this semester was stressful. Especially, in probability. Probability is the one topic that got me stuck like no other. Tjoh! it was just too much, I guess. First test was challenging ☹. Tests are rather painful when you confuse one component or information, you feel like you might get 25/40 at times. I thought binomial distribution was hard, because I wasn't getting the answers everyone was getting, only to find its because I don't know what do when $P(X<1)$ or $P(X>1)$. The moment we had to use the binomial formula for more than one trial was interesting. Or the Poisson formula and figured it used averages. I was really confused, especially with the tables (Normal and the t tables). I didn't know when to use the table or how to use the table. Sometimes I would use a figure above the needed number in the Z table. It was hard. Complex.*

Students struggled with the symbolic representations of statistical concepts and formulae. Often confusing when and where to apply the various formulae. The statistical probability tables were also confusing to students along with the topics of probability and probability distributions. Students continue to merge their aversion for mathematics with the difficulties they experience in learning statistical content. Some students have even employed artful methods of arriving to solutions to multiple choice questions without necessarily understanding the reasoning behind the question.

6.3.1.2 The practicality of probability and statistics as a whole. Many of the 'AHA' moments came about when students could link the application of statistical concepts to practical problems. Their mastery of the various concepts through application to real-world phenomena, during the tutorial activities, made them consider themselves a *statistics 'expert'*.

> *I never used to understand statistics, especially in high school, when we did statistics. The statistical part of mathematics, I never used to understand it. But then as we did it in class, in the statistics lecture and in the Tut Group, I got to understand probabilities*

and all that. I have come to understand a lot about statistics than before I did Business Statistics. I have come to understand that information presented in numbers has been accounted/obtained through statistics. So this semester most of the things I would be doing in statistics pertain to real life situations. The knowledge taught in Business Statistics made us understand the outcome of it when linking it with the things happening in the real world. I even understand how statistics works, how economists work using statistics. The practicality of probability and statistics as a whole. For example, how statistics predict the spreading of HIV & AIDS in South Africa using samples. I was tempted to say to myself, "Oh Stats SA uses these things we are learning to make some statements and predictions". I always asked myself how do weather forecasters, forecast weather that turned [out] *to be really true sometimes, now I understand that stats is involved and probability. I really didn't see the use of statistics and how they affect our lives. But now I have come to see how we can predict future occurrences by using the frequency of past occurrences. After all, we all watch the weather after the news ☺. The thing that simplified everything for me was that although statistics required a lot of formulas, most of it was in the calculator so it made life easier. The topic I loved most was sampling distribution, because it has formulas that are straightforward, all you have to do is to determine the distribution that is used and apply your formula. After taking time and re-doing what was done in the class, it all made sense, as I understood the purpose and use of regression, then I felt little bit relieved. I asked questions that related to my confusion which helped me understand and also brought some of my 'AHA' moments. Through commitment to the tut and paying attention in class, I could understand more about the subject. I knew I got it when I started getting 80% of the questions right.*

Students' mastery of statistical concepts came through when they were able to link its application to the real world. The integrative nature of concepts was revealed to students' and reinforced through its application to real-world problems in the tutorial sessions. Students' appreciated seeing statistics being used in real world phenomena. Some felt they mastered specific concepts when they performed well in tests and attributed their understanding to *commitment to the tutorial*.

6.3.1.3 STUCKNESS → into → AHA. Documenting their experiences of their journey of understanding, students' described their experiences of learning in the discipline as *interesting yet frustrating*. For many students, the arc of their journey of understanding began on an unsteady footing, but ended with a firm understanding of disciplinary concepts.

> *When I started stats I had a bit of a skeptical view about it, because people used to tell us that it's a very difficult module, you need to work really hard. At first I was worried, how am I going to understand stats whereas I escaped maths during high school and engaged with maths literacy. Everything was just like written in a language I didn't understand. I felt the load. It's interesting yet frustrating because you would think you understood in class, do it at home, you end up with question marks. But as the semester went on, we began to understand with a few hiccups here and there. Once you are there, once you do it, you actually see that it's not actually bad. I don't think that stats will ever be an easy subject but it gets better with time, depending on just how much you want to know. Test 2 was a nightmare, but I believe it's not as bad as I think. What I found difficult in test 2 was Chapter 5. The theory!!! I won't be beaten twice. Exam is my day to avenge myself. Negative thoughts into positive thoughts – improvement.*
>
> *The more I practiced, it became easier and easier. Yes, it's better now than before STUCKNESS → into → AHA. I enjoy it more. I remember in the past years I was always told that stats is the most difficult module in second semester, only to find it is not as bad as they say I'm handling it just fine. My journey of understanding was difficult, but the more I attended the group, it really helped me understand and, enjoy the understanding of statistics. Things are so much different now, I look forward to attending statistics every day.*

There were trepidations before embarking on this course, because students heard stories about the difficulty of the course and their insecurities about mathematics. Initial disappointments with test marks notwithstanding, students assert that through thinking positively, attending the tutorial programme and continuous practice of examples their journey of understanding in statistics improved considerably.

6.3.1.4 AHHA!!! P and q are constant *I never noticed that until I got it in the group tut. Participation in the tutorial programme was a pivotal element in furthering students' along their journey of understanding. The various components of the tut group – small group active learning activities and accessibility to the lecturer allowed students to gain a *broader understanding of the topics*.

> *There are somethings that I didn't understand in class but I didn't ask because I was afraid that my class mates would look at me. When you are shy like me, sometimes I'm scared to ask. And then because we have this group, I get chances to ask and then some other student, who did understand in class, they will tell me what I didn't understand in class. The tut sessions have been very beneficial for me because questions that are difficult to ask in class are easier to ask in the tut session because there is a small amount of students. I would either ask our lecturer or tut group mates which made things even easier for me than to go over hours trying to figure something on my own. The most challenging part was to actually understand the question and figure what was expected of me. I never gave myself time to practice on my own, I would only hear things from class. I overcame this by bringing this matter in the tut group and practice and practice. Working in groups helped me to have more understanding where others come up with ideas that make it easy to answer questions. Everything was still very fuzzy, especially during simple linear regression and sampling distribution but the tut sessions really did help together with hard work. AHHA!!! P and q are constant * I never noticed that until I got it in the group tut. Business Statistics have helped me understand real world problem-solving using linear regression, very well. Thanks to the tut group, now I can bet using probabilities pity I haven't won any ☹. Probability has always given me a problem since high school, but this tut session helped me understand it better; because this programme has my back "AHA" ☺, they are not a problem at all. Before I entered the group, my understanding was so little, and I just thought I would fail. But then as I came to the group, my understanding changed and now I understand more, because I*

can relate it to things that are happening in real life and be able to tackle whatever question I am given. There's a lot I understand in this tut group, since we're using examples that are relevant and real-world examples to solve practical problems. I have a broader understanding of the topics that we studied in class and the tut, because the class was more theoretical and the tut was based more on practical and real life examples, which helped me view statistics in a wider angle. My knowledge of my own learning did change by being in this tut group, because I learnt new things and found ways to understand stats by even using everyday problems.

I have come to an understanding that I can relate what I am learning into reality. Overall, I loved and hated the subject. Most of the time I'll be like I'm going to do my homework at home, but then I don't get to do it. Then when we attended the tut group, it forced me to think and it forced me to answer the questions which made me understand a bit more. Most of the things that I didn't understand in class, I was able to understand in the tut group. Understood it more with tuts and being comfortable in the class. I joined the tut so I understand the content so I am happy I did. I give credit to my lecturer, she was committed and patient to us students, it really helped having her around. She made everything better. More than anything I have enjoyed having Mrs. Ananth as a lecturer. She has taught me - stats (well obviously ☺), kindness, ability to use my intuition.

The constructs of the tutorial sessions, involving comfortable small group interaction around reality based activities grounded in a statistical concept and the opportunity it afforded to liaise with a *committed and patient* lecturer, advanced students' along their journey of understanding. Students' metacognitive journey developed when they found that their understanding of statistics improved by relating statistics to everyday problems.

6.3.1.5 When I understood statistics my world became so much better ☺. Students' personalities often impacted on their journey of understanding in the discipline and conversely, their journey of understanding made an indelible impact on themselves as learners and impression of their abilities, motivating some to *consider teaching statistics*.

Statistics is difficult to understand and pass. That affected me, I came with that belief. A very challenging subject that wants you to learn to think for yourself. Solving for x's was never one of my strong points and I think I accepted that during my high school days. Statistics is a module you must start understanding from the beginning, just so you can understand it better. It is not a subject that you can just rush now that exams or tests are around the corner; it needs time and commitment. The negative emotions in my learning, I deal with it by giving the learning the time to try and practice more and also seeking help from others. My understanding of my own learning and thoughts changed by being a part of this tut programme in a good way. Learning in groups was difficult for me as I prefer working alone, that way I find myself most comfortable, but coming to the tut helped me see that groups can at some points be more productive than working alone. It changed the way I learnt as there were people who you would discuss the content with and it made it easier to understand. It made it more fun ☺

I understood my own learning after I attend this tut group. Through hard work and dedication it becomes easier and even fun. I understand by focusing while the lecture is explained. I overcame the "stuckness" by understanding the concepts of each chapter and what was expected of the question asked. By learning at home, in class and in the tut I came to understand the new knowledge taught in Business Statistics, because I could solve my problems faster and get ready for my tests better. Personality: "Fake it till you make it" using that saying played a huge role in me giving answers like I actually understand, until I actually understood through time. One day I would like to be a teacher. I will now consider teaching statistics and make my learners like it and understand it better than myself.

By embarking on this journey of understanding in statistics with the belief that the subject is difficult, and by placing pressure on oneself to understand the topics from the onset only added to students' struggles in their understanding in the discipline. However, learning through the uniquely structured tutorial programme, practicing examples at home and paying attention in class transformed students' thinking about their metacognitive and metalearning capabilities. They were now able to improve their problem solving skills and prepare better for tests while gaining the confidence to declare that they too could teach statistics someday.

6.3.1.6 Synopsis: Fundamentals of the Journey of Understanding

The blurring of mathematics with learning new statistical content knowledge can leave students feeling overwhelmed. Additionally, the language of statistics, in terms of symbolic representations of discipline-specific terminology and the application of formulae led to a lot of confusion. Bad experiences of learning descriptive statistics and probability as part of the high school mathematics syllabus would often surface, prompting an aversion towards studying statistics during the semester and inducing anticipatory anxiety towards learning statistics. The tutorial programme provided students with an additional opportunity to engage with the concepts and the format of the activities – structured group work around concepts embedded in relatable, real-world applications – promoted a deeper approach to learning, which enhanced their understanding of the content. Over the course of the semester, students moved towards a deeper and more complete understanding of statistical concepts. However, the progression in their understanding was not linear, it entailed time and increased effort through an increase in engagement with the content through the tutorial activities and working through past exam papers; and a positive personal outlook. Feeling stuck on certain concepts was a common element of the Journey of Understanding – these were termed as the students' 'moments of stuckness' that were overcome through students' investing time and effort in practicing additional examples, and by participating in the tutorial programme, which allowed them ease of access to the knowledge of their peers and lecturer. Reaching an understanding of particular concepts (most frequently, linear regression, probability and probability distributions and sampling methods) was considered a breakthrough 'AHA' moment that brought clarity and a new perspective on the course content and sometimes on real-world phenomena as well. Students' metacognitive perception was heightened through a greater self-knowledge and awareness of how their academic histories, attitudes and self-beliefs affected their Journey of Understanding. This included taking cognisance that meaningful learning may only be achieved if understanding of the concepts is allied with application of this understanding.

The next section offers a description of the fundamentals of the affinity Personal Journey.

6.4 Personal Journey

Through their studies, students' Personal Journey was transformed. Personal Journey was analysed to be a secondary driver in the system. Several sub-affinities captured the meanings students' ascribed to Personal Journey.

- **we encounter new things as we grow in life;**
- **but you can actually use it wherever you go so it's all good;**
- **I left with the question: "Is statistics correct?";**
- **that helped take away the negative thoughts I had about stats; and**
- **general perception of learning improved.**

The following section provides evidence of students' meaning of this affinity in the form of composite quotes.

6.4.1 Fundamentals of Personal Journey

Opening Statement: Learning in Business Statistics 201 and the tutorial programme brought about a transformational effect on students' personal development and perceptions of oneself. Students' credited various factors for being instrumental in their growth – peer collaboration in the tutorial sessions, active learning activities, engagement with the lecturer, and perseverance. Students also experienced an ontological shift in their learning, reflecting on how their views on mathematics and learning, in general, have been significantly altered. Being described as a secondary outcome in the system of influences (in Chapter 5), Personal Journey is impacted on by the affinities of Tut Group and Journey of Understanding but, in turn, also influences the affinity of students' Emotions.

6.4.1.1 We encounter new things as we grow in life. Students' reflections on their experiences of learning in BSTS 201 and the tutorial programme was somewhat philosophical with many proclaiming that the experience helped them *become more confident* in their abilities and what they can achieve in life.

In spite of being terrified by people about how difficult Business Statistics is, I said to myself "I will fight, I am not a loser, everything has got its limitations". I had a hope that I will overcome any unforeseen obstacles in Business stats. It had its pros and cons, like anything else would, but it was fine, we encounter new things as we grow in life. The journey has taught me perseverance and not to be afraid to aim high and work very hard to achieve and to reach full potential. Learning statistics did change the way I thought about the world. Yes it did. You can achieve anything if you put your mind to it. I believed from the first day, when I got my matric results that I can do something better in life. School life hasn't been easy; the only people who believe in me are my family. Each and every day I always want to do something that will make them proud of me. My background is the only reason why I work hard. My background and my personality affected me in my learning journey. I have learned to be persistent. What I learned is that if I set goals for myself, I put in the effort and I work tirelessly, I will achieve what I want to achieve and I'll succeed in whatever I put my mind to. Being the inquisitive person I am, I have learned that I enjoy statistics a lot, because I always want to question the knowledge I am given. This module has made me question how the stats we see on TV, newspapers, etc. were calculated/compiled. Yes it changed me. I just believe in myself. Hardwork, dedication, commitment. I was able to improve myself. So I became more confident. Statistics has groomed me personally since I can see things now, a different point of view. Learning statistics has helped me to see myself at large, it made me believe that there are changes for me to become a better person in future. It made me believe there is a 95% chance for me to leave a mark in this world. So I can say that I'm groomed by studying statistics. So some decisions, I can approach it using statistics knowledge. The one thing I learnt from this tut group and statistics 201 is that I think I gained more knowledge, I was more knowledgeable. And actually doing it and seeing that it's not as difficult, it also brought confidence to me. My personal journey, being in this programme, it made me want to achieve more and it gave me more confidence. Yes, it gave me confidence. I think personally I have grown. My ability to understand has changed for the better and personally I think it has been good. Getting to find yourself and growing as a person despite everything, because you are seeing the skills and everything else that you have. So it kind of brings out things you didn't know about *yourself. So I found that maybe I could consider like teaching or something, because I think I'm really good with working with others, especially sharing and helping each other. Well, with all of this, it made me realise that as much as it's a module, it's something that's going to help with my life. So I now apply it with everything that I do.*

From the above students' descriptions, we see an ontological shift in students' perception of self and their learning. They offer the view of having been *groomed* by their positive experiences of learning statistics to not quit on their goals and to persevere in their life's ambitions. This has encouraged a new-found sense of confidence in their own abilities and aspirations. Furthermore, successfully understanding disciplinary content and applying it to real world problems has developed students into critical thinkers. Students are no longer passive receptors of statistical data, but are now cautious and critical about the statistical information they read and see in the media.

6.4.1.2 But you can actually use it wherever you go so it's all good. The learning journey in statistics helped shape a new found interest in mathematics and helped fashion a conversion of attitude from a general aversion towards mathematics to an, albeit, resigned '*maths is not so bad*'.

First time I attended Business Statistics 201, it felt like I was hit by a bomb. I was not excited at all, because I don't like maths – CPF was brought to use in the first year (CPF = Cram Pass Forget). Learning stats for the first time this semester felt like here we go again, what is maths doing now? We never became friends with maths. I panicked because I knew that probability would be done during the module and I was never good with probabilities. First lecture begun, where scary fomulae appeared then I started panicking and wondered if I will make it. At first, I had problems of identifying the suitable formula for the question. From the first day I attend this tut, I saw that something good is coming but the other part of my mind told me that I won't be able to do it, because people told me that stats is not for people who did maths literacy at school. The more classes I attended, the more I started to have interest in mathematics. Look at me now!

> *Who knew I would get 70% on stats? Lol!! I've also learned that maths is not so bad if you practice. I used to think DUT never loved us because of this maths but you can actually use it wherever you go so it's all good. Learning statistics wasn't optional (this semester). At first I would have never chosen the module, but now I can even study it next year.*

Learning in the tutorial sessions helped to transform students' perceptions towards mathematics. *Scary formulae* aside, students' learned to appreciate the wide-ranging practicality of statistics and irrespective of the level of mathematics achieved at high school, through dedicated attendance at classes and practice, success in statistics is attainable.

6.4.1.3 I left with the question: "Is statistics correct?" Interacting with their peers and applying statistical concepts to *solving real life problems* helped students grow in confidence and understanding.

> *At the beginning, statistics looked hard, but when I started doing it, it become easier and more exciting to study, because of the tut sessions. I joined the extra class to better my understanding about statistics and indeed it did. In this tut programme, I learnt to work with my peers, which is something I was not used to, as I preferred studying/working on my own. I never thought that working with a group of people can work for me, but it really worked. My group working skills have improved, because most of the time, the experiments we did in the tut required us to work in groups. I found that the saying 'practice makes perfect' is true, because when I understood concepts and I was doing them at home and I got to explain to my friends, it made me understand more when I gave information to other people. It helped me grow as a person and know how to interact with my peers, since I'm mostly a private person. So yes, I can say it helped me gain self-confidence and how to be a participant. Solving real life problems opened my mind and I started understanding some of the things I never understood. Recalling the first activity we did working with the group, where we had to measure each other's heights and shoe sizes. I left with the question "is statistics correct?" The answer to that*

question is that it is approximately (≈). I liked the idea of using this method (reality problem solved).

The tutorial programme provided an opportunity for students to interact with their peers, sometimes on a slightly elevated level, when they had to teach and explain concepts to others. This was viewed as growth in some students who are generally reserved, and this gave them a heightened sense of self-confidence and made them open to the idea of being participants in future collaborations. Teaching their peers also helped to solidify their understanding of the content. The extra practice that the reality based tutorial activities provided enhanced students' understanding in statistics by helping them experience the concepts in new and different ways.

6.4.1.4 That helped take away the negative thoughts I had about stats. The lecturer's disposition towards her students, her *positivity and constant patience*, encouraged students to persevere in their understanding in statistics.

I never thought that there are people who are not from your family who could help you to do better each and every day. Who can help you reach your goal. Mrs. Ananth's positivity and constant patience has helped me deal with negative emotions/challenges. The way I dealt with challenges was that if I get stuck, Mrs. Ananth is here to simplify things so I would seek help in the tut session. The responses I received from ma'am were very encouraging and helpful. Then that helped take the negative thoughts I had about stats being hard away.

Students tend to thrive under a caring, nurturing hand. Lecturer attributes of positivity, constant patience, encouragement and helpfulness are the qualities that students assert are influential to their learning.

6.4.1.5 General perception of learning improved. Students' experiences of learning statistics in the tutorial programme impacted on their metacognition and metalearning perceptions, in terms of how they view themselves as learners and the learning process, in general. Many students now have a deeper appreciation of and *better opinion about learning*.

> *There was a time when circumstances affected my learning, not specifically in stats, but my learning in general. My own learning and thought processes actually improved by being part of this tut programme. I have a better opinion about learning as a whole and how stats can be useful in our daily lives. I've learned to be fast and communicate with other people. Ask questions when I have them. I engage with other learners. I've gained how to answer questions. Firstly, you have to read question and understand what is required from you to do it. I focused on the positive emotions and challenges in my learning of the tut because all the negative would have just driven me away and I wouldn't have all the knowledge that I have now on statistics. One thing I was not used to was practicing. I used to practice the day before I write. But in this group, tut group, I saw that the more you practice, you get better at it. Most of the time when I study something and I come to difficult parts, I'll do it tomorrow or I'll ask someone tomorrow. But with statistics, I've learned to overcome whatever stuckness I come across. So now I'm eager to set higher marks. For instance, I got 65% for Test 1 and I set a higher goal, I wanted to get 90%, and I got 82%, which is fine. I've learned that since I now understand statistics, I can even do much better in other modules as well. Even if I won't have to be with the group, but I now have the courage to tell my lecturers if I don't understand, ask them questions and even ask my peers in class.*

Students' metacognitive consciousness improved from their experiences of learning statistics and participating in the tutorial programme, where they came to the realisation that focusing on the positive aspects of a challenge rather than dwelling on the negative aspects serves learning best and to persevere with it. Through continuous practice, meaningful engagement with one's peers and lecturers on troublesome concepts actually becomes a learning aid. Meta-learning perspectives changed by realising that procrastination simply delays the understanding of a concept, where once a barrier has been crossed, it only becomes easier to vault others.

6.4.1.6 Synopsis: Fundamentals of Personal Journey

Studying statistics and participating in the tutorial programme over the semester wrought an ontological shift in students in terms of their metacognitive and meta-learning perceptions. Students seemed to be in awe of their success in learning statistics, a subject that they were warned about for its being difficult, and involving mathematics and *scary formulae*. Their positive experience in learning in the discipline grew them personally in terms of self-confidence, whether from their ability to teach peers to interacting with a lecturer, and has allowed them to aspire to greater goals in life. They have reached the realisation that they are capable of asking for help from peers and lecturers and that their learning is best served by perseverance and constant practice. Students have realised that procrastination is the enemy of success and that learning successes may be compounded by dedication and hard work. All these personal attributes will make the learning journey easier to traverse, but having a lecturer who is helpful, patient, and encouraging makes the journey all the more enjoyable.

6.5 Emotions

Students' journey of learning in the discipline were replete with a myriad emotions. These emotions arose from various sources – encountering new knowledge, being reacquainted with concepts that proved to be troublesome in their academic history (mathematics), the process of learning in itself, and assessments. From participants' description of the range of feelings they experienced, I extracted the following sub-affinities.

- **but then you still carry on with it in the end;**
- **we all think we're leaving it behind;**
- **I was seeing myself failing but then that all changed because of the group;**
- **all the happiness, the joy and maybe some sad moments; and**
- **I am ready for the exam ☺.**

The following section presents the fundamentals of the affinity Emotions as a composition of participants' quotes.

6.5.1 Fundamentals of Emotions

Opening Statement: Emotions was a primary outcome in the workings of the system. Students communicated having experienced a range of emotions in their learning of statistics. Specifically, students' initial feelings of stress and fear of studying a new discipline with its underlying mathematics content gradually metamorphosed into feelings of happiness, joy and ultimately love for the subject. Participation in the tutorial programme played a central role in students' metamorphosis of feelings towards learning in statistics.

6.5.1.2 But then you still carry on with it in the end. Initially, students' feelings towards studying statistics was one of fear and trepidation. Fear of the unknown (not sure of what to expect in the module) and fear of the known (unpleasant encounter with statistics in high school). To some, the encounter with the content of the subject was like, *Boom*, an explosion going off in their heads.

> *The moment I saw that I will be taking Business Statistics this semester, I trembled, frightened and scared since I heard rumours, people saying the worst is yet to come, stats is going to show us flames. My emotions were not good, because I was so scared of statistics. I was frustrated and scared of the module because of high school, statistics, all those things. I had a skeptical view, wasn't even sure if I will pass the module. When I started doing it, it looked harder than I thought. Oh my word, learning stats is like "Boom". How I felt about stats was that I wasn't really happy, I was a bit stressed because I had this mentality that it's difficult. It was fear, frustration, I was sad. Your mind tells you statistics is going to be hard and then your mind just makes you feel all kinds of emotions. At times you feel like crying. At times you feel happy. At times you just don't know what to do with yourself. That's just statistics. But then you still carry on with it in the end.*

Initially, students experienced many negative feelings about studying statistics. Most of these feelings could be attributed to the rumours about statistics being difficult. Their first impression of the course was equated to experiencing a manner of explosion. But students resigned themselves to accepting that they have to do the course.

6.5.1.3 We all think we're leaving it behind. The fear of interacting with mathematical concepts and formulae in the discipline affected students' emotions. Students felt frightened by the prospect after having *escaped maths from high school*. But after a semester-long interaction with the course content and participation in the tutorial sessions, students no longer feared maths, but actually grew to love and understand it.

> *For the first time, I felt frightened, because I didn't do something like this in school. I only know basic maths, algebra. But then in statistics you have to do a lot of formulae and everything. There was a point where I thought I wasn't gonna make it because it felt like too much and I thought I escaped maths from high school. We all think we're leaving it behind, but actually it came back. I was only good when I had to solve X's and do all the other equations, but not this. I love maths now. I love maths, I love statistics. I used to hate it because it was a bit complicated. Now I like it, I'm happy when I do it. The more I do it, the more I understand it, the more I like it.*

From being afraid of the unfamiliar content, to only knowing basic mathematics and to feeling overwhelmed by the mathematical content, students actually ended the course declaring their love for mathematics and statistics. This was a turnaround that students attributed to continuous practice, which leads to familiarity and understanding.

6.5.1.4 I was seeing myself failing, but then that all changed because of the group. Overall, participation in the tutorial programme nurtured students' positive emotions for learning in the discipline. The tutorial activities set a tone of being *fun and informative,* which made for a happy experience.

> *Before it was fear, frustration, I was sad, I was seeing myself failing, but then that all changed because of the group. The first tutorial session was exciting, to say the least. I hope the next sessions will eradicate the fear completely, and replace it with a passion and a hunger to learn more. My feelings of learning statistics changed from feeling bored to excited about learning statistics, because of the tut and seeing how it is applied in real life circumstances. Once I joined the group, it changed my view of stats. I went from*

> *being stressed to being more relaxed and confident in other modules too. Now, I tend to understand more and understanding makes me feel happy. Most of the time it was just positive emotions, not really sad or depression, anything like that. It was just positivity due to the tutorial group, because it helped stimulate positivity. After attending the tut group, I started seeing myself improve. So I just become happy. I am so happy I have got to a point where stats has become one of my favourite courses this semester. I'm very happy to be a part of this tutorial programme. ☺ I wish I learned it when I was doing my first year. This was a really fun experience for me. In my entire three years of studying here, I've never experienced so much joy. I even look* [forward] *to coming to each and every tut because you're so fine and you're so cool with us. It has been an amazing experience. Theee Best! I'm very happy and I think I have fallen in love with this module as it changed the way I see the world as a whole. I wish I only did statistics. Best decision ever. I 💙 statistics now, yippee! It's good. That's all I can say. It's very good. Right now I'm ☺ happy.*

From initially feeling fear and frustration towards studying statistics, students' experiences of learning in the tutorial programme, developing a collegial relationship with peers and lecturer helped cultivate happy emotions towards learning in the subject. Joining the tutorial programme transformed students' perceptions towards studying statistics from being stressed about it to absolutely loving it. This *amazing experience* being a part of the tutorial programme allowed students to engage with their other modules with a relaxed and confident approach.

6.5.1.5 All the happiness, the joy and maybe some sad moments. Students' experiences of learning in the discipline was *not a matter of fixed emotions*. The learning of disciplinary concepts fostered a variety of emotions in students, where feelings of anxiety, stress and frustration when confronting these troublesome concepts quickly transforms into joy and happiness once the concept has been mastered.

When it comes to emotions, it varies. It was not a matter of fixed emotions, but it varies according to the situation I faced during that time. For example, if I'm studying and then I get myself into a situation whereby I don't know what to do, I don't understand what I'm studying, then surely I get stressed, frustrated, and sad. But the moment I understand something, trying to master it, and then I become more excited and happy. Basically all the happiness, the joy and maybe some sad moments when you don't understand some things, and all the joy that we feel when we achieve understanding. When I was first studying linear regression modelling, I felt like this thing is very difficult, I can't understand anything about this. And then I joined the tut group and we did that activity about height and shoe size. That is the day where I started liking stats and enjoying it more and more. Binomials, it's one of the chapters I wasn't really good at. I would say I feel good about stats now than before because I understand some chapters. Binomial distribution 💙 *favourite* 💙 *. Figuring out how to calculate an equation is the most AWESOME feeling. I'm really getting used to statistics and enjoying it, probability distributions and modelling was good; I am learning every day we have the programme. I am so happy I have got to a point where stats has become one of my favourite courses this semester. Learning statistics really changed me as a person and also to be able to view other things differently than I did before learning statistics*

Before: formulae: ☹ → *After: formulae:* ☺

Attempts at mastering specific disciplinary topics generated a multiplicity of emotions within students. Students felt *stressed, frustrated* and *sad* in their attempts to understand troublesome concepts such as linear regression and binomial distribution. But through the reality based activities in the tutorial sessions, both their understanding and emotions improved. The ability to master a troublesome concept brought about a radical change of feelings towards the subject with feeling *AWESOME* and a lot of drawings of hearts now featuring in students' descriptions of their experiences of learning in the discipline.

6.5.1.6 I am ready for the exam ☺. Preparation for tests and test results also raised a variety of emotions in students. From experiencing elevated stress levels before writing a test to wishing *I wrote all my tests like that*, students' range of emotions were intense and wide-ranging.

> *When I studied for my Test 1, I did not experience difficulties while I was using the study guide given to us. The problem began when I started answering past papers. The questions that appeared there were different from the examples we did in class, but I managed to work through them, hence the 'A' that I obtained, which I am happy about. I was very prepared for test 1, it was not a problem, especially the regression topic. I did a lot of previous papers. But in terms of result, I wasn't satisfied. More than 85% but very disappointed that it is less than 90% which is what I aimed for. The tut we are doing really helped me a lot. My results are good and that makes me happy and therefore encourages me to continue to excel in the upcoming test. Probability is the only difficulty I have right now, which cost me 100% for test one. My preparation for Test 2 was a bit stressful but as I practiced more and did past papers, my stress levels went down and I was ready for my test. Second test was actually fun and exciting* […] ☺ *wish I wrote all my tests like that.*
>
> *Test one (80%) → Test two (90%) → Final exam [picture of a celebratory balloon]*

Working through past exam papers proved quite trying for students, as the questions were different to the ones that they attempted in class. However, through diligently practicing these past question papers, and through attendance of the tutorial programme, students were able to achieve satisfactory results in their tests. If their first test mark was not what they wanted to achieve, it made them feel disappointed, but at the same time, it spurred them on to work even harder to reach their goal for the second test. Achieving good results in both tests helped to quell stress levels, and bolstered student's confidence in their abilities to tackle the exam with a newfound eagerness and expectectaions of success.

6.5.1.7 Synopsis: Fundamentals of Emotions

Encountering and trying to grasp new concepts in the discipline is sometimes stressful and frustrating. In the case of statistics, the understanding of new concepts may, more often than not, depend on a student having a solid grasp of previously learnt mathematical concepts. If the students' mathematical foundation is unstable, then their learning journey in statistics could prove to be quite overwhelming and generate anticipatory anxiety about learning in the discipline. This induced sad, negative feelings in students. Attempts at mastery of disciplinary concepts through participation in the tutorial programme and its peer interaction and fun, engaging activities made for a comfortable learning environment and increased students' enthusiasm for attending the tutorials and learning in the course. This enthusiasm led to positive feelings about learning statistics, this in turn makes for more positive attitudes and feelings towards learning in other modules. The primary negative feeling attributed towards assessments was students' disappointments at not being able to achieve their desired grade score. But this had the fortuitous effect of encouraging students to work harder to achieve their desired goal in the forthcoming assessments. Student's predominant feelings and emotions of their experiences of learning in statistics was one of a sense of achievement and accomplishment that translated into joy and love for the subject.

6.6 Concluding comments

This study is framed by the threshold concepts view of learning (see Chapter 3). According to this conceptual framework, a students' learning journey necessitates crossing conceptual thresholds, which is characterised as journeying through a liminal space. A learners' journey through the liminal space is sometimes fraught with feelings of confusion or uncertainty attributed to the disruption of the learners' status quo, where the acquisition of new knowledge may disturb the learner's sense of self in terms of being, thinking, and doing. The threshold concepts framework views learning as embracing both cognitive and affective features and the ability to learn is susceptible to the learners' social environment and emotional well-being. Thus a central theme in threshold concepts oriented literature is how students transition the liminal space and ultimately acquire understanding of disciplinary concepts. The foregoing description of the fundamentals of the affinity Tut Group would suggest that one of the means by which successful traversing of the liminal space could be achieved is through the adoption of the threshold concepts-enriched tutorial programme format, since it promotes disciplinary learning in both cognitive and affective aspects, as follows.

The Tut Group was analysed to be the primary driver in a system depicting students' experiences of learning statistics in a threshold concepts-enriched tutorial programme. The essential features of this tutorial programme - small group, reality-based activities, being provided with the solutions to the tutorial activities, keeping of reflective journals, and an opportunity to interact with a lecturer who displays patience and encouragement towards her students - can be described as the foundation on which to build learning and understanding in statistics. The duality features of learning (cognitive and affective) embraced by the threshold concepts view of learning is reflected in the fundamentals comprising the affinity Tut Group (see section 6.2.1) as follows.

The fundamentals provide insights into the cognitive nature of disciplinary learning through the tutorial constructs of peer collaboration, real-world application of concepts and the ability to reference the solution to the tutorial tasks. Tut Group, in the threshold concepts-enriched tutorial programme, offered cognitive support for students' conceptual development, where they came to see peers and lecturer as an important resource for learning and in group interactions attained deeper understanding of statistical concepts through exposure to multiple perspectives, and through their own expression of thoughts and understanding. These small-group interactions gave the reserved student the confidence to ask and answer questions not only in statistics but across their modules. Real world application of statistical concepts gave students' a deeper understanding of the content and encouraged a conceptual shift in students' thinking through students' critique and evaluation of statistical data offered in the media. These findings have significant bearing on current debates around teaching and learning in statistics. The fundamentals of Tut Group also begin to reveal the affective influences on learning in terms of peer support in the group, the opportunity to write down one's thoughts on learning in statistics, to receive feedback on these reflections, and the lecturer's disposition and attitude towards her students. These have all been shown to impact on students' emotional well-being which in turn impacts on their understanding in the discipline. The Tut Group provided a secure and nurturing environment where students' sense of self was altered through interactions with their peers and lecturer. This validated their thinking and grew their confidence.

The magnitude of bearing the affinity Tut Group has on the rest of the components in the system cannot be emphasised enough. I view Tut Group as emanating an energising life-force to the rest of the system, inducing and reinforcing learning and understanding in the discipline. This is also evident in the rest of the system where the tutorial group (programme) is a common thread running through the fundamental descriptions of the remaining affinities, viz. Journey of Understanding, Personal Journey and Emotions, and is fundamental to students' acquisition of statistical knowledge in this case study context. The influences of Tut Group will be further expanded upon in Chapter 7.

The affinity, Journey of Understanding, was characterised by moments of "stuckness" and "AHA". Moments of impasse were prompted by students' attempts at understanding troublesome disciplinary threshold concepts, such as symbolic representation of statistical terminology, probabilities and probability distributions, amongst others. However, students were able to traverse this liminal space by increasing the time and effort put into engaging with the content through the tutorial activities, working through past year papers, and just by having a positive outlook. Journey of Understanding sheds light on the cognitive aspect of disciplinary learning by highlighting students' cognisance that continuous practice of statistical problems and marrying understanding of concepts with its application are key to developing a deeper understanding in the discipline. The integrative nature of threshold concepts was reflected when students' were able to reconcile the identification of the probability distribution with the choice of probability distribution formula to use and/or the application of concepts to real world problem-solving. Affective constructs in terms of maintaining a positive outlook on learning, believing in one's abilities and the simple act of asking a peer or lecturer for help also impacted on students' learning in statistics. Together, these cognitive and affective constructs yielded many of the students' "AHA" moments.

According to the threshold concepts view of learning, the mastering of troublesome disciplinary concepts may involve an ontological shift in the learner. This was evident in the fundamentals comprising the Personal Journey affinity. Students appreciated understanding how mathematics is integrated into the statistics discipline, where their achievement at being able to understand the statistical concepts with its embedded mathematics grew their self-confidence, and has allowed them to aspire to greater goals in life. Reserved students identified their active engagement with their peers and lecturer in the tutorial sessions as personal growth. Their learning was enhanced by being able to ask for and offer help during the group tasks. This ontological shift may be attributed to cognitive and affective influences.

Students' feelings towards their experiences of learning statistics was captured in the affinity Emotions. Emotions was identified as a primary outcome in the analysis of the system. Once learners are within the liminal space, the learner tended to oscillate between positive and negative emotions in their attempt to grasp certain disciplinary concepts. This is clearly evident in the fundamentals comprising the affinity Emotions. This yo-yoing of emotions is a potent reminder that learning is both affective and cognitive, and that the journey through the liminal space may often entail identity shifts, which can result in unpleasant journeys (Cousin, 2006b).

These findings will be revisited in the light of the extant disciplinary literature, particularly within a threshold concepts orientation, in Chapter 8. Next, Chapter 7 describes the relationships of influence that exists among the four affinities.

CHAPTER 7

INDIVIDUAL REALITIES WOVEN IN THE WORDS OF THE CONSTITUENTS:

THE COMPOSITE AFFINITY RELATIONSHIPS OF INFLUENCE

7.1 Introduction

The descriptions in Chapter 6 gave a more detailed view of each affinity in terms of its fundamentals. In this chapter, the affinity relationships of influence that constituted students' reality of their shared experience of learning statistics in a threshold concepts-enriched tutorial programme will be described and discussed. In Chapter 6, the affinities were considered in descending order of delta, corresponding to a left-to-right reading of the SID, from drivers to outcomes of the system. Likewise, in this chapter, relationships of influence per affinity are ordered according to delta values, thereby providing the reader with a sense of the overall placement of the affinities in the SID (Northcutt & McCoy, 2004). The ways in which the affinities directly influence one another are elaborated on in the following sub-sections. Data has been drawn from students' individually completed ARTs, individual responses submitted during the first focus group session, written reflections, and individual interviews. In sections 7.2, 7.3, and 7.4, the three affinities Tut Group, Journey of Understanding and Personal Journey, relationships of influence are described, respectively. In section 7.5, I offer some concluding comments.

7.2. Tut Group: Relationships of Influence

The previous chapter described and discussed the fundamental characteristics and mechanisms of the individual affinities of the system. Participants' construction of the Tut Group affinity positions it as the prevailing guide and informant of participants' understanding in statistics. As the primary driver in students' learning in statistics, Tut Group is instrumental in driving and/or influencing all three other affinities in the system, as depicted in Figure 7. Many of the underlying influence of Tut Group in relation to the other affinities are evident in the description of the fundamentals of the other three affinities from the previous chapter. The ways in which Tut Group directly influences each of the other three affinities in the system is discussed in the following subsections. These descriptions are informed from students' completed ARTs, interviews, written reflections and written responses from the first focus group session. Influences are presented in descending order of delta, from affinities that are stronger drivers to affinities that are stronger outcomes in the system, as shown in the numbers on the arrows.

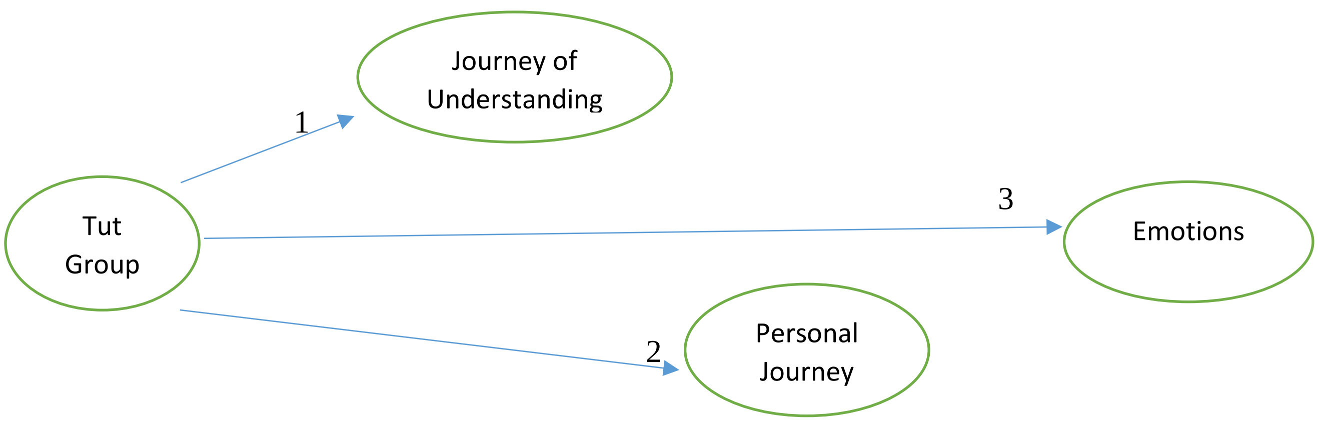


Figure 7: Tut Group: Relationships of Influence

7.2.1 Tut Group influences Journey of Understanding

Participating in the tutorial programme facilitated learning by providing processes that helped students along their journey of understanding, moving them from 'stuckness' or impasse to providing insight into the disciplinary concepts and their own learning processes.

> *I think the tut group influences the journey of understanding, because it is the tut group that helps us practice and understand Business Statistics more. It is very easy to fail statistics, and in seeing that, I knew that joining the tut sessions would really be of help because it is where you get a clear understanding of statistics and all the topics we had*

to cover, of what to do and how to do it. My progression of statistical concepts was due to using the tutorial group as a tool, which made the content easier to understand. Because working in groups makes it easy to understand the journey of stats and goals. In the group there were lots of practices which made more sense and improved understanding. There are things you don't understand when you are doing it on your own, but being in a tut group helps to understand those things – like when you are doing self-study and you get a question that you really don't know how to answer it – which formulae to use then at the tutorial group they will explain it in a simpler way so you can understand it. Being in the tut group increased our level of understanding in the module. I believe that from attending the tut that's where the things were clarified and simplified so the group helped a lot in understanding. They are somethings that I didn't understand in class, but I didn't ask because I was afraid that my class mates would look at me. I get a chance to ask my questions in a tut group. So I think that's a reason why most people came here, to get more of an understanding. In this tut group there are so many people that help you to understand what you didn't understand. For you to have a better understanding, you have to be in groups so the thing that you don't understand, you ask others, they tell you. It's about helping each other. By attending the tutorial group I was made to understand some of the things I did not understand before because we had to work in groups, we had more [examples] *to practice with the real data. I get the chance to interact with other students, to help each other and to ask questions* [about] *anything that I found difficult. We help each other better understand what we are working with. When I struggled to understand something the tut came in handy as I would either ask our lecturer or tut group mates which made things even easier for me than to go over hours trying to figure something on my own. The tut group helped me to understand the subject or module as a whole. For us to have better understanding we ought to have a tut group which contributed a lot. The more you attended and did more tasks in the tut group, the more you understand the aspects of Business Statistics. It is the tut group that helps us practice and understand statistics more. The tut group has helped to better one's knowledge about statistics from the extra exercises we did in class to the practical activities. Tut group provided practical and real examples to make me understand. Like the example whereby we're measuring our height and the shoe sizes, it* *was something that was practical, it was done in front of us, which made me understand something that is practical. I have come to an understanding that I can relate what I am learning into reality. The tut was based more on practical and real life examples, which helped me view statistics in a wider angle. My progression of statistical concepts was due to using the tutorial group as a tool which made the content easier to learn. The tut group influences your understanding because more of the work is explained in the tut group. Yes, definitely, being part of the tut group helped me understand Business Statistics. So if it wasn't for the tut group, maybe I wouldn't be as good as I am with statistics. Attending these tutorials helped me see how much of the work we do in class I really understand. There is nothing difficult in the tutorial group, instead I gain more knowledge. The aspect which I find difficult was understanding the topics. The tutorial really helped me in understanding probability. This tutorial programme gives me more understanding of probability. Everything was still very fuzzy especially during simple linear regression and sampling distribution but the tut sessions really did help together with hard work. AHHA!!! P and q are constant * I never noticed that until I got it in the group tut. I'm really getting used to statistics and enjoying it; probability distributions and modelling was good; I am learning every day we are have the programme. As time progress and engaging with the group for Business Statistics tut, it really help*[ed] *me a lot to overcome my difficulties and helped me improve my marks. What I like about this tutorial is that I get different types of questions, which assist me to prepare for my tests and exam. The most challenging part was to actually understand the question and figure [out] what was expected of me. I overcame this by bringing this matter in the tut group and find more practice and practice. I liked the idea of having a journal so we'd get feedback from some of the things I didn't understand in class. There isn't anything that I don't like* [about the tutorial sessions] *but if anything comes up, I will write it in a reflection on that particular day of the event. The time consumed by the tut was worth it as every tut was progressive and very helpful in learning. I think that being in a tut group increased our level of understanding* [in] *the module a bit more. I think the more we attended the classes, the more we learned about different things and the more you got understanding of what we are doing. There are things that I was able to understand because I joined the tut group. So if I didn't attend the tut group, I would not be able to* *understand. If it had not been for the tut group I don't think my understanding would be as clear as it is right now. Without the tut group, personally, I think I wouldn't understand stats even now.*

Tut Group directly influenced both cognitive and affective elements of the Journey of Understanding. The small group setting made it easy and comfortable for collaboration with peers and communicate with the lecturer, either during the tutorial sessions or through reflective writings. This provided emotional support through the challenges of learning. Conceptual understanding was attained through the programme processes of reality based group work activities. This allowed students to learn by listening to others' perspectives and to verbalise their own understanding and by actively engaging with the concepts they were able to relate what they learned to everyday problems. This allowed students to gain a deeper understanding of the disciplinary concepts.

7.2.2 Tut Group influences Personal Journey

Students' Personal Journey encompassed both academic and personal development, both of which were influenced by the fundamentals of the Tut Group.

As you are working as a group in this tut, you are sharing your opinions that improve our personality because we become more confident. So it improves our Personal Journey. Before I was shy to ask other people; [the] *tut group groomed me and helped me to interact with fellow students. If you are a person who works alone and attended the tut group, you learnt that working in groups is much better than working alone. It contributed by making it easy to work with people; made me communicate more with other people other than my class friends and that helped me to pass very well. Sometimes* [you] *need to interact with other people to obtain more knowledge in your personal life; it really, really helped me for my personal journey, to grow and to progress in the future. It made me communicate more with people, not only in my class but with everyone around me, which is good, because you are not supposed to stay in your own personal bubble, you're supposed to get to know more about people. Working with other people* *and knowing each other, solving the problem which maybe sometimes you'll find it difficult to solve it on your own and the responses I received from ma'am were very encouraging and helpful. I personally think it was the things that we did in the tut group that grew me and made me believe in myself because at first stats really had me doubting myself but the tut changed all of that. The tutorial influenced my personal journey because if I hadn't attended the tut group, I don't think I would've been the person I am now, I don't think I would've passed test one and two. So as I attended more sessions, I had a better view of stats and now I'm fully confident in my ability as I've grasped the concepts. Yes, it showed me that you can apply it in life. Like I said, I've used probabilities. Using probability when trying to see if I should sell a lot of produce or when I should go to the library with the probability of it being full or probability of me finding a book I need. The tut group helped me become friends with maths, though we not close friends, but the tut group helped a lot. The tut group had an influence in our personal journey because the time and commitment spent in the tut shows us different things about ourselves personally and made us notice things we didn't notice. The one thing I learnt from this tut group and* [Business] *Statistics 201 is that you can achieve anything you set your mind to. I believe in myself and I can win when I just commit myself toward what I'm doing. It made* [us] *realise that if we work harder we can achieve anything and it pushed us to our full potential. Personally, I aim higher and reach my goals. My own learning and thought processes actually improved by being part of this tut programme. I have a better opinion about learning as a whole and how stats can be useful in our daily lives. Learning statistics has helped me to see myself at large, it made me believe that there are changes for me to become a better person in future. It made me believe there is a 95% chance for me to leave a mark in this world.*

The cognitive processes developed in the Tut Group sessions influenced and augmented the requisite disciplinary understanding that enabled a new way of thinking. This inspired students' application of the newly acquired knowledge to their daily activities. Students' sense of self was reinforced by interactions with peers and lecturer: their confidence about their abilities sprouted as they discovered personal attributes that may be harnessed to achieve their goals – students did not specify the type of goal, whether these were of a personal or academic nature, but I would presume that it was a combination of both because of the following statements made by students: *It made [us] realise that if we work harder we can achieve anything and it pushed us to our full potential*; *It made me believe there is a 95% chance for me to leave a mark in this world.*

7.2.3 Tut Group influences Emotions

The thought of studying statistics evoked a range of emotions in students. Participating in the tutorial programme helped to cultivate positive feelings and stymie the negative feelings to some extent. It imparted a sense of belonging to be a part of a group of people that treats one another *like family*, and it boosted self-confidence in students' academic abilities and roused a new-found passion for mathematics and statistics.

> *I knew that statistics was a major challenge for third years so I had anxiety. Well, the reason we joined the tut group, I think it was because all of us were very sad that we were gonna do stats. We were overwhelmed about this module, we had a skeptical view, but joining the tut changed our view. Attending the tut group eased those feelings into relief; influencing my emotions positively. At first the group did not seem active, everyone was quiet, but as time went by everyone was comfortable, active, positive feelings began. The emotions come from the experiences that we go through in the tut group, as we grow and find understanding our emotions change and vary along the journey in the tuts. Before I attend this tut group I had bad emotions about stats* [but] *the tut group changed my emotions: from negative to positive, and made us happy. From fear, frustration, sad to ecstatic ☺. Before a person attends the tut group, sometimes he feels negatively. So he loses confidence. But while he attends the group, he is able to realise that this thing is easy, I can do it. So his emotions become positive. I think the tut group influences the emotions because now I am, okay, I am happy to be in the tut group as it has helped me to improve my understanding. The tut group kept me sane. It was confusing, but then it kept you in a place where you could understand. The way we treated one another in the tut group affected how you felt about Business Statistics. I would say we treated each other in the group like family. If there is something that has*

stressed you, you don't think about it when you are in the tut group because some people who are within this group will come with jokes. The tut group made everyone feel happy and excited as it helped us in different ways. There is nothing better than seeing yourself improving. The tut group has helped me produce positive emotions about maths, about statistics. I love maths because of this group. Tut group really made me like stats so much. The more you enjoy the module the better and more you fall in love with it. Being in this tut group made me feel happy and the work was easily done and it helped [me] *to understand better what I missed during the lecture. My feelings of learning statistics changed from feeling bored to excited about learning statistics because of the tut and seeing how it is applied in real life circumstances. I am very happy to be in the tut group as it has helped me to improve; it helped me score more in my tests. After writing Test 1 and seeing that my results are good, I just got so excited and I saw that the tut group is really helping me and that makes me happy and encourages me to excel in the upcoming test. So the happier you are, the better you feel if I can say so. I was also happy when I saw the solution* [to the tutorial activity] *and discovered I was on the right track. I enjoy each and every time I spend at this tutorial group; our lecturer is very welcoming, kind and easy to approach, making things much easier and comfortable because we don't fear to ask or answer any questions. My feeling about this tut* [is] *I am very happy, I feel great about the tut group, it has helped me a lot and I have no regrets of joining it, it has been an awesome experience in learning. Stats is not as bad as they claim* [drawing of a dancing lady].

Participants linked Tut Group to a range of uplifting emotions about themselves, their peers and lecturer, and the discipline. They noted a sense of belonging within the Tut Group, of feeling like being a part of a family by the group members' ability to bolstered the moods of the other participants and being able to communicate with the lecturer without fear. The learning and subsequent understanding that they attained in statistics through the cognitive processes of the tutorial sessions transformed their initial feelings of sadness, fear and boredom to feelings of happiness, excitement, and ultimately love of the subject. Greater understanding in the discipline developed during the tutorial sessions translated into students' scoring well on tests. This helped boost students' confidence in their academic abilities which in turn produced more positive emotions.

7.2.4 Synopsis: Influences of Tut Group

The Tut Group's methods and procedures was an immense causal factor, directly influencing every other affinity in the system. Tut Group was influential in students' Journey of Understanding supporting both cognitive and affective elements of their learning. Active learning tasks facilitated through peer collaboration developed conceptual understanding and provided the emotional props to assist students' through the initial challenges of learning. Tut Group had a direct bearing on students' Personal Journey by inspiring a new way of thinking and being. Interactions in the Tut Group boosted students' confidence in their abilities to attain their goals, and the tutorial activities, by providing context for disciplinary concepts, opened-up students' minds to the practicality and usefulness of statistics. Students' self-belief was elevated to new heights through their learning in the tutorial programme, with many sharing the sentiment that *you can achieve anything you set your mind to*. Negative feelings about studying mathematics and statistics were transfigured into positive feelings, which were fostered by the Tut Group processes. Peer interaction during the tutorial sessions boosted students' moods and students' attainment of deeper conceptual knowledge through the group activities generated lofty feelings towards learning in the discipline and raised students' determination and morale.

7.3 Journey of Understanding: Relationships of Influence

In Chapter 6, the fundamentals of the affinity Journey of Understanding was described and discussed. Journey of Understanding is a significant affinity comprised of conceptual moments of 'stuckness', or impasse and 'AHA', or insight. In the final analysis of the system, Journey of Understanding is situated as a secondary driver influencing the affinities Personal Journey and Emotions, as depicted in Figure 8.

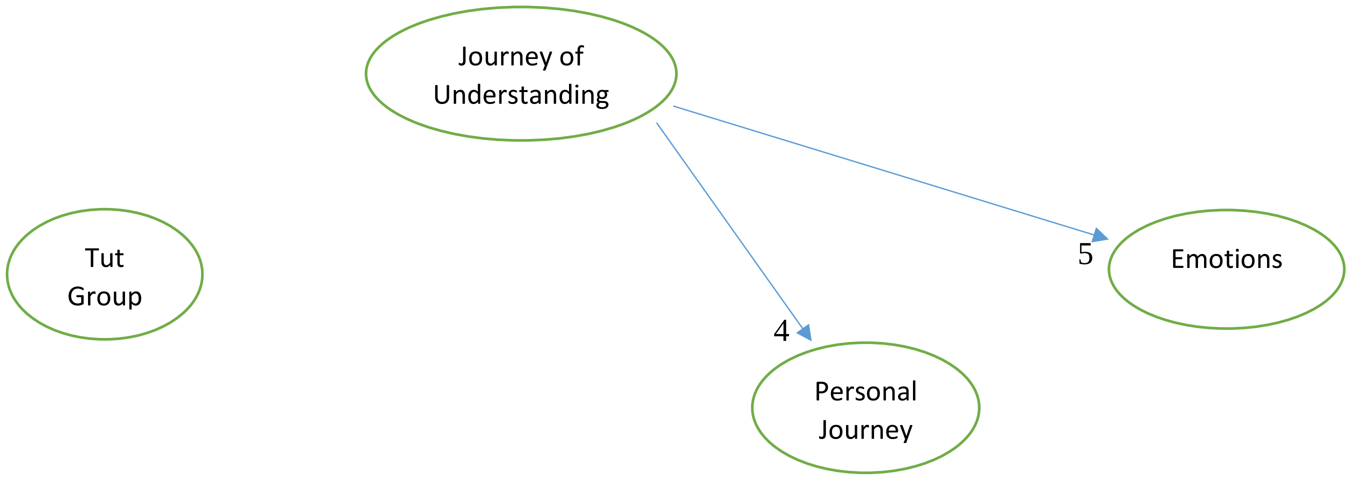


Figure 8: Journey of Understanding: Relationships of Influence

7.3.1 Journey of Understanding influences Personal Journey

Students' Journey of Understanding entailed perseverance through moments of 'stuckness' or impasse in their attempts to master disciplinary concepts. The trials and tribulations of this journey impacted on their Personal Journey as they reached a new state of consciousness about themselves, their peers and the discipline.

> *My understanding of my own learning and thought* [processes] *changed by being a part of this tut programme in a good way. Understanding in Business Statistics also developed me as an individual, the way I perceive things and the way I think. The Journey of Understanding improved my personality because when I understand something, I become more confident to* [speak] *or to share with others. When you understand and know what you are talking* [about], *the more you grow personally because you understand what you are talking about and you will be able to prove that you are* [right]. *When you understand and know what you are talking about the more you grow as a person and you feel great because you learnt something. I never thought that they are people who are not from your family who could help you to do better each and every day, who can help you reach your goals. Our tutor/lecturer always had the thing called Ubuntu; it was comforting to know that someone or people* [will] *help you* [to] *understand. Understanding the work contributed to personal growth and added*

> *confidence; improved my personality by* [helping me] *become more confident. When I started understanding stats I realised that I can make a lot of things happen, I can even do better in other studies. I really thought studying statistics would be hard for me, but when I start understanding it I just wanted to do it more often. It encouraged us to do more and improve. The more effort I put into work, the more I understood and the more I was motivated. Even when my test marks were horrendous, it still motivated me because I now knew if I applied more into this, I would get better results. I even want to continue studying statistics. One day I would like to be a teacher I will now consider teaching statistics and make my learners like it and understand it. Understanding how things are done helps you grow personally. For instance, others realised how SA data is collected through understanding statistics. This module has made me question how the stats we see on TV, newspapers, etc. were calculated/compiled. As I attended more sessions I gained a lot of skills which I used to understand more concepts. Now that I understand statistics, my Personal Journey has improved as I can now be able to answer questions on my own without having so much difficulties. I can say that I'm developed individually, because I can approach any problem now using that statistics knowledge. Firstly, you have to understand the work you are doing, then if you understand the work you're doing, then you will understand what kind of person you were in the past. What I learned is that if I set goals for myself, I put in the effort and I work tirelessly, I will achieve what I want to achieve and I'll succeed in whatever I put my mind to.*

Understanding disciplinary concepts built self-confidence as students' could now share their thoughts and opinions about disciplinary knowledge with a sense of legitimacy. Understanding in the discipline gave students the confidence to want to delve deeper in the discipline and to apply the same determination to other areas of their academic life. Becoming aware of their growing understanding in the module evoked enjoyment and excitement for the subject. Their self-determination peaked with many articulating a tireless pursuit of future goals and successes. They have also come to the realisation that they can seek support from outside of their family circle in their learning journey with *ubuntu* – a word from the South African Nguni language used to describe a conscious selflessness towards others – being ascribed to the lecturer. Students revealed a deeper understanding of the discipline by their stance of needing to critically evaluate statistical data provided in the media.

7.3.2 Journey of Understanding influences Emotions

The fundamentals of the Journey of understanding evoked an array of emotions in students.

> *I think emotions are mostly triggered along the Journey of Understanding because as you grow and understand more, you become happier and excited about everything and all other emotions come about the journey. Understanding statistics made our lives so much easier. There was less stress and that made us happy and put our heart at ease. If I did not figure out how to calculate equations and understand the question, I wouldn't be this happy today. When you understand something, you just feel stress free, and you enjoy doing it. Now I can study stats the whole day, because I understand and enjoy it. In understanding the module, it made a lot of us feel happy, because it increases our chances of passing the module. Once you understand something that got you stuck, you start feeling excited, so, yeah, understanding has an impact on your feelings. It is difficult to fall in love with your enemy. Stats has become my friend, I am starting to love it. When I don't understand something, I have bad emotions toward it, but once I understand, I love it and start to practice it more and more. Now that I understand the module very well because of the tut group, I am happy because I don't have to stress when entering the test/exam venue. The fact that I understand, I feel much happier in contrast as to when I don't understand, I get stressed and sad. Journey of Understanding influences when I studied. I'm happier compared to the other times when maybe I'd be cranky and annoyed and frustrated, because I did not understand something. Once you understand something then you become happy with it. Because you feel happy* [that] *you can get it right. My preparation for Test 2 was a bit stressful but as I practiced more and did past papers, my stress levels went down and I was ready for my test. I was surprised at the mark I got for Test Two. I did not expect it. I was very glad I passed, made me start preparing for my exam even earlier. I have go to a point where stats has become one of my favourite courses this semester. Figuring out how to calculate an equation is the most*

> *AWESOME feeling. It's interesting yet frustrating because you would think you understood in class* [but then] *do it at home, you end up with question marks. But as the semester went on, we or shall* [I] *say* [I], *began to understand with a few hiccups here and there. Things are so much different now, I look forward to attending statistics every day. I enjoy it more.*

Students' emotions oscillated along their Journey of Understanding – from feeling stressed, or annoyed at moments of impasse, to feeling elated when they understood something. Achieving a greater understanding in the discipline gave students a sense of accomplishment and enjoyment, which was crucial to instilling feelings of love for the subject.

7.3.3 Synopsis: Influences of the Journey of Understanding

Through its metacognitive and meta-learning constructs, the Journey of Understanding is a considerably influential affinity in the system. Except for Tut Group, the Journey of Understanding has influenced the two remaining affinities in the system. Progress in their attainment of conceptual goals brought about changes in their Personal Journey through a heightened metacognitive and meta-learning consciousness. This had the effect of inspiring some to pursue future careers in statistics. Students' Journey of Understanding impacted on their Personal Journey through an altered personal and worldview. Their progress in understanding statistics changed their views of learning, offering a new perspective of how disciplinary knowledge maybe applied to their daily activities, and how this may enhance their confidence, motivation, and self-belief. The Journey of Understanding was marked by moments of non-progression in disciplinary understanding which brought about negative feelings, whereas positive emotions were linked to increased conceptual understanding.

7.4 Personal Journey: Relationships of Influence

Personal Journey comprised students' heightened metacognitive and meta-learning perceptions. Through this Personal Journey of discovery of self and discipline, students experienced a wide array of emotions. Personal Journey was analysed as a secondary outcome in the system revealing a relative effect on the affinity Emotions as shown in Figure 9 below.

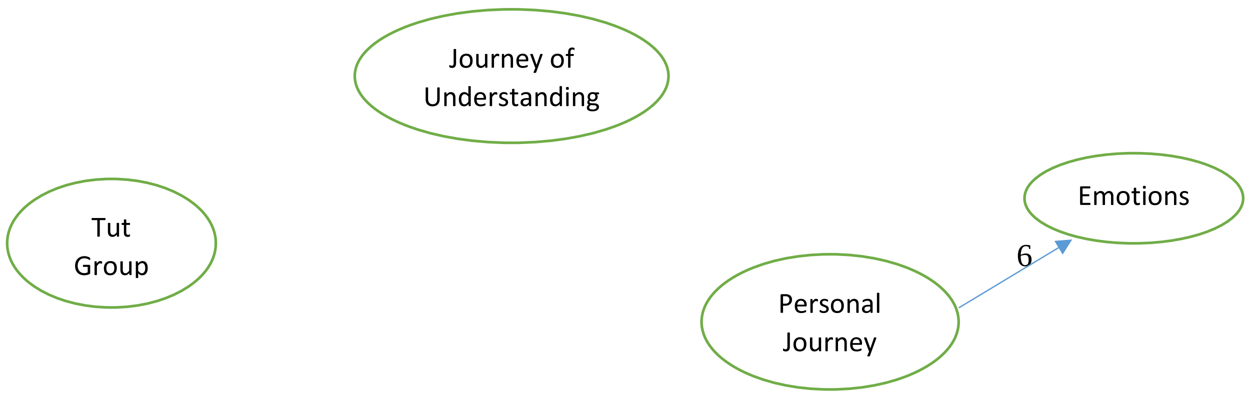


Figure 9: Personal Journey: Relationship of Influence

7.4.1 Personal Journey influences Emotions

Initially, negativity characterised students' attitudes towards studying statistics. However, the positive experiences of learning statistics in the threshold concepts-enriched tutorial programme over the semester, boosted students' confidence and sense of self-efficacy, leading to positive emotions.

The personal journey brings out different emotions as you grow and find yourself, I feel like emotions have to be influenced in order to be felt, of which the personal journey would bring out the emotions you feel as you progress. I think it was the personal journey that influenced my emotions from being sad to happy. It's been a rollercoaster. At first I would have never chosen stats as any of my modules but now I am happy to say that I can study stats as one of my modules; even next year, if I were to pursue the study and even teach stats one day. The way I dealt with challenges was that if I got stuck, Mrs. Ananth is here to simplify things so I would seek help in the tut session. Then that helped take the negative thoughts I had about stats being hard away.

The outcomes of learning stats and having [this] *knowledge gives us, or should I say me, the confidence to study other modules, no matter how difficult they may be; and I was encouraged to study harder. People felt in the tutorial in all kinds of ways, that anything can be achieved, and gaining confidence made us feel a lot better. Realising that you are capable of other things will improve your emotions. For instance, knowing that your opinion can help someone else, realising that you're capable of helping others and participating in a group, that would make you feel good about yourself, like you're worth something. That would make you feel happy. The more you experience real life problems and start to apply stats* [to them] *it becomes more and more interesting. I am now happy because of what I have gained from the tut group and that I have discovered that I have got this and I will pass with flying colours.*

Students' Personal Journey experienced in their pursuit of statistical knowledge evoked a variety of emotions. Students' sense of achievement in their mastery of conceptual understanding encouraged their self-confidence and reinforced self-worth which led to affirmative feelings. Students' also felt good about their ability to apply statistical methods to their everyday problems.

Findings from the fundamentals and influence of Personal Journey will be discussed further in Chapter 8.

7.5 Students' final reflections

At the conclusion of each individual interview, I asked students to express any final thoughts or comments that they may wish to make about their experiences of learning statistics. This section briefly presents all seventeen of the participants' final comments on their overall experience of learning statistics. Their responses are presented below as a composite quote in keeping with the IQA protocol of representing individual realities.

Overall, Business Statistics, my feelings towards it at the beginning, I can say that I was a little scared, but now I can say that it is interesting. It's really helped me a lot in many things. I love it because I can see that it is a very practical module which is useful even in the future if I want to pursue my studies. So it's a very interesting module, which I love. It was very helpful for us *to have a tut group; I'm very happy with the tut group. By joining this group, it made me do more activities and understand everything better. And it made studying very easy - I've actually enjoyed statistics even though I thought I would hate it. This was really a fun experience for me. In my entire three years of studying here, I've never experienced so much joy. This tut group really helped me a lot, I really saw my marks improving and statistics is my best module. I want to* ***[say]*** *thanks for this opportunity to be a part of this tut group. I look* [forward] *to coming to each and every tut because you are so fine and cool with us. You have been wonderful and this group that you created, it just helped me a lot and I* [can] *see myself passing. Thanks for putting extra effort so we can pass this module. We really enjoyed* [our] *time with you; and thank you for giving us this opportunity because it's helped us a lot and I hope and I wish all the best for you; on your journey.*

In Chapter 5, the SID provided a telephoto view of the phenomenon under study, namely students' experiences of learning statistics in a threshold concepts-enriched tutorial programme. This provided the group's collected view on their experience of learning statistics. Although the individual interviews did not set out to elicit views on the SID as a whole, focusing instead on exploring individual participant's meanings for each affinity and relationships of influence, the above responses provided a sense of students' lasting views of their experiences of learning statistics from the perspective of individual participants. It was reassuring to find that the experiences of individual participants seemed to pair with the SID developed at the group level. Descriptions offered by the participants suggested that the Tut Group was a pivotal element, impacting both their cognitive and affective aspects of learning in statistics. Students emphasise the role of the Tut Group in developing their individual and disciplinary thinking, linking it with a sense of self-belief and self-efficacy. They recognised the relevance of this newly-acquired knowledge to their future aspirations of studying further. These self-relevant outcomes created positive feelings generally and about the discipline specifically. These individual views resonate strongly with the group's experiences depicted in the SID.

The seventeen participants quoted above all had positive experiences of learning statistics, in which Tut Group influenced and enhanced their overall disciplinary and personal progress. It is conceivable that some students' construal of certain fundamentals comprising the various affinities are negative or unfavourable but due to the over-powering presence of positive experiences/sentiments expressed by students, it is these affirmative sentiments of students' learning experience that pervades the system. Adverse sentiments are not strongly reflected in students' articulations thus its potentially destructive impact is curtailed. The implications of this systemic view of learning are considered further in Chapters 8 and 9.

7.6 Concluding comments

This chapter has focused on the relationships of influence that exists amongst the affinities of the system, the threads that link them and that describes students' learning in statistics. The SID offered an aggregated representation of students' learning. The analysis and representation of the findings of participants' individual realities was aligned to the visual ordering of the affinities in the SID. Thus emphasising the order of influence of the affinities portrayed in the SID.

The Tut Group affinity describing the threshold concepts-enriched tutorial programme offered cognitive and affective support for students' on their Journey of Understanding: support in the form of a secure and nurturing environment, where peers and lecturer would come to be regarded as a resource for learning, and where small group discussions of the reality based activities enabled deeper understanding of disciplinary concepts and the feedback to students' writings in reflective journals provided the oft-desired individual attention critically lacking in a large classroom setting. This Tut Group provided the tools for students to overcome their 'stuckness' and experience 'AHA' moments in their Journey of Understanding. Through the Tut Group students' Personal Journey of self-realisation was impacted. Students' confidence in their ability to achieve academic and personal goals were heightened and this sense of empowerment and self-efficacy that the Tut Group caused also gave rise to powerful positive emotions in students' towards learning in the discipline and positing them in a positive state of mind.

Journey of Understanding, characterised by moments of 'stuckness' and 'AHA', can evoke strong personal and emotional responses. As a secondary driver in the system, Journey of Understanding influenced the affinities of Personal Journey and Emotions. The aspects of the tutorial programme helped to foster metacognitive consciousness and provide cognitive and affective support to students in their Journey of Understanding. Progress in students' learning influenced their Personal

Journey through an increase in conscious effort, motivation, and self-determination. These transformations brought with it strong, positive feelings for self and discipline.

Feelings of fear and anxiety diminished or disappeared completely as confidence in their disciplinary knowledge grew. Participants linked happy feelings to their learning and personal progress. These excited feelings were extended to themselves as individuals, statistics as a field and life in general. Emotions was the ultimate outcome of students' experiences of learning in statistics. All of the students' experiences in their learning journey manifested itself in their emotions. Predominantly, positive emotions arose from their learning experiences and from their beliefs' about themselves in relation to learning.

The SID for this study was generated by the participants themselves, as a group, and its visual mind-map about how the components of learning inter-relate seems to align with individual students' views as described in section 7.5.

Findings from the fundamentals (Chapter 6) and influences (this chapter) of the four affinities will be discussed further in relation to the extant literature and the theoretical framing of the study in Chapter 8.

CHAPTER 8

FINDINGS AND DISCUSSION: EXPERIENCES OF LEARNING STATISTICS IN A THRESHOLD CONCEPTS-ENRICHED TUTORIAL PROGRAMME

8.1 Introduction

This study seeks to deepen understanding of students' learning in statistics. This entailed the use of IQA processes and reflective journals to elicit rich descriptions from participants in the threshold concepts-enriched tutorial programme that was offered alongside mainstream BSTS 201. Chapter 5 described the affinities that participants identified in the first focus group session as the components of meaning of their learning in statistics. Chapters 6 and 7 weaved together students' thoughts and perceptions of individual affinities and the interactions amongst them. These reflections were presented primarily in the voices of the participants in the form of composite quotes taken from participants' individual interview transcripts, reflective journal writings, and musings that were generated during the first focus group session. These contemplations offered an illumination of the fundamentals and influences of the affinities. These chapters laid the foundation for a system-level synthesis of the phenomenon under study and therefore did not engage with the extant disciplinary literature.

In this chapter, I distil key findings from the system synthesis and I attempt to discuss the study's findings in relation to existing statistics education literature and the threshold concepts framework literature that serves as the theoretical framing of the study. I theorise the extent to which the study findings conform to or deviate from extant literature and further understanding of students' learning in statistics. Section 8.2 offers key findings extracted and confirmed by the fundamentals and influences of the affinities.

In a necessarily long chapter, my discussion of these findings continue the metaphor of the double-helix strand of DNA, introduced in Chapter 2, to describe the cognitive and affective components of learning evident in the extant statistics education literature. I draw together common threads from both data chapters to arrive at composite conceptualisations that together describe the cognitive and affective implications of participants' experiences of their semester-long learning in statistics in relation to extant statistics education literature.

Threshold concepts theory scholarship features in the discussion of the findings as the bond between the intertwining cognitive and affective strands of learning. This integrated approach to presenting the study's findings and discussion offers a comprehensive assessment of the system and mirrors the SID mind-map of the phenomenon under study. A pedagogical journey beginning with the mind (cognitive) ultimately impacts on the self (affective) through the prism of a threshold concepts-enriched tutorial programme. Section 8.3 provides some concluding comments and points the way to Chapter 9, which reflects on the study as a whole.

8.2 A holistic approach to learning in statistics

Chapters 6 and 7 provided a complex, multidimensional portrayal from the participants of their experiences of learning statistics in a threshold concepts-enriched tutorial programme. Many of the descriptive findings that emerged from the data were closely related and recurring themes in the system. I abstracted the key findings from these integrated recurrent themes to be discussed in this section. The findings offered here will be discussed in relation to the two interwoven strands (cognitive and affective) reflected in existing statistics education research, relevant threshold concepts-oriented scholarship, and to pertinent broader scholarship.

8.2.1 Barriers to learning in statistics

There are as many variants of experiences of disciplinary learning difficulty as there are students. Nonetheless, it is possible to draw out a few topics on which participants' considerations of content difficulty and the resultant sense of feeling stuck seemed to converge (section 6.3.1.1). Difficulty seemed to arise from the abstract way in which concepts and techniques were typically presented in lectures, which seemed to have little to do with reality. It seems that in the traditional pedagogical approach, the connection of formal knowledge to students' everyday knowledge may not have been substantive enough to enable deep comprehension of theoretical concepts and techniques. In this section, I discuss students' conceptions of barriers to their understanding in the discipline. Students identified their fear of mathematics as an impediment in their studying statistics. Along with experiencing mathematical anxiety, students also expressed the challenges they experienced in trying to understand certain statistical concepts. Students' viewed these troublesome concepts as obstacles in their learning journey. Another barrier to disciplinary learning that I perceived throughout the duration of the tutorial programme was students' apparent aversion to e-learning pedagogical tools as exemplified in their reticence to engage with each other through the online discussion board created for the tutorial programme.

In section 8.2.2, I will then proceed to present and discuss the findings on how students were able to scale these barriers and transcend their feelings of fear and frustration to engage meaningfully with the disciplinary concepts.

8.2.1.1 Mathematically-related troublesome-ness

Students' proposed their fear of mathematics as the key barrier to their successful engagement with any form of statistical work (see section 6.2.1.2). The mathematised aspects of the statistical learning were preponderant in participants' reflections on sources of difficulty and sense of impasse in the discipline. This is not surprising, given the mathematics embedded in many statistical constructs, and the empirically established role of mathematical ability in performance in statistics (see for instance Dupuis et al. (2012); Galagedera (1998); Galagedera et al. (2000) and others mentioned in Chapter 2). Fear of mathematics is commonly referred to as mathematics anxiety, which is a negative emotional response that is evoked within some people when they are confronted with having to deal with numbers or math-related scenarios (Suarez-Pellicioni, Nunez-Pena, & Colome, 2016). Students may display anxiety when confronted with number work because of their experiences of school-based mathematics (Onwuegbuzie & Wilson, 2003; Vygotsky, 1978a). This was clearly the case in this study with many students declaring: *"Like most students I didn't have the best experience with maths in high school"* (section 6.2.1.2).

Students' reflections revealed that the source of their mathematics anxiety may be attributable to environmental factors, where there may be a dissonance between the value of the subject and control over it (Buckley, 2013), and experiences of school-based mathematics. Based on Pekrun's theory of emotions in the classroom (2006), anxiety in the classroom is experienced when there is incongruence between control over a task and the value placed on the task. One may consider maths as being of high value due to its being considered (by society) as an indicator of general intelligence, and the feeling of a lack of control in relation to maths may stem from the idea that maths is difficult (Buckley, 2013). As one student reflected, *"Despite my dedication to the subject it just didn't love me back"* (section 6.2.1.2). This would suggest that the student values maths but feels as though they do not have much control in relation to the subject. As such, this conflict between the value students place on the subject and a sense of the lack of one's power in relation to learning in the discipline may be construed as a partial reason for students' displaying anxiety towards studying statistics.

The other concern students had about studying statistics relates to their general experiences of learning mathematics in high school, and of learning Mathematical Literacy, in particular: *"I did Math Literacy by the way, that is the main reason I want to attend the tutorial"* (section 6.2.1.2). This statement suggests that students perceive themselves to be somewhat lacking in their mathematical capabilities by virtue of the fact that they studied Mathematical Literacy in high school instead of Mathematics. Students' self-perception of having a limited level of mathematical preparedness echoes some of the criticisms levelled against the subject Mathematical Literacy. That is, the quality of the subject does not afford students access to various avenues of tertiary study (North, 2015), and the subject affords inadequate support and development to students for higher-order reasoning and problem-solving skills due to their limited engagement with applying multi-step procedures in a variety of contexts (Jansen, 2012a, 2012b, 2016; Venkat, 2010; Venkat et al., 2009).

These issues, along with the role of teachers (Suarez-Pellicioni et al., 2016), have a direct bearing in relation to students developing mathematics anxiety. Research shows that there is a clear negative correlation between teachers' own levels of mathematical anxiety and their mathematics teaching efficacy (Swars, Daane, & Giesen, 2006). In the South African context, this concern is heightened due to the fact that there are non-mathematics teachers, lacking in mathematical content knowledge and skills, who are teaching the Mathematical Literacy subject (Botha, 2011). Moreover, rote instruction, with an emphasis placed on correctness but providing little cognitive or motivational support, may lead to math avoidance on the part of students (Turner et al., 2002).

Where students are taught by teachers who may lack the capacity to teach Mathematical Literacy and having limited exposure to high level problem-solving and reasoning practices prove to be a dire combination, a combination that is unlikely to foster and nurture a love for mathematics, and one that is more likely to induce mathematics anxiety in students. Having developed negative attitudes towards learning mathematics, which stemmed from their experiences in high school, it is understandable that students "*trembled*" at the thought of studying BSTS 201 (section 6.2.1.2).

Students' reflections also reveal their conflation of the subjects of mathematics and statistics: *"it is the most difficult module in DUT, especially if you are doing it without any background of pure maths"* (section 6.2.1.2). Students' fears that learning statistics will prove to be difficult if one did not study a reasonably high level of mathematics in high school is testament that students interpret success in mathematics as a pre-requisite to success in statistics. These sentiments feed directly to the ongoing debates surrounding the distinction between mathematics and statistics (as explained in section 2.2.2.1 in Chapter 2). Also, students' articulated fears of studying statistics due to their perceived limited level of mathematical preparedness is directly related to the computation self-concept factor constituting statistics anxiety, which relates to students' self-perception of their ability to understand and calculate statistics (Cruise et al., 1985).

Thus, the student participants in this study exhibited a conflated view of the subjects of mathematics and statistics, wherein students' self-perceptions of their apparent limited mathematical competence were self-construed as a stumbling block in their studying of statistics. It is apparent in this study that self-perceptions of possessing limited mathematical competence may lead to statistical anxiety, and this apparent positive relationship between having limited mathematical competency and statistics anxiety hints at a conflated view of the two subjects, that is, deeming oneself to be insufficiently competent in mathematics is directly related to one's fears of studying statistics. This finding adds weight to the literature that reflects the intricate relationships among students' mathematical competence, mathematics attitude and anxiety in relation to statistics attitude and anxiety and statistics performance (Carmona et al., 2005; Silvia et al., 2008).

Further to this, the profusion of formulae and its derivations in a statistics curriculum may be considered troublesome knowledge (Wills, 2017), and this clearly comes across in the statement made in reference to the disciplinary formulae: "*the challenge might be learning and* *understanding them; it's kinda tricky"* (section 6.2.1.2). The challenge posed by learning and understanding and correctly applying the various formulae may be considered akin to the trouble experienced by students in discerning the appropriate statistical test to perform on a given data set (Norton, 2015). This troublesome-ness has been acknowledged by statistics education experts, who have advised statistics teachers to guard against overwhelming their students with, for example, intricate mathematical derivations of estimator formulae (Utts, 2016). These sentiments regarding the unnecessary mathematisation of statistical concept knowledge has also been echoed in a related discipline, namely, economics (Mearman, 2013).

However, a contrasting view may be that statistics educators also have a responsibility to apprise students as to how statistical formulae have been derived so that students may understand the consequences of statistical test results if formulae inputs are altered. This knowledge may aid in developing conceptual capabilities, thus ensuring that students' possess competent disciplinary knowledge capabilities that may hold them in good stead when called upon to complete tasks in a variety of contexts (see TCITF, section 3.5 in Chapter 3). It is expected that achieving knowledge capability will assist students in disciplinary ways of thinking and practicing (Baillie et al., 2012) – by acquainting students with the key aspects of a formula and the significance of each inputted variable to the overall result, students may be better positioned to tackle a range of problem-contexts and scenarios.

It may be argued that students might only discern key aspects of the various formulae and its appropriate use in various contexts if they are initially intimately acquainted with the derivation of the formulae. Since technological developments have taken the drudgery out of completing tedious mechanical calculations (Chance et al., 2007), this would afford students the opportunity to focus on understanding statistical formulae and interpreting results. As one student observed: "*The thing that simplified everything for me was that although statistics required a lot of formulas, most of it was in the calculator so it made life easier"* (section 6.3.1.2). In this way, time-saved from having to perform complex analytic calculations may now be spent on imparting a solid grasp of formulae derivations, an essential aspect, in my opinion, for developing students' knowledge capabilities.

The foregoing discussion describes and discusses mathematically-related troublesome aspects, as articulated by students, of disciplinary learning. This troublesome-ness is informed by students' previous encounters with mathematics in high school, and by their anticipatory concerns of having to study a mathematically informed subject whilst possessing (self-perceived) limited mathematical proficiency. Students reflected on their struggles with the mathematical underpinning of statistical conceptual knowledge: *"Statistics is difficult to understand and pass. That affected me, I came with that belief.* […] *Solving for x's was never one of my strong points"* (section 6.3.1.5).

This reflection expresses students' beliefs about: (i) mathematics (its level of difficulty); (ii) the extent to which they consider statistics to be a part of mathematics or requires mathematical skills; (iii) oneself as a learner of mathematics or statistics; (iv) the usefulness or value of statistics to one's future career (see section 6.3.1.2); and (v) what learning in a statistics classroom entails (see section 6.2.1.1). Beliefs are developed over time, shaped by cultural factors, stable and resistant to change, and largely comprised of a cognitive component as opposed to an emotional one. Thus, these inter-related facets provides a context for students' approaches towards and interpretation of classroom experiences in statistics (Gal, Ginsburg, & Schau, 1997). Therefore, it is important for statistics educators to take into consideration students' beliefs (as noted above) as, arguably, one's attitudes towards statistics influences, and is influenced by, one's own beliefs (McLeod (1992) as cited in Gal et al., 1997).

In the discussion of this study's findings that follow, the student participants' beliefs will be discussed and expounded upon further as it relates to their experiences of learning statistics over the semester (see section 8.2.2.7).

The following section highlights students' encounters with troublesome statistical concepts and discusses these findings in relation to the extant statistics education literature.

8.2.1.2 Disciplinary-related troublesome-ness

Students' reflections on their learning in statistics highlights several areas of troublesome issues that they encountered: the use of statistical terminology and the Greek and Roman letters used to symbolise them;[51] the correct choice of formula to use for questions; the topics of probability; and

[51] For example, $\mu = mean$; $\sigma = standard\ deviation.$

probability distributions: binomial, Poisson, normal and Student's t distributions (see section 6.3.1.1).

A discussion of each of these troublesome aspects in terms of this study's findings, and in relation to the extant literature, is elaborated upon in the following sections.

8.2.1.2.1 Disciplinary lexis

Language plays a critical role in the classroom (Kaplan, Rogness, & Fisher, 2014), where it is the means by which new ideas are communicated, understanding is built, and ideas are processed, and it provides a method by which student learning is assessed (Thompson & Rubenstein, 2000). One of the key essentials to being deemed statistically literate is to be able to communicate statistical concepts and results in both verbal and written form (Parke, 2008). The two-fold requirement of verbal and written communication ensures that the student's conceptual understanding may be ascertained through: (i) her written interpretation of concepts; and (ii) her ability to communicate her understanding to others (Rumsey, 2002). As students become exposed to the language of statistics, they may make faulty connections between the technical, domain-specific usage of certain words and their common everyday meaning (Kaplan, Fisher, & Rogness, 2010). These words are described as having lexical ambiguity (Barwell, 2005). In statistics, words such as (but not limited to): association, average, confidence, random and spread are considered to be lexically ambiguous words as they have a range of meanings in everyday communication and some have more than one meaning in mathematics and statistics[52] (Kaplan et al., 2014; Sharma, 2016). In addition to being able to move between every day and academic ways of communicating ideas, students must also relate these expressions to mathematical symbols and text (Salehmohamed & Rowland, 2014), thus, the language of statistics can sometimes be challenging to students (Bay-Williams & Herrera, 2007; Boero, Douek, & Ferrari, 2008; Dunn et al., 2016; Lavy & Mashiach-Eizenberg, 2009), making the subject seem more difficult than it already is (Kaplan et al., 2010).

In this study, the 'language of statistics' overwhelmed students: *"Everything was just like written in a language I didn't understand. I felt the load"* (see section 6.3.1.3). The tendency "to equate

[52] For example, the word *independent* in the statistical topic of regression can be used to describe an explanatory variable, as well as to describe whether a *set* of explanatory variables are related to each other or not (Dunn et al., 2016).

learning statistics to learning another language" can contribute to students' statistics anxiety (Onwuegbuzie, 2000b, p. 324) and these negative attitudes may reduce student retention and promote a surface approach towards learning in the discipline, as students may not perceive statistics as being useful or meaningful (Willcoxson, Cotter, & Joy, 2011). Thus, to communicate in the language of the discipline, a student needs to gain a firm grasp of: (i) the new discipline-specific terminology; (ii) the lexical ambiguity of certain words; and (iii) the symbolic representation of these words and concepts, by means of various pedagogical approaches - as evidenced in the extant statistics education literature (Dunn et al., 2016; Kaplan et al., 2010; Kaplan et al., 2014).

Student participants in this study did not, however, voice any problems that they may have experienced with respect to disciplinary understanding due to the English language being the medium of lecture delivery. The international literature, Sharma (2016), and in South Africa, Nolan (2002), offers some insight into the English-second language barrier to disciplinary learning. Nolan's (2002) study reported deficiencies in students' language and mathematical ability. Although, the student participants in Nolan's study expressed that their understanding of the terms 'at least' and 'at most' needed to improve, as well as their understanding of the terminology in probability, the students largely "regard[ed] their mathematical skills/ability as problematic" and the "major problem" to their learning in quantitative techniques (Nolan, 2002, p. 1 and 6) – this latter finding chimes with the findings of this study as discussed in section 8.2.1.1.

The next section discusses various statistical concepts that students expressed as being troublesome concepts in the learning journey.

8.2.1.2.2 Troublesome statistical concepts

The following student quotations highlights several disciplinary topics, where linear regression analysis, sampling theory, probability and probability distributions (binomial, Poisson, normal and Student's t) are deemed troublesome by students to their learning in statistics. A couple of these topics have already been identified as disciplinary threshold concepts in the extant literature - linear regression modelling and sampling distributions (Dunne et al., 2003; Norton, 2015).

"I understand the working concepts of most but hated having a lot of info to study […] *binomial distribution was hard* […] *only to find its because I don't know what do when* $P(X<1)$ *or* $P(X>1)$ […] *or the Poisson formula and figured it used averages* […] *I was really confused* […] *with the tables (Normal and the t tables)* […]*when I was first studying linear regression modelling, I felt like this thing is very difficult, I can't understand anything about this" (6.3.1.1; 6.4.1.2; 6.5.1.5)*

A disciplinary concept is considered threshold if it is likely to be: transformative, probably irreversible, integrative, possibly bounded, potentially troublesome (Meyer & Land, 2006). In this study, students expressed the idea of studying probability as being potentially troublesome to their learning in the discipline: *"I panicked because I knew that probability would be done during the module* [...] *probability is the one topic that got me stuck like no other* […] *probability is the only difficulty I have right now, which cost me 100% for Test One"* (section 6.3.1.1 and 6.5.1.6).

Students, through the aid of the various pedagogical approaches adopted in the threshold concepts-enriched tutorial programme (to be discussed in section 8.2.2.3), expressed their experiences of learning probability as being transformative; and their utterances further revealed that their experience of learning probability as being integrative (see sections 6.2.1.6 and 6.3.1.2). These findings are elaborated upon below.

Learning the topic of probability through the tutorial programme approach wrought epistemological and ontological transformations in students' learning (see section 6.2.1.6). Students acknowledged that their *"understanding has been broadened"* and that this improved knowledge translated into a sense of effortlessness when performing probability related activities. Students expressed experiencing ontological shifts in disciplinary learning through: *"Without the tut group I wouldn't have* […] *known that stats is also for dummies (not just the smart ones)"*, being able to successfully acquire knowledge of probability concepts bolstered students' self-confidence, with students imparting a sense of disbelief almost at their own capabilities.

The integrative nature of the concept of probability was revealed to students' and reinforced through its application to real-world problems. Students mentioned two statistical topics as examples of the application of statistical ideas to real-world problems: the use of sampling theory to predict the spread of HIV/AIDS in South Africa, and probability used by weather forecasters to make predictions (section 6.3.1.2). Students' began to appreciate and see the value of probability vis-a-vis its application to real world phenomena.

In the extant threshold concepts literature, with respect to the statistics discipline, the topic of probability is considered as having the ‘potential’ to be deemed a disciplinary threshold concept (Wills, 2017). However, from the above discussion, students’ experiences of their engagement with the topic of probability encapsulated the troublesome, transformative (epistemological and ontological) and integrative nature of this disciplinary concept. Notwithstanding the absence of the expressed views of participants as to the “probably irreversible” and “possibly bounded” (Meyer & Land, 2006, pp. 7, 8) aspects of this disciplinary concept, this study’s findings puts forward the case for the topic of probability to be reasoned a disciplinary threshold concept as it possesses transformational capacity - the “superordinate and non-negotiable” characteristic of a threshold concept (Land et al., 2016, p. 16). Through the student participants’ reflections on their learning in probability, one may conceptualise and interrogate the difficulties associated with learning in this topic. This may ultimately encourage serious-minded debates and discussions towards contemplating changes to pedagogical approaches to the teaching of this topic. This will be elaborated upon further in section 8.2.2.3.

The next section discusses students’ perceived reticence to engage with e-learning pedagogy in their learning in the discipline.

8.2.1.3 Information and communication technology (ICT)-related troublesome-ness

Information and communication technology (ICT) pervades tertiary education in the 21st century. The use of ICT in education is a global phenomenon, where South Africa cannot afford to lag behind if its skilled workforce is to remain productive and competitive in a global market.

In South Africa, practical use of computers begins at school between the ages of 11 and 15, however, schools in rural areas lag behind in its expansion of ICT programmes due to various factors: technological under-development, low literacy levels, and poverty (Bhero, 2012). Thus, students from disadvantaged communities are often marginalised in their struggle to cope at university, due to their limited access to certain degree programmes, limited ICT capabilities and their lack of access to computers (Bharathram & Kies, 2012; Bhero, 2012).

This study was conducted on the ML Sultan Campus of the Durban University of Technology (see Chapter 4). The ML Sultan campus was formerly known as ML Sultan Technikon, a historically disadvantaged institution in terms of resources provided. Thus, infrastructural and access constraints are a major concern when considering the implementation of technological/e-learning pedagogy on this campus (Bharathram & Kies, 2012).

Notwithstanding these infrastructural challenges, as part of this study, student participants were encouraged to participate in an online discussion board as part of the Blackboard classroom created for the tutorial group participants. The rationale for the creation of the online discussion board was informed by the findings from MacDougall's (2010) study on learning statistical threshold concepts. Creating an online discussion forum would potentially provide an opportunity for: (i) less confident learners to participate; (ii) learners to evolve into tutors, thus, acquiring a richer form of learning; (iii) the educator to be alerted to new and continued troublesome concepts highlighted by individual students' comments and/or queries; and (iv) space to contemplate and reflect on one's learning (MacDougall, 2010, pp. 22-24).

However, student participants in this study failed to participate in the online discussion board, citing the following reasons for their lack of participation: *"I know that they* [tutorial solutions] *are being posted on Blackboard but not all of us have access to Blackboard. Some of us don't have laptops, smartphones and others are not registered as yet therefore they can't use a library"* (student's reflective diary). This reflection undercut what I initially perceived as students' aversion to engage with ICT, and at the same time, it underscored the issue of marginalisation of disadvantaged students, as these students cannot meaningfully engage with technologically-enriched pedagogical approaches due to a lack of availability of resources. This finding adds credence to the notion of the digital divide in developing countries like South Africa, which experiences a distinct divide between those that have access to technology and technological skills and those that do not (Cloete, 2015).

Another issue alluded to, albeit obliquely, is the issue of late registration of NSFAS-funded students. Many students are funded by the National Student Financial Aid scheme (NSFAS), and due to a variety of administrative-related issues, these students are often registered late (Nicolson, 2017; Phaladi, 2016; Seale, 2018). Although these students were allowed to attend lectures and write the scheduled tests for the course, their test results were withheld and they were invariably excluded from accessing on-campus resources in the form of access to computer labs and libraries, as they did not possess a valid student identification card. The late-registration of NSFAS-funded students, poses a tremendous challenge to educators who may want to incorporate ICT into their curriculum, as some students will not have log-in access to the online course work and will lag behind in their learning.

Nevertheless, the experience of this study suggests that not all forms of technological pedagogy was necessarily shunned by participating students. Students engaged enthusiastically with each other and myself on the WhatsApp group chat that was created for the tutorial group participants. Discipline-related discussions spiked around the times of tests and exams, with many students asking for assistance with questions from past papers and posting messages of encouragement and motivation to their peers, thus highlighting the cognitive and affective strands of learning. The study findings (students' posted messages) suggests that the WhatsApp medium of communication proved effective in offering a socio-constructivist approach to learning in statistics (Amry, 2014; Naidoo & Kopung, 2016). Thus, due to the "explosion in mobile telephony and its widespread use even in rural areas" (Bhero, 2012, p. iv), this study's finding proposes the utility of mobile telephony as an alternative and viable medium for ICT in statistics classrooms in South African higher education institutions.

Another perspective on students' non-engagement with the online discussion board was offered as follows: *"… it's because* [students] *get some opportunity in class* [for discussion]. *So maybe they don't get time to go to Blackboard. I think it is better if a person tells you face to face something than writing it"* (students' interview transcripts).

The above statements suggests that through the opportunities created in the tutorial sessions (working in cooperative groups), students were able to engage in face-to-face discussions with their peers. Students considered this face-to-face interaction as adding meaningful value to their learning experience. As such, they did not find the need to engage in discussions on the online discussion board. This discovery adds bearing to findings from the extant literature on e-learning in South African universities, where students articulated preferring a blended learning experience (mix of face-to-face and online interaction) as they found value in face-to-face engagement (Rohleder, Swartz, Bozalek, Carolissen, & Leibowitz, 2008). The question that then remains is as to whether the student participants in this study have used the online discussion board resource if they did not have the opportunity to participate in group discussions in the classroom. I expect that they would have participated on the online discussion board if this was the only medium for group communication. I base my opinion on the findings from this study (WhatsApp group chat was widely embraced by student participants) and findings from the extant literature where online forums and chat rooms were found to promote collaboration, communication and interaction thereby enhancing the learning process (Bagarukayo & Kalema, 2015; Rohleder et al., 2008). In fact, these are precisely some of the sentiments that this study's participants attributed to their experience of working in groups during the tutorial sessions (to be discussed in section 8.2.2.1). This study's findings in conjunction with the findings from the extant literature would suggest that disciplinary pedagogical approaches should include opportunities for students to interact with one another, preferably face-to-face, in meaningful disciplinary discourse, thereby enhancing the learning experience.

Synthesis (8.2.1.1 – 8.2.1.3): Barriers to learning in statistics

Students' initial reactions to studying statistics was a combination of fear, trepidation, and anxiety. These feelings stemmed from students' seemingly unpleasant experiences of learning mathematics in high school. Students considered their learning in Mathematical Literacy in high school ill-equipped them (and this may be attributed to a variety of reasons – as noted in section 8.2.1.1) with the skills needed to be successful in their study of statistics. These self-perceived feelings of limited mathematical ability triggered students' forebodings towards studying statistics. Thus, students' mathematical anxiety generated feelings of statistics anxiety. This would suggest that students share a conflated view of mathematics and statistics, assuming that their unpleasant experiences of learning mathematics will recur in their learning of statistics. Hence, students' beliefs as it pertains to their perceptions of: (i) themselves as learners of mathematics and statistics; (ii) mathematics and its level of difficulty; (iii) the extent to which statistics is similar to mathematics or an extension thereof; (iv) the value of statistics to one's future career; and (v) what learning in a statistics classroom entails, contributes to students' attitudes towards statistics and ultimately their experience of learning statistics.

Disciplinary-related troublesome-ness were informed by: (i) the use of lexical ambiguous statistical terminology and mathematical symbols and letters; (ii) statistical topics of probability; probability distributions: binomial, Poisson, normal and Student's t distributions. Students' experiences of learning the topic of probability lend this topic to being seriously considered as a disciplinary threshold concept. As such, this finding may be used to inform pedagogical approaches to teaching this topic in the future.

The final barrier to students' learning in statistics in this study was related to their engagement with ICTs incorporated into pedagogical activities used for the tutorial programme. Social (students' valued face-to-face interactions over online discussions) and economic factors were largely responsible for students' lack of commitment towards engaging on the online discussion forum. However, due to the widespread availability and affordability of mobile telephony technology in South Africa, this form of ICT was readily embraced by students in this study. Thus, the study findings suggests that the incorporation of mobile telephony technology into statistical pedagogical activities is a viable option that promotes socio-constructive learning in the classroom.

The next section will offer a fine-grained analysis of the factors that helped students scale the above barriers to disciplinary learning.

8.2.2 Scaling Barriers: Evoking the might of the cognitive-affective strand on a pedagogical pilgrimage towards disciplinary learning

The abstractness of statistical concepts (and its underlying mathematics) is a significant source of difficulty and stuckness or impasse; working in small cooperative groups with peers allows one to see its use by linking it to the real world and, by reflecting on one's learning, renders concepts meaningful, facilitates understanding and enhances students' sense of self and agency.

Most participants felt they had progressed towards deeper and more complete understanding of statistics concepts over the semester, but this transition had not been straightforward. Instead, it demanded time and effort and brought periods of uncertainty and confusion. A sense of stuckness regarding certain concepts or statistics in general appeared to be a common experience. Overall, the students' descriptions of their routes towards disciplinary understanding match those mapped by the threshold concepts framework. This correspondence is particularly evident in the features of difficulty and stuckness or impasse discussed in section 8.2.1, and in the transformative and other threshold properties of reaching understanding, to be considered in this section. Although the epistemological and ontological shifts associated with conceptual crossing is well documented in the extant threshold concepts literature, relatively little is known about these transformations, and the qualitative nature of learning, as it relates to the statistics discipline.

From the group SID (see Chapter 5), the semester-long threshold concepts-enriched tutorial programme that the students participated in, was analysed to be the catalyst, driving students' understanding and learning in the course. Sections 8.2.2.1 – 8.2.2.3 offers an analysis of the pedagogical tools that were adopted in the tutorial programme, which students credited as being beneficial to their liminal crossings or their cognitive attempts at scaling the barriers to disciplinary learning. Further discussions in section 8.2.2.4 illuminate understanding of how the various pedagogical approaches adopted in the tutorial programme supported metacognitive aspects of liminal learning transitions, while sections 8.2.2.5 – 8.2.2.7 offers a discussion of how these pedagogical approaches also supported the affective aspects of students' liminal crossings.

8.2.2.1 Constructing conceptual understanding and a sense of self through teamwork, discussion and expression

A shift towards cooperative, engaging pedagogy that promotes an active learning environment can lead to deeper understanding of discipline and self.

The active, participatory, cooperative approach of the tutorial sessions made the traditional lecture-based pedagogy fade in significance in the minds of the student participants. This collaborative[53] approach to learning was a prominent feature of students' learning experiences in the tutorials. There was a tangible difference in the learning that they experienced in the tutorials, an experience that led to a deeper, constructive conceptual understanding as compared to their previous experiences of learning in a quantitative subject (section 6.2.1.3).

Students' evaluation of the effectiveness of the pedagogical approach used in the tutorials is consistent with research into teaching innovations in statistics, and its underpinnings in educational theory that advocates active learning approaches in which students are engaged in constructing their own knowledge (Kalaian & Kasim, 2014; Kinkead et al., 2016; Lee et al., 2014). A social

[53] In keeping with other studies in statistics education, I use the terms "collaborative" and "cooperative" interchangeably to refer to the group-based pedagogical approach used in the tutorials, and not in the strict sense where learning is unstructured and the roles of teachers and students are undefined (Johnson, Johnson, & Smith, 2014).

constructive perspective of learning draws attention to the value that social interaction and articulation brings to students' conceptual understanding and meaning making of disciplinary knowledge (Garfield, 2013), and that points to "[c]ooperative learning [as] an unusually strong psychological success story […] now a standard and widespread teaching procedure" (Johnson & Johnson, 2009, pp. 374, 375).

As noted in Chapter 2, most studies on small group, active and cooperative learning in statistics describe or guide the implementation of such approaches, and (or) measure their impacts using quantitative techniques. Although, this study did not set out to measure learning impacts, participants' self-reported improvement in understanding accords with empirical findings that collaborative approaches enhance students' learning in statistics, particularly in terms of critical analysis and application (Chen, Chen, & Chen, 2015; Kalaian & Kasim, 2014; Zieffler, Garfield, Alt, Dupuis, Holleque, et al., 2008). My findings, arising in a different (qualitative) paradigm and context, indicate that group interaction and discussion can enhance learning in statistics (as well as interaction levels and self-confidence), and offer substantiations and explanations that add depth to our understanding of how and why this may be so. Three significant mechanisms of learning in small, interactive groups came to the fore for the participants in this study, namely: the potential of collaborative teamwork, the role of multiple perspectives, and the power of articulation.

First, being able to work on an activity within a group gave students' insights into the merits of collaboration and teamwork, and on their own, individual, strengths and weaknesses (see sections 6.2.1.3 and 6.3.1.5). Group collaboration on the completion of the tutorial exercises, and the threshold concepts which they contained, emerged as an influential learning mechanism. This heretofore latent capability to collaborate with peers and work as a team to complete a task, had a transformational effect on students, with many of them lamenting the fact that they did not attempt collaborating with peers earlier on in their academic careers. Thus, group collaboration informed and enhanced students' perceptions of self, their skills and knowledge of disciplinary content (see section 6.2.1.3).

The second, closely related mechanism was that of hearing multiple explanations from the peers in the group on how to proceed with the assigned activity for the tutorial session. Being privy to a variety of explanations allowed students to construct, correct, revise, refine and internalise a deeper conceptual understanding (*"we get to see things from other people's point of view and breakdown* *the information so that it's easier to understand* […] *I get more assurance about my problems with stats and understanding"* section 6.2.1.3). This group discussion of the tutorial exercises enabled a layered approach to conceptual meaning-making, as the articulated explanations and understandings of disciplinary content, gleaned from various perspectives, converged. Thus, it promoted a deep approach to disciplinary learning as students' correct, revise and build on their individual understandings.

Lastly, a related learning process was that of students' verbal expressions and articulation of their individual understandings. The mere act of verbalising their understanding or lack thereof, to their peers, allowed students' to create, correct and refine their statistical reasoning: *"I had to do a lot of explaining which helped me discover what I did not understand in class"* (section 6.2.1.3). The spoken expression during the tutorial sessions was a novelty for many students, where traditional lectures did not require this of them and some expressed being too *"shy"* to ask for help during lectures (section 6.2.1.9). Related to their recognition of the enabling impacts of discussion and articulation was participants' marvelling at their being able to communicate with the lecturer during the tutorial sessions. This was seen as an opportunity that is rarely available in a traditional lecture setting (section 6.2.1.9). Aside from the learning-enabling aspects of discussion and articulation, students' realised that through peer discussion and articulation they grew in confidence and they were equipped with a new life-skill of being a contributing member in group collaborations. This is a skill that is certain to hold them in good stead in both their personal and future professional lives (Garfield, 2013). Being a contributing member in group discussions helped students' *"grow as a person* […] *it helped me gain self-confidence"* (section 6.4.1.3).

Appreciation of the mechanisms by which group interactions may enhance learning in statistics is reflected in arguments for increased use of active, cooperative activities and class discourse within disciplinary teaching (Ben-Zvi, 2011; Garfield, 2013; Kinkead et al., 2016). Research confirms and recognises the conceptual learning and skill-development benefits of collaboration (Kalaian & Kasim, 2014), but stops short of providing detailed, qualitative descriptions of these mechanisms from the students' perspective. The present study extends our understanding of how cooperative pedagogy may engineer students' understanding in the discipline by elaborating on the cognitive and affective shifts that accompanied students' cooperative learning experiences in the threshold concepts-enriched tutorial sessions.

While these paths to learning (teamwork, discussion and articulation) may remain underexplored in statistics education, they accord with the established social and cognitive views of learning outlined in Chapter 2 (Ben-Zvi, 2011) with empirical findings that students' cognitive and affective development is enhanced by cooperation in problem-solving (Garfield & Ben-Zvi, 2007; Lee et al., 2014). Further, the process of constructing understanding through collaboration and teamwork has been identified as an essential 21st century skill (Trilling & Fadel, 2009)[54] that may drive students' success in the workplace by proving that they are able to work harmoniously as an effective member of a productive team (Kivunja, 2014).

From participants' reflections (section 6.2.1.3), the five principles of cooperative work proposed as being essential for achieving effective teamwork was evident in the tutorial sessions (Kagan, 1994). Students' articulated experiences of working in groups reflected: (i) positive interdependence; (ii) individual accountability; (iii) equal participation; (iv) group processing, and; (v) simultaneous interaction. No member sat by observing what others were doing, taking the credit for the other members' hard work. The process of constructing understanding through discussion with peers is born out of a Vygotskian theoretical framework that emphasises the importance of social interaction in the development of mental thought processes. This resonates with social-constructivist theory that views language as central to thinking and learning (Mercer & Littleton, 2007; Vygotsky, 1968). The 'multiplicity of voices', a central tenet to dialogic teaching (Alexander, 2008), posits the 'power of talk' as the 'tool of tools' that helps students' to formulate, correct and refine their thoughts (Reznitskaya & Wilkinson, 2015). Thus, in a dialogic setting, language offers a 'social mode of thinking' (Mercer & Littleton, 2007) allowing students' to collectively engage in meaning making of shared experiences, and to solve problems.

Research in mathematics content knowledge (see, for example, Lehrer and Schauble (2005); (Resnick, Salmon, Zeitz, Wathen, & Holowchak, 1993; Yackel & Cobb, 1996) emphasises the importance of the careful orchestration of "talk and tasks", where students are expected to master disciplinary conceptual knowledge (algorithms, formulae, symbolic tools as well as accepted facts

[54] Trilling and Fadel (2009) identified critical thinking, problem-solving, effective communication, creativity, innovation, leadership, professionalism and work ethic, teamwork and collaboration, working in diverse teams, and project management; computing, information, ICT and media literacies, as essential skills for the 21st century student's success in today's society.

and theories) but also be adept at reasoning with the ideas and tools of other disciplines (Michaels, O'Connor, & Resnick, 2007, p. 238). The spoken word is not merely about articulating one’s understanding – it also serves to build one’s understanding. Thus “thought is not merely expressed in words; it comes into existence through them” (Vygotsky, 1986, p. 210). The processes exemplified by this study’s participants would seem to cohere with the view that “[s]ensemaking and scaffolded discussion … are seen as the primary mechanism for promoting deep understanding of complex concepts and robust reasoning” (Michaels et al., 2007, p. 239).

The process by which students’ collectively recollected, reflected and articulated their understandings of disciplinary concepts during the tutorial sessions can be recognised in the idea of “reflective discourse and collective reflection” required for transformative learning (Mezirow, 2000, pp. 10-11).

Within threshold concepts literature, the use of cooperative learning processes has thus far not been strongly emphasised or deeply explored in threshold concepts-oriented studies in statistics, although there are evident complementarities and synergies with broadly sketched principles for effective teaching and learning (Burch, Burch, Bradley, & Heller, 2015; Thompson, 2008).

Aspects of group work, as discussed above, make cooperative learning approaches especially accommodative of some of the threshold characteristics (Meyer & Land, 2003). Group discussion allows students to change their minds and adjust their understanding of a concept as they articulate their own thoughts and hear those of others. This can ease their progress through the liminal phase of learning, during which understanding of a concept may be characterised as being both troublesome and transformational. Thus the “messy journeys back, forth and across conceptual terrain” (Cousin, 2006a, p. 5) may be made with relative ease and more rapidly in the company of peers.

Discussion accommodates the “recursiveness and excursiveness” (Land et al., 2006, p. 202) that are likely to characterise threshold concept learning, as students oscillate between lay and disciplinary understanding of a concept (Pang & Meyer, 2010). Teamwork, discussion and articulation might allow for a more rapid advancement in understanding due to the immediate feedback and synergies generated within the group, thus accelerating the processes of recursion, pondering and doggedness that conceptual mastery entails. These processes help students to reduce their multiple navigations across the liminal space. Discussion with peers has the added advantage of being more likely to meet students who may have recently understood a concept and might have a better sense of which of its features are sources of difficulty and impasse, and would thus be well placed to offer a clarifying explanation, rather than a lecturer who may have long-since forgotten the experience of crossing a particular conceptual threshold (Land et al., 2006); as articulated by a student:*"group work is the best compared to individual work, and you get more information and easy ways to tackle the question"* (section 6.2.1.3). Peers offering help deepen their own understanding and learn to articulate it clearly for others (Salemi, 2002). Moreover, group discussion and articulation directly support the discursive aspects of learning threshold concepts (Land, 2014; Meyer & Land, 2003): in hearing their peers' understandings of statistics problems and expressing their own, students are afforded opportunities to acquire, practise and internalise the discourse of statistics.

8.2.2.2 Constructing understanding through context

Abstractness of statistics concepts is a significant source of difficulty and stuckness or impasse; incorporating meaningful contexts and the use of real-data into classroom activities can lead to deeper conceptual understanding and an appreciation of the real-life relevance of statistics. Thus seeing their use (or usefulness) renders concepts meaningful, facilitates understanding and enhances students' sense of agency.

Another influential aspect of the tutorial sessions for students was the collection and analysis of real-data sets assigned to the tasks. Working with real-life data was not only a novel experience for students, but it also *"was really amazing; was superb!!!"* (see section 6.2.1.4). This experience deepened students' understanding of statistical concepts, enabling them to see the usefulness and benefit of statistics to their lives and its functionality in related disciplines.

Students' reflections concur with the views expressed in the statistics education literature (reviewed in Chapter 2) that the incorporation of the use of real-data in classroom activities that use constructivist-based active learning techniques can prove to be valuable pedagogy. By creating realistic circumstances and meaningful contexts in classroom activities, students were able to properly apply what had been learned during the traditional classroom lecture periods, and create statistical understanding: *"So whatever we did in class, when you come to the tut group, we put it into practice and we understand more of the concepts that we did"* (see section 6.2.1.4).

The tutorial tasks generated contexts in which students were able to see the 'bigger picture' (see section 6.2.1.4). Thus, the value and meaning of statistical concepts may be fully realised rather than narrowly focusing on facts, theories and formulae. The real-life context of the activities presented students with a complex learning situation of statistical concepts. This complexity encouraged students' curiosity and interest to the extent that some students employed *"real life experiments to try and understand the work better"* as a learning technique to verify and confirm conceptual understanding (section 6.2.1.4).

Furthermore, the relevant, contextual teaching of statistical concepts motivated students to construct or reconstruct their previous (mis)conceptions of disciplinary concepts: *"… to see how real life statistics is implemented and finding out that all the methods really do work* […] *the practicality of probability and statistics as a whole"* (sections 6.2.1.4. and 6.3.1.2).

Through the realistic contextual activities, students became acquainted with the interconnectedness of statistical ideas and this encouraged more meaningful statistical conceptual reasoning and understanding, thus, enabling students to transfer these statistical ideas to new, unlearned problems (section 6.3.1.2).

The tutorial activities that encouraged student-led investigation of a statistical topic in a realistic setting reinforced the role of the learner as the owner of their self-constructed knowledge, which proved to be quite empowering to students as they felt in control of their learning (section 6.3.1.4).

The application of real data in statistics instruction has been increasingly recommended in the field of statistics education research (Neumann et al., 2013) due to the highlighted role that the use of real and motivating data has in developing students' statistical reasoning abilities (Garfield & Ben-Zvi, 2009). In addition to the use of real data in teaching statistics, the importance of data context – "the real-world phenomena, settings, or conditions from which [data] are drawn or about which data pertain" (Langrall, Nisbet, & Mooney, 2006, p. 1), to the discipline of statistics, has also been emphasised as it is context that distinguishes the discipline of statistics from that of mathematics (Moore & Cobb, 2000), and provides meaning for data analysis (Konold & Higgins, 2003).

From a theoretical perspective, the incorporation of real data into statistics instruction aligns with the constructivist (Garfield & Ben-Zvi, 2009) and socio-constructivist (Nilsson, 2013) learning theories. Within these learning theories students learn to construct knowledge based on their experiences of working with real data sets, thus enhancing students' abilities to think and reason statistically (Garfield & Ben-Zvi, 2009; Nilsson, 2013). However, contrasting positions exist on the role of context in developing students' statistical reasoning. One view held is that data-context or contextual knowledge (the setting) of the real world situation, and knowledge of how the data were generated (Pfannkuch, 2011), must be either highlighted or suppressed during various points in students' journeys of informal reasoning in inferential statistics, as context may sometimes distract students in their learning of abstract elements of statistical concepts (Pfannkuch, 2011). Arguably, the interaction between statistical enquiry using data-contexts and statistical theory or knowledge accelerates the process of enculturation of students into statistical ways of thinking and practice (Langrall et al., 2006; Pfannkuch, 2011).

The shifting interplay between data-context and statistical knowledge and conceptions is considered a fundamental element of statistical thinking "because information about the real situation is contained in the statistical summaries, a synthesis of statistical and contextual knowledge must operate to draw out what can be learned from the data about the context sphere" (Pfannkuch & Wild, 2004, p. 20). Students' oscillation between the use of context knowledge and statistical knowledge in their attempts at building conceptual understanding is akin to the recursive and excursive (Land et al., 2006) requirement of threshold concepts learning. Additionally, the use of questions that require contextual interpretation in statistics assessments has been recommended to encourage deep learning of statistical threshold concepts (Diamond, 2011). As one student expressed: *"I understand more, because I can relate it to things that are happening in real life and be able to tackle whatever question I am given"* (section 6.3.1.4). Thus, building statistical knowledge through real data contexts helped students forge a deeper conceptual understanding that may be applied to their reality – a learning outcome that, arguably, may be recognised as successful disciplinary threshold crossing (Diamond, 2011).

The use of relevant, contextual-data in statistics learning activities may also have bearing on decolonisation of the curriculum.[55] One of the challenges raised in South Africa is the idea of relevance and context in higher education curriculum. Given that learning activities are an integral part of the curriculum, one way of ensuring that the curriculum fits the current context and is relevant to students is to reconceptualise our learning activities and methods in the discipline. This may be achieved by sourcing relevant, local-context issues that lend themselves as discipline-appropriate learning activities. Using relevant, locally sourced data sets may allow students to appreciate the underlying statistical concepts, as students would be able to identify with the context sphere, thereby adding value and meaning to the statistical summaries (an idea alluded to by participants in section 6.3.1.2).

Moreover, the use of real-world contexts and real data directly support the integrative and irreversibility aspects of learning threshold concepts (Baillie et al., 2012): conceptual understanding was cemented by linking students' newly acquired disciplinary knowledge to meaningful real-life contexts. This ensures that the newly learned concepts are seamlessly integrated into students' experiences and, by doing so, these concepts are not easily forgotten. This study's finding proposes that to construct and reinforce disciplinary knowledge, students ought to engage in statistical activities involving real-world contexts, which is thus likely to accelerate students' journeys through the liminal space.

Difficulty seemed to arise from the abstract, theoretical way in which concepts and techniques were typically presented in lectures, which seemed to have little to do with reality. It seems that when it comes to the traditional pedagogical approach, the connection of formal knowledge to students' everyday knowledge may not have been substantive enough to enable deep comprehension of theoretical concepts and techniques. Making simplifying assumptions and applying formulae could appear illogical and even illegitimate to a student who is not fully aware or accepting of the underlying premises, such as where one student noted: *"I just could not understand what and why I am calculating"* (see section 6.3.1.1). Since this is a precursor to analysing the situation, not understanding these modelling procedures would stall students'

[55] In 2015, South African students instigated a campaign to decolonise the curriculum in higher education institutions, motivating for free tertiary education, and taking action against the Eurocentrism that stymies African epistemologies in local universities (Hlabane, 2017).

understanding of statistical tests. Further to this, even if students had a "*basic understanding*" of formulae and their use, they might find it challenging to *"know what formulas to use for each example given"* (section 6.3.1.1). In other words, deeper understanding was required for tasks involving application and analysis rather than mere algorithmic manipulation, and students would need to move from being stuck in superficial, mechanical approaches, towards high-level conceptual learning.

These comments recall various types of troublesome knowledge (Perkins, 2006), as it relates to statistics concepts (Bulmer et al., 2007), as sketched out in Chapter 3. Participants found that *"although statistics required a lot of formulas, most of it was in the calculator so it made life easier"* (section 6.3.1.2), implying that formulae were mechanically applied, without full understanding. This could be routine and meaningless "ritual knowledge", unsupported by a grasp of the underlying conceptual or mathematical models or the ability to articulate the real-world relationships the formulae represent. This type of knowledge would also be 'inert' if not actively used or connected to real world events. The scepticism some students expressed around modelling techniques suggests these might be experienced as 'alien'. As noted in Chapter 2, not recognising the validity of abstraction and the relationship of abstracted concepts to real situations will make it difficult for students to grasp the logic and use of these theoretical constructs. Moreover, their perceived irrelevance may undermine students' motivation to persevere with attempts to learn them (Neumann et al., 2013).

Similarly, the troublesome nature of statistical topics appears to stem from its abstractness and (initial) perceived detachment to real contexts. Students described their struggles with them in vague terms — "*fuzzy*", "*interesting*" (sections 6.3.1.4 and 6.3.1.1) — suggesting again that they experienced ritual, inert and alien properties. However, *"now I understand more because I can relate it to things that are happening in real life"* (section 6.3.1.4). It would seem that appreciating the value of the various statistical methods in the context of applications addressed such issues. As students came to understand its purpose, it appeared to be relatively straightforward to remember, apply and interpret the results of the appropriate formula or test: *"all you have to do is to determine the distribution that is used and apply your formula"* – section 6.3.1.2.

These aspects of troublesomeness provide insight into sources of confusion and incomplete understanding that have implications for how these concepts might be more effectively taught and learnt. Seeing concepts in the context of applications brings out their relevance for students, and facilitates understanding and recall. When participants saw the usefulness or applicability of statistics concepts in real contexts (on a personal or broader scale), their knowledge became more meaningful, and they felt motivated to continue learning. For instance, some explained how the relevance of the concept of simple linear regression became apparent to them when they used it to predict a person's height from their shoe size (see section 6.2.1.4), and said they could recognise its applicability in everyday contexts when contemplating the predictions made by economists (see section 6.2.1.4). Seeing the relevance and applicability of theoretical concepts in this way can help students' learning so that their understanding is internalised and easily accessed. The importance of seeing the use of particular concepts is closely linked to the idea of deeper approaches to learning motivated by a need to 'know why', rather than simply memorizing formulae and mindlessly performing calculations. It also reflects the conjunction of understanding and ability to apply that inheres in the TCITF (Baillie et al., 2012) (see chapter 3 and further discussion in Chapter 9).

8.2.2.3 Reinforcing statistical understanding by blending a multiplicity of pedagogical approaches

Integrating an array of pedagogical approaches in the teaching of statistics can positively impact students' learning journeys. Engaging students in a variety of approaches may enable them to see the bigger picture and to move from 'stuckness' or impasse to 'AHA' or insight.

The variety of teaching approaches used during the tutorial sessions (small group learning, working in cooperative groups, activities incorporating real-data handling, keeping reflective journals, and being provided with the solution to tasks at the end of the tutorial sessions), provided a lush contrast to the mundane textbook examples demonstrated during the normal lecture periods (section 6.2.1.5). From the onset, students' had an inkling that BSTS 201 would be *"a module that needs to be practiced in order to do it well"* (section 6.2.1.5). As students attended the threshold concepts-enriched tutorial sessions over the semester, they came to view these sessions as *"extra* *lessons which provided useful information"* (section 6.2.1.5). These *"extra lessons"* were productive to students' learning in the module and, overall, the unique learning format that students encountered in the tutorial sessions left an indelible impression on students' experiences of learning statistics over the semester: *"If I were to rate the tut I would say 11/10 ☺ If it were a hotel I would say it's a 6 star hotel lol!! I would rather miss my birthday party than miss the tut"* (section 6.2.1.8).

Teaching approaches encountered in the tutorial sessions including working in small groups, using real data in activities, keeping reflective journals, and being handed detailed solutions to tutorial activities, coalesced into an enriching learning experience that students could tap into when preparing for tests and exams (section 6.2.1.5). The benefits of the pedagogical approaches of cooperative group work and working with real data to understanding in statistics have been noted and discussed in sections 8.2.2.1 and 8.2.2.2. The sections that follow discusses the effects of the other pedagogical approaches adopted in the tutorial programme on students' disciplinary learning.

Students felt comfortable asking for assistance within the small group setting of the tutorial class as opposed to feeling *"shy"* or *"scared"* in the large lecture classroom set-up (sections 6.2.1.9 and 6.3.1.4. Learning in small groups, writing in reflective journals, and being handed detailed solutions to tutorial questions have been identified as additional learning aids by this study's student participants. "The effectiveness of [small] learning groups is determined by the extent to which the interaction enables members to clarify their own understanding, build upon each other's contributions, sift out meanings, ask and answer questions" (Boruvkova & Emanovsky, 2016, p. 45). This resonates with students' articulated experiences of working in cooperative groups (as discussed in section 8.2.2.1). Students worked with each other in groups (usually 3 to 5 members per group) in a small class setting (the tutorial class size ranged between 15 to 20 students per session) to solve complex and authentic problems that helped develop content knowledge as well as problem-solving, reasoning, communication and self-assessment skills. The findings from this study, with regards to the benefits of learning in small groups, are in line with research conducted on the science, technology, engineering and mathematics (STEM) disciplines. A meta-analysis performed on 225 STEM studies that documented student performance in courses with at least some active learning versus traditional lecturing, revealed that active learning improved students' examination results and pass rates across all class sizes – although the greatest effects were in small (sample size < 50) classes. Thus, these results support active learning “as the preferred, empirically validated teaching practice” in STEM classrooms (Freeman et al., 2014).

The idea of being given a voice or being heard is carried through in students’ articulated partiality towards keeping a reflective journal. The journals afforded students *“the ability to voice your opinion* […] *through writing”* (section 6.2.1.9) and students’ valued this opportunity for direct, personal communication with the lecturer that the journals afforded.

The reflective writing journals were instrumental in students’ learning journeys as it afforded an opportunity for students to actively participate in their own learning, organise their thoughts, and reduce stress (Bargate, 2012; Ersozlu & Kazu, 2011; Ward & Meyer, 2010) (section 6.2.1.9). Additionally, the reflective journal entries provided a starting point for learning as it enabled students to write down their observations and experiences, whilst centering students in the learning process (Boud, 2002; Moon, 2006) by allowing students to integrate life experiences with their understanding of a topic (see sections 6.2.1.4 and 6.3.1.2). In this way they offered insight into the transformative, integrative nature of learning disciplinary concepts, and the possible shifts in identity (see (Baillie et al., 2012) that learning threshold concepts may entail for students. As one student noted: *“My initial impression of Business Statistics was that it’s a complex module as it requires high cognitive thinking and intelligent students. But then again, I was eager to take on the module as I’m always eager to learn new things. Every opportunity that comes my way is an opportunity to learn new things so that is why I decided to participate in the tutorial programme.* […] *It was kind of difficult having to leave my friends and work with new people. But eventually it worked out”* (student’s reflective journal writings). Thus, through students’ reflective journal writings, this study reveals actual accounts of the transformative, integrative and re-constitutive experiences that students’ encountered in their learning of disciplinary threshold concepts.

The use of reflective learning journals in this study had three distinct advantages for me as the researcher – it served as a pedagogical tool, it was used as an aid in teaching instruction and was instrumental in the development of relationships with student participants (O'Connell & Dyement, 2011). The reflective writing journals assisted me in cultivating a bond with my students as I got to know individual students’ idiosyncrasies of engagement with the subject matter through my feedback to them: “*Students eagerly await feedback to their reflective writings. A few of them were* *showing my written replies to their friends, clearly proud of my feedback to them. A very heartening experience to witness*" (researcher's reflective diary entry, 11 October 2017).

Students also voiced their appreciation at having access to the solutions to the exercises as a form of reference to check against their own workings: *"I was happy when I saw the solution and discovered that I was on the right track"* (see section 6.2.1.9). In this way, potential misunderstandings/misinterpretations were revealed and re-learned. This finding serves to augment the extant research into disciplinary threshold concepts, which holds the view that the statistics curriculum is enriched by using visual, narrative, and mathematical approaches with detailed examples, quizzes, and exercises to assist learning by application (Thompson, 2008).

Learning from examples is considered a powerful pedagogical tool in the mathematics education research (Leinhardt, 1993), with the most common reference being to "worked examples" (Zhu & Simon, 1987), that is, step-by-step solutions to exercises provided by the teacher or a textbook. Learning from examples is "supposed to demonstrate the use of specific techniques, which are in turn to be mimicked or lightly modified by students in dealing with similar examples" (Zazkis & Leikin, 2007, p. 15). Having access to detail solutions to the tutorial activities would seem to facilitate students' recursive and excursive (Land et al., 2006) trips along the liminal space. This allowed misunderstandings to be re-learned, as students grappled with new disciplinary knowledge: *"After taking time and re-doing what was done in the class, it all made sense … then I felt little bit relieved"*- section 6.3.1.2.

It is further suggested that the examples elicited from students have the potential to reveal students' conceptions of disciplinary knowledge, their difficulties and possible inadequacies in their conceptions (Zazkis & Leikin, 2007). In this study, students' generated a rich variety of general, easily accessible examples of their conception of the statistical topics of probability and sampling (see section 6.3.1.2). These examples also served to highlight the integrative nature of learning disciplinary threshold concepts, where students are able to apply their conceptual knowledge to real life examples.

Perhaps, the most enlightening statements of students' conceptions and/or perceptions of the discipline of statistics is the following: *"this module has made me question how the stats we see on TV, newspapers, etc. were calculated/compiled* […] *I left with the question "is statistics correct?" The answer to that question is that it is approximately (≈)"* (sections 6.4.1.1 and

6.4.1.3). These statements exemplify students' active engagement in constructing their own knowledge, and resonates with the belief that "when learners generate their own representations, questions and problems, they probe and crystallize [sic] their knowledge more deeply than when they are given ready-made facts" (Watson & Mason, 2005, p. 209). Thus, it is clear, from the foregoing discussion that adopting a variety of pedagogical approaches (small group interactions, co-operative group work, real-world activities involving the use of real data, keeping reflective journals, handing-out detailed solutions to exercises) in the introductory statistics classroom can form an interconnecting web, which has the potential to ignite and sustain students' learning in the discipline.

In general terms, beyond the tutorial exercises, participants concurred that overcoming stuckness on specific concepts centred on finding alternative explanations from peers and the lecturer and by diligently practicing a variety of questions using techniques employed in the tutorial sessions, so that multiple perspectives could come together to illuminate the concept. This approach to dealing with content difficulties also revealed students' effective use of self-regulated learning strategies (Winne & Hadwin, 2008). Moving through stuckness by drawing on the resources and perspectives of others could be experienced as expanding one's own capabilities: *"It changed the way I learnt as there were people who you would discuss the content with and it made it easier to understand. Through hard work and dedication it becomes easier and even fun"*- section 6.3.1.5. This growing sense of self-efficacy increased students' self-confidence in their learning abilities, thus increasing their motivation to persevere in their learning (section 6.4.1.1), the motivation to perform at one's best (section 6.4.1.5), and, ultimately, the motivation to pursue desired future career goals (section 6.3.1.5). This finding will be discussed further in section 8.2.2.4.

Mechanisms for moving through an impasse are suggested by participants' comments on the tutorial exercises (section 6.2.1.4), and emerge as a corollary of attributing difficulty with abstraction. First, as already noted, engaging with the concept in an applied context could give students the 'why' that paves the way for understanding, and the participants felt that the tutorial activities were based on relatable applications that made the use and relevance of the concepts under discussion clear (section 6.2.1.4). Moreover, the exercises broke problems down into short sub-questions, and guided students through the steps of modelling in the process of constructing their analysis. Taking apart and making explicit what was required allowed students to take the necessary steps to understanding, and arrive at their own solutions.

Harnessing the cooperative learning processes described in Chapter 6 and highlighted in section 8.2.1.1 above meant that participants could progress through the abovementioned steps towards understanding, by articulating their reasoning to peers, having their mistakes corrected along the way, and hearing multiple interpretations. In this way, students could develop full yet focused, discipline-appropriate responses to relatively challenging problems that they would probably not have been able to answer had they been couched as direct, single questions that skipped over (or assumed full awareness of) the intermediate steps required to answer them.

The potential benefits of scaffolded learning tasks in statistics have been documented (see for example Chance et al. (2007), Giraud (1997). The tutorial tasks had commonalities with many of the active learning pedagogies advocated in statistics education research (outlined in Chapter 2), and the confirmation of their effectiveness by the present study is not particularly surprising. However, participants' descriptions of the metacognitive and affective impacts of working collaboratively through these exercises add to our understanding of processes for facilitating the move from stuckness to meaningful conceptualisation in statistics. Furthermore, students recognised that they could apply the skills and mind-set that they developed in the tutorial sessions to other problems (section 6.4.1.1).

Participants revealed that they had now mastered some of the implicit rules or procedures of statistics analysis that comprise the 'underlying game' or 'episteme' of disciplinary practice (Land et al., 2006; Perkins, 1999). 'Knowing why' and seeing the use of concepts emerged as central to moving through stuckness, and was associated with a sense of empowerment and agency that participants appeared to derive from having attained meaningful knowledge. This suggests that the significance of meaning in learning is not only about making sense of concepts in context; meaning also denotes that knowledge is experienced as personally relevant, as having value and purpose, and as pertaining to issues in which students are invested. Meaning in this sense is also indicative of identity relevance; it is closely linked to the transformative and identity aspects of threshold concepts scholarship, and like these aspects of the threshold concepts framework, resonates with Mezirow's views on transformed meaning perspectives (2000). These implications are revisited in later findings.

8.2.2.4 Igniting students' metacognitive and metalearning shifts along their disciplinary learning journey

A change in pedagogy and interaction with peers can transform students' conceptions of and approaches to learning, and alter their perceptions of self by enhancing students' sense of personal empowerment and capability, and by reducing endemic anxiety and self-doubt associated with learning.

Many students juxtaposed their learning in the tutorial group with their experiences of learning mathematics and/or statistics (as a component of their high school mathematics curriculum) in a traditionally taught class. With a traditional (lecture-based) experience, students were likely to resort to a surface approach to their learning, adopting a *"Cramming, Pass, Forget"* learning approach to their modules, as opposed to its inverse approach: *"The more I do it, the more I understand it, the more I like it"* (sections 6.4.1.2 and 6.5.1.3). These findings resonate with well-documented concerns in existing scholarship (reviewed in Chapter 2) about the pace and volume delivery typical of lectured introductory statistics courses. In contrast to the one-way delivery of lectures, students saw the benefits of shifting towards a deeper approach in the tutorials. The sessions allowed them more time to construct meaningful knowledge and encouraged fuller engagement (Garfield, 2013), and accommodated the iterative nature of conceptual learning (Land et al., 2006), by providing repeated and varied 'takes' on concepts.

Participants saw that their prior engagement with, and understanding of mathematical and/or statistical concepts that they had encountered in high school, was somewhat deficient and incomplete. They associated fuller or deeper understanding with being able to apply concepts, and emphasised the need to be able to relate concepts to practical problems, relevant to everyday life and *"be able to tackle whatever question I am given"* (section 6.3.1.4) – to grasp the reasoning behind theoretical ideas, including their use in formulae. While they acknowledged that cramming before a test or exam had served them well in the past in being able to pass, students realised knowledge thus acquired was all too ephemeral and soon forgot what they learned. Students also noted the importance of practice for mastering statistical concepts and its application, but these had to be based on understanding in order to be useful. This deeper approach to learning was ultimately far more effective in enabling them to recall and employ statistical concepts.

Their recognition that they had not fully grasped statistical content present in the high school mathematics curriculum bears out the learning concerns of South African mathematics and statistics educators noted in Chapter 2 (Christiansen, 2007; Jansen, 2016; North et al., 2014; Venkat et al., 2009). This adds to existing evidence that the focus of an introductory statistics course should not be placed on learning a set of tools and procedures (GAISE, 2016), and that some students may not have grasped the fundamentals teachers believe they have covered. Our understanding of this issue may be enhanced by the clear distinction students made between *"cramming"* (linked to traditional lectured delivery) on the one hand, and *"understanding"* linked to the desire to know why, on the other. This accords with the notion of deep and surface approaches to learning (Marton & Saljo, 1976) considered in Chapter 2. Students taking a surface approach tend to "learn to respond to key words or data structures with memorised procedures", by contrast, taking a deep approach involves "understand[ing] the purpose of the analysis, the kinds of situations to which it should be applied, the type of data that should be collected, the algorithm involved in the test and the meaning of the conclusions" (Hubbard, 1997, p. 4). Notably, students' intention is decisive in distinguishing these approaches to learning, and the need to *"be able to tackle whatever question I am given"* described by participants, matches the intention of understanding and seeking meaning, which defines a deep approach to learning. Participants' conjunction of understanding and application of concepts, which the threshold concepts-enriched tutorial programme exercises promoted, again highlights the pursuit of meaning and context, and resonates strongly with a threshold concepts perspective and the view of learning as conceptual change (Davies, 2012).

In recognising that their conceptions of knowledge and learning had changed, students identified a *Personal Journey* process that accompanied the specific conceptual shifts they experienced as they grasped content. They moved from a focus on procedures and formulae and reproducing a body of content to a deeper understanding of meaningful, transferable principles, tools and language that they could apply in varied contexts. Additionally, instead of conceiving of learning as an individual, text-based process, participants came to see it as a socially constructed activity, as outlined in section 8.2.2.1 above. This could be characterised as crossing a metacognitive threshold, which is an idea that aligns with both threshold concepts perspectives (Entwistle, 2008) with earlier theories on the development of students' conceptions of knowledge (Perry, 1970) and learning (Saljo, 1982) over the course of their experiences in higher education, as synthesised by (Entwistle, 2008, p. 28):

> …these processes are interconnected as students become more aware of the nature of academic knowledge and how their learning may be better adapted to developing those forms of knowledge. This implies a shift in focus from the task itself to the process of learning.

Participants' comments in describing the fundamentals of Tut Group, Journey of Understanding and Personal Journey reflects students' evolving conceptions of learning that correspond broadly to those proposed by Saljo (1982, cited in Entwistle, 2009). That is, from reproducing, applying and using acquired knowledge, through to crossing an important learning threshold, learning equates to understanding when one exerts effort into meaning-making for themselves; by making sense of ideas by relating them to their previous knowledge and experience; and by transforming information into personal meaning, thereby shifting their world-view and sense of self (a theme that reoccurs in section 8.2.2.7 below). For this reason, effective pedagogies is vital in fostering deeper approaches to learning and thereby the desired conceptual transformations that comprise disciplinary mastery. The notable turnaround in participants' conceptions of learning statistics over the course of the tutorial programme of this study suggests that the various pedagogical approaches adopted may have enabled or accelerated their crossing of this metacognitive threshold. Pedagogical approaches, such as small group discussions (structured around the real-world context of tutorial tasks guiding conceptual development and application), participants' writings in their reflective journals, and being provided with detailed solutions to tutorial exercises, all served to make the process of learning more meaningful, and this seemed to play a central role in helping students move from unthinkingly carrying out analytical procedures, to deep understanding.

Students' conceptions of learning mathematical content knowledge can themselves be understood as a form of prior knowledge, which influences their learning engagement in the discipline and shapes the ensuing learning outcomes (Entwistle, 2008). Students described instances of metacognitive stuckness, such as perseverance and frustration, with ineffective study methods: *"you would think you understood in class, do it at home, you end up with question marks"* (section 6.3.1.3). This may be explained as failing to breach the threshold that gives on to new views of knowledge and learning. If students take the surface view to gaining disciplinary knowledge that sees a body of knowledge as transmitted by teachers and books, only to be absorbed and reproduced in exams, a deeper approach to learning will evade them (Entwistle, 2009). Arguably, crossing this metacognitive threshold is essential for constructing understanding of disciplinary threshold concepts. In order to cross this metacognitive threshold, students must not only reach a changed view of knowledge, but they must also develop an awareness of, and take control over, their own learning processes. This constitutes the more specific notion of “metalearning” (Biggs, 1985; Meyer, Knight, Callaghan, & Baldock, 2015), which will be revisited in further findings below.

From students’ responses, this study confirms that it is possible to pass high school mathematics without developing a sound conceptual understanding of the statistical topics covered in the curriculum (section 6.3.1.2). The possibility of passing mathematics in high school without developing the expected curriculum prescribed proficiencies is a major concern in the South African educational landscape (Christiansen, 2007; Jansen, 2012b, 2016; North et al., 2014; North, 2015; Venkat et al., 2009; Zewotir & North, 2011), and was discussed in Chapter 2.

As students’ realigned their conceptions of knowledge and learning, they also developed a nuanced conception of understanding in relation to the disciplinary assessment requirements of the introductory statistics module. In BSTS 201, assessments are based exclusively on multiple choice questions. One student revealed a strategic, albeit surface, approach taken to answer calculations-based multiple choice questions thus: *“since we are asked in a MCQ way, I would simply work around the given answers till one satisfies the question, especially in calculations”* (see section 6.3.1.1). To do well in assessments, students need to apply the knowledge and understanding under pressure. Although the assessment questions were exclusively multiple choice, students were required to answer questions posed in a disciplinary-specific manner, that is, questions that required students to exhibit conceptual understanding in calculations, graphs, and theory-based responses. Students recognised that an initial sense of having understood theoretical content might not necessarily translate into good marks in assessments. This led students to attempt identifying possible reasons for and elaborate upon some abilities and techniques that may be used to rectify this problem (sections 6.5.1.6, 6.3.1.4 and 6.3.1.5). It would appear that the struggle that some students experienced in trying to reach the high-level application demanded in assessments might be due in part to an apparent disjuncture between what students learn in class, and what they are required to perform in tests (Biggs, 1999). Some saw to it that they breached the gap themselves, where certain participants mentioned using past assessments to familiarise themselves with the disciplinary approach, and continuously practicing (section 6.2.1.5) examples at home, or with peers.

Practicing problem questions in this way accords with Brabeck, Jeffrey, & Fry's idea of "deliberate practice" (Brabeck, Jeffrey, & Fry, 2011, p. 1). Engaging in deliberate practice entails students paying attention, rehearsing and repeating, that is, taking a deep approach to learning. This approach can lead to new knowledge and skills, which can later be harnessed into more complex knowledge and skills. Deliberate practice has its contrast in rote learning (a surface approach), which is unlikely to improve performance (Brabeck et al., 2011). Working through past tests and examination questions may at first appear to be a strategic, assessment-oriented approach; however in light of students' comments, and Brabeck, Jeffrey, & Fry's insights, a more likely interpretation seems to be that they have recognised the potential of attempting varied applications to deepen and consolidate disciplinary understanding. This type of individual effort seemed to be a decisive factor in strong performance, and is related to students' metacognitive consciousness, motivation, and sense of responsibility for and control of their learning, discussed in further findings below.

A striking number of participants (including those who emerged as the strongest members of the group) said that at the beginning of the tutorial programme, they had felt intimidated at the prospect at learning statistics over the semester. They thought that they had inadequate mathematical knowledge and felt intellectually inferior by having matriculated with the subject Mathematical Literacy, and felt that this would be a stumbling block in their attempts at being successful in statistics. This was often compounded by self-doubt in social situations, such as feeling *"shy"* or *"scared"* to ask for help from the lecturer in front of other students (section 6.3.1.4), as this could potentially expose any faulty reasoning that they may have. Within a relatively short amount of time, the group sessions helped to manage and mitigate these feelings.

Issues around self-belief and building confidence have not been deeply explored in studies of learning in statistics, despite their arguable relevance in a discipline often characterised as being difficult. Subsequent findings (sections 8.2.2.5 – 8.2.2.7) will examine affect more closely, and discuss the (limited) research on conative aspects of learning statistics. This finding focuses on the ways in which the pedagogical approaches engaged in the tutorial programme appeared to help students overcome this sense of deficit, and become more confident about their abilities to participate in the group work and discipline. From participants' descriptions, tutorial discussions could enhance their self-assessment of their competence in statistics, as they found themselves making contributions to group work that added to, or corresponded with their peers understanding, or even revealed their own limited understanding. Approaching tasks as a group, created a synergetic process, where students could learn from each other, and that made it more likely they would be able to solve the given problems (section 6.2.1.3). The results of working in groups may be identified as building self-efficacy, collective capability, and responsibility. From the first tutorial session, participants could begin to restore the deficits in their own competence that many felt contributed to a sense of personal empowerment, as they came to feel more confident about themselves and their abilities. Each of these will be discussed further below.

The initial self-perceptions students described correspond to a lack of self-efficacy (Bandura, 1986): they doubted their capabilities in terms of their mathematical (seen as a pre-cursor to statistics) knowledge, and as contributors to the group. Self-efficacy has bearing on motivation, academic performance, and well-being (Bandura, 1986; Pajares, 1996) that recur in later findings. A sense of self-efficacy, or belief in one's capabilities to successfully complete a task motivates one to persist despite setbacks, immerse oneself completely in a task, and persist until one attains success. In the mathematics education research literature, mathematics self-efficacy was found to be more predictive of students' problem-solving abilities than their individual mathematics self-concept,[56] their perceived usefulness of mathematics, prior experience with mathematics, or gender (Pajares & Miller, 1994).

This study's findings suggests that students' sense of self-efficacy was boosted by the pedagogical practices employed in the tutorial programme, which helped students' overcome their chequered experiences of high school mathematics and negative mathematics self-concepts, and helped students *"to see the skills and everything else that* [they] *have"* (section 6.4.1.1). Beliefs about one's self-efficacy may be informed by enactive mastery experiences, vicarious experiences, verbal/social persuasions, and affective and physiological states (Bandura, 1986; Usher & Pajares,

[56] "Self-concept differs from self-efficacy in that self-efficacy is a context-specific assessment of competence to perform a specific task, a judgement of one's capabilities to execute specific behaviours in specific situations. Self-concept is not measured at that level of specificity and includes beliefs of self-worth associated with one's perceived competence" (Pajares & Miller, 1994, p. 194).

2009). From participants' reflections, it would seem that interactions in the tutorial group afforded participants positive experiences of all four, as they came to understand concepts and solve challenging problems, observed their peers successfully doing the same, reflect on past and current performances, and reassured and encouraged by peers and lecturer in a comfortable, non-threatening environment.

The most powerful source of self-efficacy are accomplishments that students have achieved for themselves, namely mastery experience (Usher & Pajares, 2008), especially if the task was particularly difficult, requiring an increased effort. A high sense of self-efficacy based on past successes will encourage students to persist in their endeavours even in the face of challenges. This high sense of self-efficacy was clearly evident from participants' reflections on their experiences of learning statistics during the group tutorial sessions, with some students' even expressing a desire to teach statistics someday: *"I will now consider teaching statistics and make my learners like it and understand it better than myself"* (section 6.3.1.5).

Group work also afforded an opportunity for self-evaluation by allowing students' to bench-mark their capabilities against that of their peers. This helped many students to form positive opinions about their competencies in statistics (section 6.2.1.3). In other words, the group provided the participants' with cues signalling their progress in learning with respect to the other participants (Usher & Pajares, 2008), further enhancing students' sense of self-efficacy in the discipline (section 6.4.1.1.) Verbal feedback from the lecturer – including written feedback in the case of comments made in students' reflective journals - and peers, helped to boost students' confidence in their disciplinary capabilities: *"I never thought that there are people who are not from your family who could help you to do better each and every day. The responses I received from ma'am were very encouraging and helpful. Then that helped take the negative thoughts I had about stats being hard away"* (see section 6.4.1.4). Lastly, students' expressed their experiences of learning in the tutorial programme as being *"amazing"* and one of *"joy"*, crediting the tutorial programme for helping to *"stimulate positivity"* towards their learning in the discipline. The general consensus amongst the student participants was that regular interactions within the tutorial sessions helped to increase students' emotional well-being, and reduced negative emotional states (see section 6.5.1.4). All of this had the desirable effect of heightening students' sense of self-efficacy (Bandura, 1997). This growing sense of self-efficacy in turn increased students' intrinsic desire to understand, and their readiness to engage with conceptual content (not only in statistics but also with other modules that they were studying (sections 6.4.1.1 and 6.4.1.5)), and seems to be an important reason why many experienced their learning in the groups as personally empowering.

Interestingly, a sense of personal empowerment also appeared to derive from the sense of collective capability and responsibility that emerged in the tutorial groups. This collective capability is tied to both of the previous findings: the collaborative, discursive processes that effected conceptual learning, and participants' changed conceptions of knowledge as meaningful and socially constructed. Participants increasingly came to see peers as a significant additional resource for learning, in the tutorial sessions and beyond. Students who might initially have been reluctant to request help from peers or the lecturer would now do so more readily (section 6.2.1.9), confident of a positive response (section 6.4.1.5). As the sessions continued through the semester, the sense of the group members taking collective responsibility for their learning strengthened, wherein it was noted: *"we in the group help each other* […] *everyone was participating making sure we get correct answers"* (section 6.2.1.3).

Participants saw the value of thinking and learning as a collective, marvelled at receiving this support from non-family members, and found it *comforting* knowing that there were others that they could rely on (peers and/or lecturer) to help them along their journey of understanding, with one student going so far as describing the lecturer as having *ubuntu* (section 7.3.1) – "a way of life based on the values of respect, compassion, and connectedness, all advocating that an individual's humanity is made possible through the humanity of others" (Cherrington, 2017, p. 75). It may be argued that this finding highlights students' growing sense of awareness of the fundamental interdependence of people according to an Afrocentric perspective (Venter, 2004) where "people mutually recognise the obligation to be responsive to one another's needs" (Mkhize, 2007, p. 46) as well as their own. Thus, students' learning experiences in the tutorial programme offered a transformed way for students to experience themselves, the world and the future – a manner of learning that may be linked to hope theory (Scioli & Biller, 2009) – that is, "an active orientation that enables agency and interpersonal engagement directed at pursuing purpose and well-being" (Cherrington, 2017, p. 75).

The findings of this study resonate with the view that encouraging active, cooperative learning experiences that create safe and creative spaces for critical dialogue, allowing for multiple voices and experiences to be heard, could in turn foster a sense of collective hope characterised by the values of connectedness, caring, and collective agency (Cherrington, 2017), a finding that is congruent with collective-oriented African cultures, wherein the proclivity is towards collectively promoting well-being (Mkhize, 2007; Venter, 2004). This stands in counterpoint to 'Western' epistemologies that promote individualism in South African universities (Backhouse & Adam, 2013), where the prevailing culture is against collaborative thinking and leanings are towards seeing fellow students as one's adversary in an attempt to position oneself as being "smart, worthy or wise" (Mezirow, 2000, p. 11). This finding may also add substance to the discussions on how the country's higher education curriculum may be internationalised in ways that promote the decolonisation process by "developing a unique South African education brand that foregrounds *ubuntu* (humanism)" (Mheta, Lungu, & Govender, 2018, p. 6). Students' comments suggest that within the group, competitiveness was replaced by solidarity and synergy, which promoted their conceptual and metacognitive development as well as encouraging a shared spirit of understanding and imparting a sense of community within a university classroom (Cherrington, 2017).

Learning within the group was felt to be personally empowering to individual students. Resolving problems and constructing knowledge amongst themselves on a basis of mutual respect for each other's abilities despite variation in individual strengths enhanced not only students' conceptual understanding and perceptions of their capabilities in statistics, but also their sense of responsibility for and control over their learning. Thus, *"when we attended the tut group, it forced me to think and it forced me to answer the questions which made me understand a bit more"* (section 6.3.1.4). The shift where responsibility for learning was taken up collectively by the group was tied to the format of the tutorials, with its emphasis on understanding being constructed through group discussion of topical problems, rather than being formally taught by a lecturer or tutor. This entailed the deliberate dismantling of the traditional roles and power relations of the authoritative teacher and subordinate students dispensing knowledge, respectively. As tutor, I consciously transferred as much authority to the group as was feasible (Mezirow, 2000) and remained in the background, playing a primarily facilitative role. I decided on the tutorial topics, and the exercises provided the content and questions that guided discussion. This I did through careful observation of the group's readiness and relying on intuition and experience. The participants were collectively responsible for making meaning and constructing their knowledge, guided and prompted by the tutorial tasks. The sense of being responsible for constructing their own understanding through group discussion appears to have been sufficient to bring about significant shifts in the way participants viewed themselves as learners. A pedagogical format that entrusts responsibility and transfers authority for learning to the group might be experienced as empowering, because it signals to the students that the teacher deems them capable and meriting of that trust.

Consideration of the possible sources of participants' anxiety and lack of confidence points to a substantial anticipatory or pre-liminal component: they were affected from the outset, before they had even begun to engage with the threshold concepts in the exercises. Students' reflections suggests that the source of their insecurities lay in part in their biographies, in past and contemporary experiences of learning, including previous experiences of learning statistics, as well as in other courses at university, and their earlier schooling history. These experiences, which are largely unconsciously held, but form a potentially self-perpetuating part of students' frames of reference (Mezirow, 2000). If these self-beliefs are negative and limiting, they would need to be reconstituted as a "new, more capable story" (Cozolino & Sprokay, 2006) to enable students to advance in learning.

In terms of the capability approach, (Walker (2012) drawing on a body of earlier theoretical work by (Sen)), students' capabilities is broadly conceived as "those valuable beings and doings which enable us to choose and live in ways we find meaningful, productive and rewarding individually and collectively for the good of society" (Walker, 2012, p. 453), and may be influenced by the impact of educational conditions on their identities as learners. This perspective on students' self-concepts as learners corresponds with the idea of 'pedagogical stance', which is influenced both by the choices students make in a learning situation, and by the individual learner history they bring to the learning environment (Savin-Baden, 2016). This view is borne out by participants' recollections of their past learning experiences in section 6.4.1.1.

Coming to see oneself as a capable learner seems to have clear threshold properties, centred in the transformative capacity of a reconstituted self-concept. Until students attain this view of themselves, their learning is likely to be held back by their self-beliefs and the learning choices that ensue. Students' conceptions of themselves as capable learners can be engendered by pedagogical approaches that affirm and signal their capability in the eyes of the teacher; by their sense of collective capability; by their growing individual self-efficacy beliefs; and by the underpinning conception of learning as the social construction of meaningful knowledge, in which they are active agents (as discussed in section 8.2.2.1 above). Together, these elements can encourage them to rewrite their views of themselves as capable learners. Changes in students' conceptions of and approaches to learning, and in their views of themselves as learners, have been recognised as necessary shifts in traversing the broad liminal process of becoming a student in higher education (Berg et al., 2016; Cousin, 2014). These metacognitive and identity transformations might be seen as thresholds to threshold capabilities and together they can activate a capable self to embark on the further transformations required by disciplinary learning (Baillie et al., 2012).

Synthesis (8.2.2.1 – 8.2.2.4): Cognitive and metacognitive reformations

The conceptual transformation associated with crossing learning thresholds is an aspect of the threshold concepts framework that has not been widely documented in threshold concepts studies in statistics. While much of the discussion under this finding is confirmatory of existing research in statistics education, this study offers revelatory substantiation of the threshold concepts framework perspective in a context where relatively little is known about the qualitative nature of learning. Furthermore, this study extends understanding of possible ways in which students' crossing of learning thresholds may be facilitated or accelerated through group processes that support cognitive and affective aspects of liminal learning transitions (the latter considered more fully in latter findings). Cooperative learning processes of peer discussion and articulation (section 8.2.2.1), and real-world applications that brought about meaningful conceptualisations (section 8.2.2.2), seem to promote transformative conceptual understanding and the development of a statistic gaze on real-world events. These processes, along with a multiplicity of pedagogical approaches (sections 8.2.2.3), underpinned students' sense of capability and helped foster deeper approaches to learning (8.2.2.4).

The following three sections (8.2.2.5, 8.2.2.6 and 8.2.2.7) will discuss the conative and affective constructs of disciplinary learning, as it pertains to this study's student participants.

8.2.2.5 Overcoming fear and trepidation: Conative and affective constructs

Embarking on the disciplinary learning journey entails consciously staying the course, choosing to fight rather than flee in the face of cognitive challenges and affective demands; learners' psychological resources will influence their persistence and progress.

Learning statistics concepts while progressing through the Journey of Understanding from 'stuckness' or impasse to 'AHA' or insight was not an automatic process for participants because conceptual learning could require repeated attempts, practice, and time, making this transition might demand great personal effort and perseverance. Contemplation of students' reflections suggests that consciously staying the course also seems to require particular traits or psychological constructs that operate at a deeper level of the self and interact with the motivation provided by students' values and beliefs. Participants referred to determination and hard work in reflecting on their journeys to understanding (section 6.2.1.5.). Their descriptions of moving through impasse by seeking out alternative explanations and conducting real-life experimentation of difficult material, and their reflections on their own learning practices and study habits (sections 6.2.1.5, 6.2.1.4, 6.2.1.8 and 6.2.1.9) are as follows: *"I have an increased hunger to learn ever since I joined this group"*. This summarises the importance of initiative, conscious effort, and self-regulated learning strategies. Those who felt they were coping and progressing in their learning expressed a sense of agency and self-efficacy, and they faced challenges with self-belief and a plan, and attributed good performance to their own efforts and study approaches (sections 6.3.1.4 and 6.3.1.5). On the other hand, some participants alluded to deeper problems around their own motivation, procrastination, and underperformance (section 7.2.1.8).

A shift in students' conceptions of learning to emphasise understanding constructed in the light of *'when I understood statistics my world became so much better☺'* (section 6.3.1.5) made metacognitive and affective demands on them. This view of learning brought home the reality that they would have to deal with uncertainty and incomplete understanding, enroute to mastery. They might not grasp concepts and theories immediately, could be forced to question what they thought they knew, and would have to tolerate and trust the process (section 6.3.1.5 and 6.4.1.1). Students might face additional affective discomfort as a result of deeper engagement with content that raised existential or moral questions for them (section 6.4.1.3). A cornerstone of the threshold concepts framework, is the recognition of these difficulties and demands that inform the view of learning as a transformative transition through a liminal space.

Nonetheless, threshold concepts scholars acknowledge that this liminal traverse is one of the less well-understood aspects of learning (Land & Rattray, 2017; Rattray, 2014, 2016). Participants' descriptions point to particular traits, attitudes and/or behaviours that impacted on how they negotiated liminality, and these may serve to extend our understanding of students' progress through this transition. Broadly speaking, these students' descriptions of self-will, effort, perseverance, self-regulation, and self-direction suggest the employment of conative constructs (Huitt & Cain, 2005) as the third component of mind historically identified in psychology (cognition and affection being the other two psychological domains, according to (Snow & Jackson, 1993)). Connation provided a "commitment pathway" (Snow & Jackson, 1993) along which students activated and directed their behaviour and action (Huitt & Cain, 2005), thereby significantly influencing the course of their learning. Furthermore, they were closely associated with affective constructs including elements of personality, attitudes, or predispositions that could favour or hinder their learning.

Further pertinent personal constructs are indicated by the affective, metacognitive, and conative features of learning that recur in the descriptions of affinities Personal Journey and Emotions in Chapter 6. These affinities depicted the affective and identity-centred components of participants' learning. Students' reflections acknowledge that managing their emotions was important in shaping the trajectory of their learning in the discipline, choosing to rather focus on the *"positive emotions* […] *because all the negative would have just driven me away and I wouldn't have all the knowledge that I have now on statistics"* (section 6.4.1.5). By the same token, students' reflections, captured in the group SID (see Chapter 5), overwhelmingly indicated that the trajectory of their Journey of Understanding significantly impacted upon their Personal Journey and Emotions (see sections 7.3.1 and 7.3.2). Emotional responses to mathematics anxiety, statistics anxiety, stuckness, and assessment (sections 6.5.1.2, 6.5.1.3 and 6.5.1.6) might derail students who could not access psychic resources (internal or external) to stay the course. Progress in learning required students to maintain stable affect, stay optimistic in the face of challenges, identify and work towards achievable objectives, and show resilience in recovering from setbacks (section 6.4.1.5). Implicit in all of these descriptions is a sense that these students took ownership of and responsibility for their learning — their successes and failures, and their affective responses.

Personal traits and attitudes suggested by participants' reflections as influencing the extent to which they persisted in the face of difficulty include fortitude, determination, and resilience; self-beliefs including (but not limited to) a sense of self-efficacy with regard to the discipline; self-awareness, including metacognitive insights; an ability to manage one's emotions and retain an optimistic outlook; agency and taking ownership of one's learning; and academic commitment. These constructs are useful, as they signify the means by which considered goals, reflecting a sense of congruence between discipline and identity, may be translated into decisions and behaviour that advance students' learning (section 6.3.1.5).

Returning momentarily to the SID, the graphic representation of these personal constructs lies in the linear relationship stemming from students' participation in the Tut Group to their Journey of Understanding through Personal Journey to Emotions. All of these constructs are drawn from students' reflections on their participation in the semester-long tutorial programme and are linked to positive psychological constructs, which represents a shift away from problem-focused psychology, and towards that of building gratitude and strengths to help create a good life (Peterson, 2013). Although the data is dominated by positively couched descriptions of those who reflected on the clear progress they felt that they made, there were also some students who identified problems in their own procrastination and lack of persistence (section 6.3.1.4), and some who remained at an impasse with particular concepts, or with statistics generally (section 6.3.1.1).

Findings from the current study of viewing students' navigation of liminality in terms of these constructs resonate with emergent knowledge about how positive psychological constructs may impact on higher education learning (Williams, Horrell, Edmiston, & Brady, 2018). A key element of positive psychology elaborated here is that of a strength-based approach to learning. The use of a strength-based approach to education encourages students to focus on their strengths and has the potential to instil "high levels of emotional, psychological and emotional well-being" (Schreiner, 2015, p. 4). Through a strengths-based approach, students may take cognisance of their individual strengths, which encourages motivation, thereby leading them to greater academic success (Louis & Schreiner, 2012). Educators may encourage students to identify new ways in which to apply their strengths, thereby enabling students to actively participate in the learning process by meaningfully processing what is being taught in the moment. Thus, the ultimate goal of positive psychology would, seemingly, be to encourage engaged learning environments (Schreiner, 2015).

Positive psychology also emphasises *thriving* as a key element in success (Schreiner, 2015), defining a student in higher education as thriving if she is "fully engaged intellectually, socially, and emotionally in the college experience" (Schreiner, 2010, p. 4); and a successfully thriving student recognises the importance of academics, the development of time management skills, optimism, appreciation of differences in others, and community involvement (Schreiner, 2010). Extant research links these characteristics, that can be taught, to academic success (Schreiner, Pothoven, Nelson, & McIntosh, 2009). Academic settings that foster "positive, respectful, and supportive" relationships between students and educators also creates conditions in which students may thrive (Williams et al., 2018). This seems an accurate characterisation of the experiences reported by participants, who regarded themselves as making progress in their learning in statistics (sections 6.2.1.9, 6.3.1.4 and 6.3.1.5 and 6.4.1.4).

Furthermore, the positive psychological constructs highlighted by the study findings strongly complement recent exploration within threshold concepts scholarship of the impact of PsyCap characteristics (as discussed in section 3.4.1.2) on how learners cope with liminality (Rattray, 2016). From a threshold concepts framework perspective, Rattray hypothesises that learners who believe themselves to be capable (self-efficacy), attribute success to their own efforts (optimism), monitor and align goals and the pathways to reaching them (optimism), and persist in the face of difficulties (resilience). Students possessing these affective assets may cope more effectively with liminal learning transitions than students who, despite having intellectual capacity, lack these affective assets and may remain stuck. Once again, this seems an accurate characterisation of the attitudes and traits reported by participants who regarded themselves as making progress in their learning in statistics (sections 6.4.1.1). Although this study did not set out to measure psychological constructs, the findings offer some early substantiation and illustration of the impacts posited by Rattray (2016). Participants' reflections on their Personal Journey recorded in Chapter 6 also align with the suggestion that PsyCap is associated with "a willingness to engage and take ownership of the learning and with awareness that learning does not simply happen but, rather, it requires effort and agency" (Rattray, 2016, p. 73).

I have emphasised positive psychology not only because of incipient threshold concepts framework research exploring that construct (PsyCap), but also because research suggests that these positive psychological constructs is a resource that may be developed or accumulated. Its utility is therefore only explanatory, but also rests in its being a potential area for interventions to support learning (Rattray, 2016). This is an implication that will be returned to in Chapter 9.

8.2.2.6 The effects of affective learning: Pervasive and influential emotions

A spectrum of affective responses can arise from, and in turn impact on, all learning and personal well-being.

Learning is not simply a cognitive process, but also includes an emotional aspect to the process, and feelings, both positive and negative, seemed to permeate every aspect of participants' experiences of learning statistics in lectures and on the tutorial programme. These emotions arose from reflections of previous learning experiences, from processes of learning and engaging with the disciplinary content, assessment, or from the learning environment. They seemed to permeate the learning experience in complex ways to influence students' learning, and may therefore also be detected as affective undercurrents in many of the other findings reported in this chapter.

However, in the SID (see Chapter 5) of this study, students' Emotions were the primary outcome of students' disciplinary learning experience. This would suggest that students' emotional well-being was directly impacted by their experiences of learning statistics in the threshold concepts-enriched tutorial programme over the semester. Students felt apprehensive and anxious encountering new content, which was heightened by the discipline's underlying mathematical content. The experience of stuckness, or impasse, and struggling to understand and internalise content on one's own was frustrating and demotivating for many (section 6.3.1.1). Working through past exam question papers caused anxiety for some (section 6.5.1.6); poor performance on assessments could be disappointing, while finally understanding concepts and achieving good grades brought about a sense of accomplishment and increased motivation (sections 6.4.1.5, 6.5.1.5 and 6.5.1.6).

There was also emotion linked to the content itself. Students described their joy and pride in mastery of concepts and theory (sections 6.4.1.1 and 6.5.1.5); a *"fun experience"* (section 6.5.1.4); a sense of discovery of thinking like a statistician (section 6.3.1.2), where a sense of achievement at reaching a full understanding of probability concepts and calculations, was tempered by a feeling of sadness as it required students to relinquish lay understanding of probabilistic games. They further described the cognitive dissonance that might arise if they perceived the disciplinary treatment of ascertaining the existence of relationships between quantitative variables as conflicting with their own ideas (sections 6.3.1.2 and 6.4.1.3). Participants described a collection of positive emotions associated with the format of the tutorial programme, and credited the tutorial group for helping to *"stimulate positivity"* (section 6.5.1.4). As described in Chapter 6, these included feelings of comfort, security, and belonging to a group with shared interests, experiences and perspectives; feeling recognised and valued within the group (sections 6.2.1.8 and 6.2.1.9); and having fun while engaged in learning (section 6.5.1.4). Participants also conveyed increasingly positive feelings about statistics (section 6.5.1.4), which they linked to reaching a greater understanding of the discipline and its applicability (sections 6.5.1.3 and 6.5.1.5). Students' feelings towards studying statistics was greatly transformed over the semester: from experiencing initial feelings of fear, frustration, sadness, and seeing themselves fail. Their final lasting impressions was one of immense joy and love for the subject (section 6.5.1.4).

The threshold concepts perspective considers the affective elements of learning to be inseparable from the cognitive. In the threshold concepts framework, the main sources of emotion seem to be attached to liminal crossings, and the potential implications of transformed understanding for learners' sense of self (Cousin, 2006b; Timmermans, 2010). These elements are evident within the sweep of participants' affective responses sketched in the preceding paragraphs. The experience of stuckness, incomplete understanding and questioning one's knowledge, as well as the psychic demands this made on participants, the importance of how they responded, and whether they had the personal resources to cope with liminality, are reflected in the data chapters and discussed in several earlier findings, notably in section 8.2.2.5, and issues around participants' emerging sense of themselves as learners was considered in section 8.2.2.4.

The emotions that students attached to the transformative aspects of disciplinary learning might at times appear almost valiant in nature: *"In spite of being terrified by people about how difficult Business Statistics is, I said to myself "I will fight, I am not a loser, everything has got its limitations"* (section 6.4.1.1). The unease around liminality and transformation is recognised as a necessary part of learning in the threshold concepts framework as it reflects the emotional investment needed for intellectual growth:

> Here, they will experience the strong affective component of (threshold concepts). There will be 'cognitive dissonance', a motivational drive to reduce unpleasant feelings of uncertainty, and 'perseverance', in which more familiar courses of action will continue to be employed despite evidence to the contrary. Too much uncertainty in this liminal state and the learner will not be able to progress beyond a surface understanding. Not enough uncertainty and the learner will not make the required transformation into a fully participating member of a community of practice. The task in curriculum design is to strike the optimal balance (Walker, 2013, p. 250).

Participants recognised that negative or difficult emotions could be useful and necessary to their learning (section 6.4.1.1). This reinforces the argument that the intention in pedagogy should be to support students to manage and learn from difficult or painful emotions associated with learning, rather than trying to eliminate them. In addition to this developmental and constructive affect, participants articulated overcoming a more dispositional type of anxiety that was brought on by feelings of intellectual inferiority and self-doubt (noted in the finding in section 8.2.1.1): *"statistics is difficult to understand and pass. That affected me, I came with that belief [w]ithout the tut group*

I wouldn't have […] *known that stats is also for dummies (not just the smart ones)*" (sections 6.2.1.1, 6.2.1.6 and 6.3.1.5). Students recognised the benefits of the constructs of the tutorial programme to their learning in the discipline (as noted in section 8.2.2.3).

Anxiety is an increasingly researched emotion in statistics education due to its multidimensionality, and its potentially debilitative effect on academic performance (Onwuegbuzie & Wilson, 2003). The multidimensionality aspect of anxiety was evident in this study, as students reported their anxiety as emanating from a variety of sources. Pressure to absorb and understand disciplinary content during structured lectured sessions made at least one student confess that "*I started panicking and wondered if I will make it*" (section 6.4.1.2). Students' reflections posits poor prior achievement in mathematics in high school as a major source of their statistics anxiety (sections 6.2.1.2, 6.3.1.2 and 6.3.1.3). Students also exhibited epistemological anxiety, in terms of "a feeling, often in the background, that one does not comprehend the meanings, purposes, sources or legitimacy of the mathematical objects one is manipulating and using" (Wilensky, 1997, p. 172), where one student noted: *"I just could not understand what and why I am calculating"* (section 6.3.1.1).

Fear of academic failure may also cause some students to adopt defensive strategies, leading to disengagement and study avoidance (Jackson, 2015). In view of this, the statistics anxiety experienced by some students can be so great that, in the absence of interventions, undertaking statistics classes may be regarded by these students as extremely negative. As one student pointed out: "*Learning statistics wasn't optional* [this semester]. *At first, I would have never chosen the module, but now I can even study it next year*" (section 6.4.1.2). This comment underscores existing research that suggests that statistics anxiety is partly responsible for students delayed enrolment in statistics courses and their subsequent procrastination, once enrolled, in completing discipline-related tasks (Onwuegbuzie, 2004).

This type of unconstructive and potentially debilitating anxiety related to pedagogy may be helpfully reduced. Considering students' emotional responses may add a dimension to our understanding of concerns about the conceptions of knowledge and approaches to learning fostered by lecture-dominated delivery (as supported by the findings in sections 8.2.2.1 and 8.2.2.3 above).

The pressure students felt to internalise and apply the complexity of concepts dispensed at a rapid pace in lectures appeared to be a source of anxiety in itself. This was directly addressed by the ways in which the group was empowered and entrusted to build understanding in the tutorial programme, helping participants to conceive of themselves as capable and in control of their own learning, as discussed in section 8.2.2.4. Students' anxiety towards learning statistics also seemed to have been alleviated by the application-oriented teaching method used in the tutorial programme (as described in section 6.2.1.4 and considered with regard to overcoming disciplinary stuckness in section 8.2.2.2); and their positive evaluation of the lecturer (as described in section 6.4.1.4 and considered with regard to imparting hope in section 8.2.2.4).

This study's findings add to and corroborate with the existing body of work investigating the impact of interventions aimed at agency and pathways to help reduce statistics anxiety (Onwuegbuzie, 1998; Pan & Tang, 2004). From students' experiences of learning in the tutorial group, where they developed an understanding of concepts through a variety of instructional methods, students discerned that continued practice leads one to improved conceptual understanding, and that an increase in conceptual understanding increases one's motivation to aim for higher goals for oneself. Thus, a motivated student will no longer have academic procrastination featuring in her mindset: "*…in this group, tut group, I saw that the more you practice, you get better at it* […] *so now I'm eager to set higher marks*" (section 6.4.1.5).

Surprisingly, assessment in tests or examinations were not a significant cause of anxiety for participants. Some anxiety was ascribed to the multiple choice question format of formal assessments, as students were unsure of how to prepare for this. However, not many students reported poor assessment performance as contributing to any anxiety that they may have felt. In fact, self-perceived poor performance on assessments served as the impetus for students to strive to achieve their set higher goals (section 6.5.1.6), as one student proclaimed: "*I won't be beaten twice. Exam is my day to avenge myself*". High levels of test anxiety generally have "a debilitating effect on attainment" (Jackson, 2015, p. 256). Research on test-related anxiety has not deeply explored students' experiences in terms of the sources of their fears, how fears are perpetuated, or the effects of fears on their learning (Onwuegbuzie, 2000a). Arguably, the portion of assessment-related anxiety that derives from unclear expectations with regard to the details of assessment requirements is not conducive to learning and could be relatively easily mitigated in class. This seemed to be the case in this study, as participants' comments suggest that assessment anxiety seemed to dissipate after practicing and working through a variety of past question papers.

Participants' accounts of emotions attaching to disciplinary content itself are surprising against the backdrop of most statistics education research, from which they are absent, but they are predicted by the threshold concepts framework in relation to economics education (Shanahan & Meyer, 2006). In particular, grasping the concept of probability evoked a sense of dawning realisation and achievement (section 7.3.2.3), which matches the explanation offered by threshold concepts framework regarding why grasping threshold concepts may be experienced as transformative. Participants' phrasing suggested that theirs was a revelatory awakening that stemmed from realising the practical application of their learning in the discipline (section 6.3.1.2). This type of emotion is developmental rather than debilitating; it is noted here not as a problem to be addressed, but as an example of how content that can seem devoid of emotion (and is usually taught as such) may not be so for students.

A participant mentioned a possible tension between estimates produced in a regression model, and the actual values. Prompting the student to ask the question: *"is statistics correct?"* (section 6.4.1.3). It is possible that internalising a disciplinary perspective, may create a level of cognitive dissonance, particularly if students do not interpret that perspective as an analytical model approximating a real-life relationship, and to be used under appropriate circumstances. While the data regarding this issue does not allow for firmer conclusions, these comments may suggest that some students have a level of metacognitive awareness that enables critique of statistical concepts, that they have understood the theoretical canon, and are able to reflect on why it may not appeal to them. This possibility has not been explored deeply enough in threshold concepts-oriented studies in statistics. However, it evokes some curriculum and content concerns that the questions typically addressed in introductory courses ought to be relevant to students so that they might be able to see the value of the discipline.

Perceptions of disciplinary worth are potentially an important influence on how students respond to learning and liminality. Whether the implicit disciplinary worth conveyed by the curriculum (and pedagogy) of an introductory statistics module peaks students' interest and enthusiasm warrants further exploration from a threshold concepts perspective. Participants also recounted an array of positive emotions emanating from their learning experiences. Reaching understanding and recognising their progress brought joy, relief, satisfaction and pride (sections 6.5.1.4 and 6.5.1.5); together with a growing sense of self-efficacy in statistics (section 6.5.1.6), these feelings motivated them to continue learning and reinforced their goals (sections 6.3.1.5 and 6.4.1.5).

Almost all participants commented on the *"fun"* element of their learning in the tutorials (section 6.5.1.4), reflecting the intrinsic motivation associated with attending the sessions, which may account in part for their positive responses to working on high-level, conceptually demanding academic activities in the tutorial tasks. Some participants expressed a sense of excitement, adventure and discovery in applying their emerging disciplinary skills. Most considerations of liminality in learning emphasise uncertainty, a transformative space that may evoke a continuum of emotional responses. Awareness of the potential emotional charge of learning raises questions for teaching. In this study, it seems that the group dynamics reinforced the element of adventure and discovery that some students felt, and also offered support for those at the anxious end of the affective learning spectrum, as noted in section 8.2.2.1.

Many participants expressed increasingly positive feelings and attitudes towards statistics, some of which were surprisingly strong, like: *"I have fallen in love with this module"*, which were linked to a recognition of their own competence and of how the discipline could be useful to them (sections 6.5.1.3 and 6.5.1.4). These comments bear out the connection of disciplinary meaningfulness, engagement and self-efficacy discussed in section 8.2.2.4, and highlight the potential strength of affective responses and the associated intrinsic motivation (Pintrich, 2003) and academic commitment that might be elicited by disciplinary learning that is experienced as congruent with one's sense of self (Human-Vogel & van Petegem, 2008).

The range of affective responses can in turn influence learning significantly. The feelings just described are not merely side-effects or a backdrop to the 'real' (cognitive) processes of conceptual mastery, but instead, participants' reflections suggest that emotions have a major impact on all aspects of their learning experiences and outcomes. This resonates with Vygotsky's view that “affect is the alpha and the omega, the first and last link, the prologue and epilogue of all mental development” (Vygotsky, 1998, p. 227). Students’ personal journeys are affected by their feelings about statistics and how it aligns with their self-concepts, values, and future plans, and in turn, their personal journey affects their feelings about themselves as learners, and their sense of self-efficacy with regard to the discipline (Personal Journey influences Emotions, section 7.4.1). Yet, the teaching of statistics generally disregards the possibility that theoretical content, as well as pedagogy and assessment, may not be emotionally neutral for students. This raises implications that will be pursued in Chapter 9.

8.2.2.7 Forging a sense of self

Learning brings new perspectives and personal development, which may bring about changes to students’ self-concepts in disciplinary and personal domains.

The view of learning in the tutorial programme suggested by participants’ descriptions as discussed in the previous findings is one of an all-encompassing transition that leads to changed views of the world and oneself. These transformations seemed to occur not only in regard to disciplinary understanding, but also in broader metacognitive spheres. Beginning with the latter, students came to see learning as socially constructed understanding of meaningful knowledge, and themselves as capable and active agents of their learning (sections 8.2.2.1-8.2.2.4). Breaching this metacognitive threshold brought forth transferable insights that comprised an important part of the personal growth described by many participants. Thus Journey of Understanding elaborated in Chapter 6 highlighted a changed view of learning as understanding rather than cramming, and a recognition of the power of discussion and articulation to build understanding (section 6.4.1.3). Many were surprised by insights regarding their social selves: “*since I’m mostly a private person* […] *I can say it helped me gain self-confidence and how to be a participant*” (section 6.4.1.3).

Threshold concepts scholarship considers “intellectual maturation” (such as the shifts just described) and “disciplinary enculturation” to be entwined (Cousin, 2008, p. 263), and this appears to match the findings of the current study. The shift in identity associated with learning in the group seemed to go beyond becoming a capable statistics student. It was also about becoming more confident and sure of oneself, and having a sense of personal growth. Together, the meanings participants gave to the Personal Journey affinity (fundamentals in sections 6.4.1.1 – 6.4.1.5) conveyed a sense of expansiveness, as their worlds were enlarged, their belief in their own capabilities enhanced, and their sense of themselves made firmer through their learning in statistics over the course of the programme. The growth they described occurred at various scales and in social, disciplinary and personal domains, encompassing newfound academic confidence (in statistics and more broadly) and enhanced interpersonal skills, changed perspectives, and for some participants, a new sense of themselves, and an emerging academic identity.

These shifts accord with self-expansion theory (Aron et al., 2004). Individuals may attain an expanded self-concept, increased potential efficacy, and greater self-concept clarity by undertaking challenging and novel tasks, as well as by acquiring new perspectives, resources and identities through interaction and identification with others. It seems likely that similar processes account for the sense of growth participants reported in the tutorials, where both routes were evident in the form of novel tasks in the form of the tutorial activities, and interaction with peers whose perspectives, resources and identities they could to some extent incorporate into their own. It is possible that this type of general personal growth or self-expansion adds to students' psychological resources (discussed in section 8.2.2.5), and strengthens their abilities to manage more discipline-specific liminal learning challenges.

Turning to disciplinary learning, participants' descriptions suggested that reaching understanding of certain concepts brought changes in their perspectives on the rest of the discipline and real-world statistics phenomena; in aggregate, these new perspectives constituted a statistics gaze through which they could interpret events in their own lives and the world at large (section 6.3.1.2). In terms of a threshold concepts view of learning, this changed worldview could be seen as a reformulated meaning frame or an ontological shift that brings a transformed personal identity into which new understandings and ways of thinking and practicing have been assimilated (Meyer & Land, 2006). Participants' comments suggested a personal appropriation of statistics logic: *"… I can say that I'm groomed by studying statistics. So some decisions, I can approach it using statistics knowledge"*. This in turn relates various instances of adopting using 'statistics knowledge' in everyday contexts outside of the classroom, such as interpreting statistical data in the news and discussing these with friends or family (section 6.4.1.1). That the development of a statistics gaze may be experienced as a personal change is further supported by participants' reflections. Meanwhile, for some, self-insights over the semester extended to a greater clarity about their future plans (sections 6.3.1.5, 6.4.1.1 and 6.4.1.2).

The conjunction of a newly attained disciplinary perspective and a shifting identity suggested by the last quote is in line with Barnett's linking of students' "coming to know" with their being and becoming: "the process of coming to know has person-forming properties […] knowing has implications for becoming" (2009, p. 435). In this view, which has clear affinities with the threshold concepts framework, learning includes inseparable processes of enculturation and maturation, and so changes who we are, as much as what we know (Cousin, 2008).

As the above reflection implied, the tutorial format and group processes gave students time and reason to reflect on themselves in the discipline, and thus crystallise longer term goals. Further, the sense of disciplinary community, together with participants' growing self-efficacy and capability (section 8.2.2.4), may have contributed to their self-conceptions as teachers, while their enjoyment of and engagement with disciplinary content in the tutorials may have persuaded them to incorporate statistics into their future plans. The threshold concepts framework suggests that because grasping threshold concepts is indicative of thinking like a disciplinary expert, which involves being and doing as well as thinking, it might lead to greater identification with statisticians, with implications for students' future choices in their studies and beyond.

The process by which participants' sense of belonging enabled their becoming seems to have been mediated by their Journey of Understanding, which influenced the extent of the shift in identity they experienced (see section 6.4.1.6: synopsis of Personal Journey). The more students' understanding in the discipline improved, the more meaningful, personally significant and identity-relevant they will consider discipline-related outcomes. In the SID, this link is reflected by the Journey of Understanding → Personal Journey vector, which may be interpreted as students' journeys of understanding (their liminal space) was "the transforming grace of in-between spaces" (Franks & Meteyard, 2007, p. 215). The centrality of this connection underscores the conjunction of the cognitive and affective in learning. For participants in this study, it seems that effective learning facilitated an experience that students found meaningful, valuable, and congruent with their individual identity and integrity. Students' values and beliefs may be viewed as the connectors bridging the cognitive-affective strands characteristic of disciplinary learning. Human yearning for maintaining positive self-worth (Shultziner & Rabinovici, 2012) is reflected in the ideas of belonging (to a peer group, a discipline), and becoming (to which individual meanings and values are essential).

Synthesis (8.2.2.5 – 8.2.2.7): Conative and affective reactions and identity shifts

These three findings uncover aspects of learning that are mostly untouched in statistics education research including a threshold concepts orientation to the discipline. While much of the account of students' learning aligns with the threshold concepts framework, there are also elements that have previously not been deeply explored, and may be usefully mapped onto the threshold concepts framework. Notably, the tutorial group was the influential element driving students' learning. The tutorial group was important in determining students' approaches to learning, and connected the cognitive and metacognitive aspects of learning (sections 8.2.2.1 – 8.2.2.4) with the affective, volitional, and identity-related elements, initialising and mediating the reciprocal impacts of these interdependent sets of factors and processes, viz. the pedagogical pilgrimage, on each other. For participants, the peer group played a significant role in supporting and facilitating affective, conative and identity-related responses to learning. The group provided a supportive liminal environment that fostered a sense of safety and belonging, within which students could express themselves with increasing confidence and affirm their expanding sense of self within and beyond the discipline.

8.3 Concluding comments

The findings abstracted from students' descriptions portray their learning in statistics as an expansive process that encompassed far more than mastery of content. The findings, broadly sketched, align with the threshold concepts view of learning as a transformative, affective process, and resonate with many of the issues around content and pedagogy in the statistics higher education literature, offering detailed and contextualised confirmation, as well as some new insights. Participants' descriptions of their learning in statistics over the semester emphasised their experiences in the tutorial sessions, casting the Tut Group, the group interactions and processes they encountered, as an important energiser of their learning. The multiple and closely entwined effects of the pedagogical approach taken in the tutorial programme supported and promoted cognitive, affective and conative dimensions of disciplinary learning. While participants' descriptions of their learning experiences in the tutorials were almost universally positive, it is important to bear in mind that these were evoked in a learning situation arranged to approach the ideal conditions suggested in literature and theory, to optimise their learning of statistics threshold concepts in order to study the details of this process. Their strong positive reactions to the group processes are thus to be expected. It remains significant that the tutorial programme was not an unqualified success in the sense that even at the time of the interviews (late in the semester), there remained unresolved difficulty and stuckness with content (as described in Chapter 6). However, it seems fair to say that the trouble with disciplinary learning that participants still experienced lies outside of the group processes that characterised the tutorial sessions, in aspects faced by all mainstream students who are expected to learn in large-class lectures, without the group-related benefits of this type of tutorial programme. The positive responses to the tutorials serve to highlight potential problems associated with traditional pedagogy, and perhaps point towards the ways in which it may be possible to create a learning environment and approach that might better enable students to meet the demands of disciplinary learning. In concluding the study, Chapter 9 reflects on how these findings have addressed the critical questions posed, and draws out their implications for practice and research.

CHAPTER 9

STATISTICS STUDENTS' LEARNING IN A THRESHOLD CONCEPTS-ENRICHED TUTORIAL PROGRAMME

9.1 Introduction

The previous chapter offered ten key findings, arranged to reflect the duality of the cognitive and affective shifts students' experienced on their pedagogical pilgrimage. This is a metaphor I have used to describe the experiences and processes of students' learning in the threshold concepts-enriched tutorial programme. These findings were discussed in relation to existing research in statistics education and threshold concepts framework scholarship. In this chapter, I provide final comments on the thesis. The following section presents an overview of the study, section 9.3 notes some limitations, and section 9.4 draws out some implications for practice and further research. Section 9.5 describes a tentative model grounded in the study findings, which may offer insights to statistics educators and to researchers using threshold concepts or analogous orientations. Concluding thoughts are offered in section 9.6.

9.2 Overview of the study

9.2.1 Background, rationale and research questions

In Chapter 1, I introduced the study, highlighting the need to deepen our understanding of students' learning in introductory statistics courses. The discipline is experienced as difficult by many students, with high failure and dropout rates, and concerns about the quality of learning, globally and in South Africa, where issues of disciplinary difficulty may be compounded by students' unpreparedness, linked to poor schooling. Enabling academic access and success here is framed by social justice imperatives, and is set in an increasingly turbulent landscape as students protest for free and decolonised higher education. At the same time, the discipline of statistics has been subject to teaching and learning reforms on a global scale. However, introductory statistics educators appear to continue to teach content in traditional, unchanged ways, while consistently expressing concern about the outcomes.

Against this background, I noted a lack of qualitative understanding of how students learn in statistics, of the experiences and processes involved, of the difficulties, and of how learning may be supported in our context. This was the broad area I set out to explore in this study. The theory of threshold concepts offered an appropriate framework that could accommodate the questions around learning in which I was interested, to yield insights beyond quantitative success factors or assessments of progression in understanding. The threshold concepts framework emerged from studies of teaching and learning in economics, and its tenets resonated with my experience of teaching statistics to undergraduates. In drawing together relevant ideas from a range of learning theories and other disciplines, the threshold concepts framework appeared well suited to framing a holistic, qualitative view of statistics students' learning.

In seeking to deepen my understanding of students learning in the discipline, I designed a tutorial programme informed by pedagogy deemed successful in the statistics education research literature, which conformed to a threshold concepts orientation, and which could also offer a vehicle to study learning. This was done through an 'arranged situation' (Naidoo & Vithal, 2014), which sought to offer optimal conditions for learning in order to study the learning processes rather than test the conditions. The research questions that structured this study were:

- How do statistics students learn in a threshold concepts-enriched tutorial programme?
- Why do students learn in this programme in the ways that they do?

9.2.2 Literature review: Teaching and learning in statistics

I took a wide-angle view of existing scholarship around teaching and learning in statistics, reviewed in Chapter 2, in terms of two intertwined strands of research. The first of these focuses on the cognitive constructs of disciplinary learning, in terms of teaching techniques and learning concerns.

Pedagogy, curricula and assessment in introductory statistics courses are similar the world over, and common problems, long-known, still persist in the form of large classes and a reliance on lecturing and textbooks over the encouragement of active learning (Loveland, 2014). Concerns have been noted about the conceptions of knowledge and approaches to learning this type of delivery fosters (Aliaga et al., 2010), but it continues to be the dominant approach globally (Garfield et al., 2012; Meletiou-Mavrotheris, 2003; Meletiou-Mavrotheris, Lee, & Fouladi, 2007). The reliance on lectured delivery is a likely contributor to the poor learning outcomes noted in statistics, with the view that "teaching as information transfer tends to leave students with an algorithmic rather than a conceptual understanding" (Moore, 2005, p. 1), as many students emerge from introductory courses without having mastered the basics (Garfield & Ben-Zvi, 2007). Accordingly, students often do not develop the transformed conceptual structures that add up to the ability to think and reason like a statistician, relying instead on surface approaches to learning (Garfield & Ben-Zvi, 2009). Consequently, they struggle with higher level application and analysis, and are unable to transfer their knowledge to real-world contexts (Cobb, 2015).

Most of this research has been conducted in the USA, Europe and Australasia. Similar work is scarce in South Africa, but emergent quantitative insights echo international concerns: South African students similarly struggle to understand, connect and apply statistics concepts (North & Zewotir, 2006), but much of the research aims to investigate the role of mathematics on statistics learning and attitude (Galagedera, 1998; Galagedera et al., 2000).

In response to these concerns, research has explored innovative teaching and learning approaches, based on active learning and constructivist pedagogy, and often entailing technological processes. This line of work reflects a recognition of the benefits of cooperative learning (Garfield, 1993, 2013; Giraud, 1997). Most of this research consists of descriptions and examples to guide implementation. Some empirical evidence of its effectiveness is provided by quantitative investigations (Keeler & Steinhorst, 1995; Magel, 1998), including findings pointing to the effectiveness of alternative, technology-based pedagogies (Gonzalez et al., 2006; Hahs-Vaughn et al., 2017; Herreid & Schiller, 2013). Less attention has been paid to explaining the impact on learning, and little qualitative detail exists to suggest why these approaches might be effective. Thus, a lacuna exists in the extant literature that addresses how and why students learn statistics in the ways that they do from a rich, contextualised, qualitative study perspective.

The second strand of research centres on the affective nature of disciplinary learning. Research conducted regarding this strand concerns itself with overcoming anxiety and negative attitudes and cultivating curiosity and awareness amongst statistics students. A major contributing factor to students' displays of statistics anxiety stems from mathematics anxiety, as students often conflate the two disciplines, much to the chagrin of statistics educators (Cobb & Moore, 1997; Garfield, 2003). It is argued that statistics is its own field, that uses mathematics (Cobb & Moore, 1997) and requires a different type of reasoning to that of mathematics, where it incorporates uncertainty and variability, as compared to the deterministic nature of mathematics (Garfield, 2003). The defining distinction is that statistics, as opposed to mathematics, is rooted in context (delMas, 2004). Notwithstanding, the innate idiosyncrasies of the two disciplines, the literature suggests that competence in mathematics and statistics is related (Lai et al., 2011), but offers limited insight into how statistics educators may alleviate students' mathematics anxiety and numeraphobia, so that students can engage meaningfully with statistical concepts. In South Africa, the challenge posed by statistics students with poor mathematical preparedness and/or mathematical anxiety has been documented (de Wet, 1998; Galagedera, 1998; Galagedera et al., 2000). Additionally, building capacity for developing statistical literacy in South African schools is further constrained by factors such as the varying levels of preparedness and awareness of statistics amongst mathematics teachers (North et al., 2014).

Students' statistics anxiety has been modelled as a multidimensional construct consisting of six factors: (a) worth of statistics; (b) interpretation anxiety; (c) test and class anxiety; (d) computation self-concept; (e) fear of asking for help; and (f) fear of statistics teachers (Cruise et al., 1985). Research findings suggest that instructor immediacy is significantly related to statistics anxiety (Williams, 2010); along with suggested pedagogical interventions on students' statistics anxiety levels such as: (i) in-class exercises, (ii) hands-on activities, (iii) lecture, (iv) real-world projects; and (v) cooperative learning (Kinkead et al., 2016; Lee et al., 2014); may greatly influence students' learning experience and improve students' attitudes and motivation in the discipline.

Chapter 2 also catalogued potential sources of statistics-specific difficulty noted in existing research. These include the lexicon of the discipline that students must master (verbal disciplinary discourse and mathematical symbolism); the importance of developing statistical 'modellers and thinkers' within the discipline (Garfield et al., 2012); and, the need to help students appreciate the value of learning statistics to their particular discipline or for their future career. Understanding of the extent to which these sources of difficulty may be pertinent for students in our context is limited and largely speculative. Thus, these concerns about learning may be understood in terms of students' taking deep or surface approaches (Marton & Säljö, 1976), and the contextual factors impacting thereon, including teaching practices, with clear relevance to the cognitive and affective debates in the two strands of statistics education research. Phenomenography (Dahlgren, 1984) has allowed a fine-grained look at conceptual development, and has illuminated some conceptual changes that learning statistics requires of students (Gordon, 2004; Reid & Petocz, 2002). Developing students' metalearning capacity is an important implication of this view, wherein the curriculum "needs to encourage [students] to be aware of their perception of their own place in the world" (Reid & Petocz, 2002, pp. 14, 15).

The foregrounding of students' experiences distinguishes this approach from most research in statistics education, but is evident within the threshold concepts perspective on learning, which framed this work of scholarship. However, this study's findings offers a nexus between the two strands of statistics education research DNA, namely cognitive and affective learning, thereby drawing attention to, and highlighting, the intertwined duality of the statistics learning experience, as articulated in the study participants' own voices.

9.2.3 Theoretical framing: Threshold concepts

In Chapter 3, I considered the theory of threshold concepts that frames the study. The essential aspect of this view of learning, which weaves together insights from several learning theories and other disciplines, is the notion that certain concepts are seen as portals or gateways to transformed understandings that, thereby, define disciplinary ways of thinking. While it foregrounds disciplinary content, the threshold concepts framework also sees learning, as well as difficulty, as inseparable from the learner and her social and personal context. As such, crossing these learning thresholds involves not only cognitive but also affective processes; and because this knowledge is transformative, it may also bring a shift in the learner's view of herself. Although the threshold concepts framework has its origins in economics education research, this study findings adds credence to the notion that the experience and processes of learning educationally critical but possibly troublesome content transcend disciplinary boundaries (Schwartzman, 2010), and reaching understanding of a threshold concept in any field is likely to be experienced as (Meyer & Land, 2003):

- transformative, precipitating conceptual and ontological shifts;
- probably irreversible;
- integrative (revealing interconnections among concepts);
- possibly bounded (serving to demarcate the discipline); and
- potentially (possibly inherently) troublesome, due to particular features of the knowledge to be gained.

The threshold concepts view of learning reflects the (anthropological) notion of liminality, that is, coming to understand a threshold concept requires crossing a liminal space of uncertainty and incomplete understanding, characterised by recursive and excursive meanderings, as students divest themselves of old conceptions and begin to embrace emergent understandings and views, which is likely to involve some discomfort, anxiety, and perhaps a sense of loss. Students' responses to challenges of liminality are central to their learning, but remain a relatively unexplored aspect of the framework (Rattray, 2016; Schwartzman, 2010). Defensive responses to liminality will likely lead to students remaining stuck at incomplete understanding, or withdrawal, and not breaching the necessary threshold. Adopting a reflective response will enable students to reconstitute the meaning frames by which they make sense of the world, and ultimately to develop a new sense of themselves, which is closely tied to being enculturated within a discipline, and identification with a disciplinary community.

A threshold concepts framework to teaching and learning has not been widely applied in statistical education research (Wills, 2017); and the few studies that have been conducted have largely focused on the identification and teaching of statistical threshold concepts (Bulmer et al., 2007; Dunne et al., 2003; Khan, 2014). These statistics threshold concepts and teaching suggestions informed the tutorial programme activities (along with pedagogical best-practices advocated for in the extant field of statistics education research), and matched my perceptions of troublesome, transformative content based on years of teaching introductory statistics.

Further important elaborations to the threshold concepts framework include the conjunction of understanding threshold concepts with application of threshold concepts in context (termed threshold capabilities), with a view of eventually developing knowledge capabilities (that is, to think and practice like a statistician). This augmented framework is known as the Threshold Capability Integrated Theoretical Framework (TCITF) (Baillie et al., 2012) (see Chapter 3), and this is where I hope the current study's findings may contribute. In Chapter 3 (see Figure 3), I presented an interpretation of the TCITF model in relation to the statistics discipline.

Upon reflection of this study's findings, I have modified this model to reflect a more holistic view of disciplinary learning (see Figure 10 below) in terms of both pedagogy and content; and the recognition that affective and identity shifts arising from conceptual reframing are implicit in the development of students' ability to think and practice like a statistician.

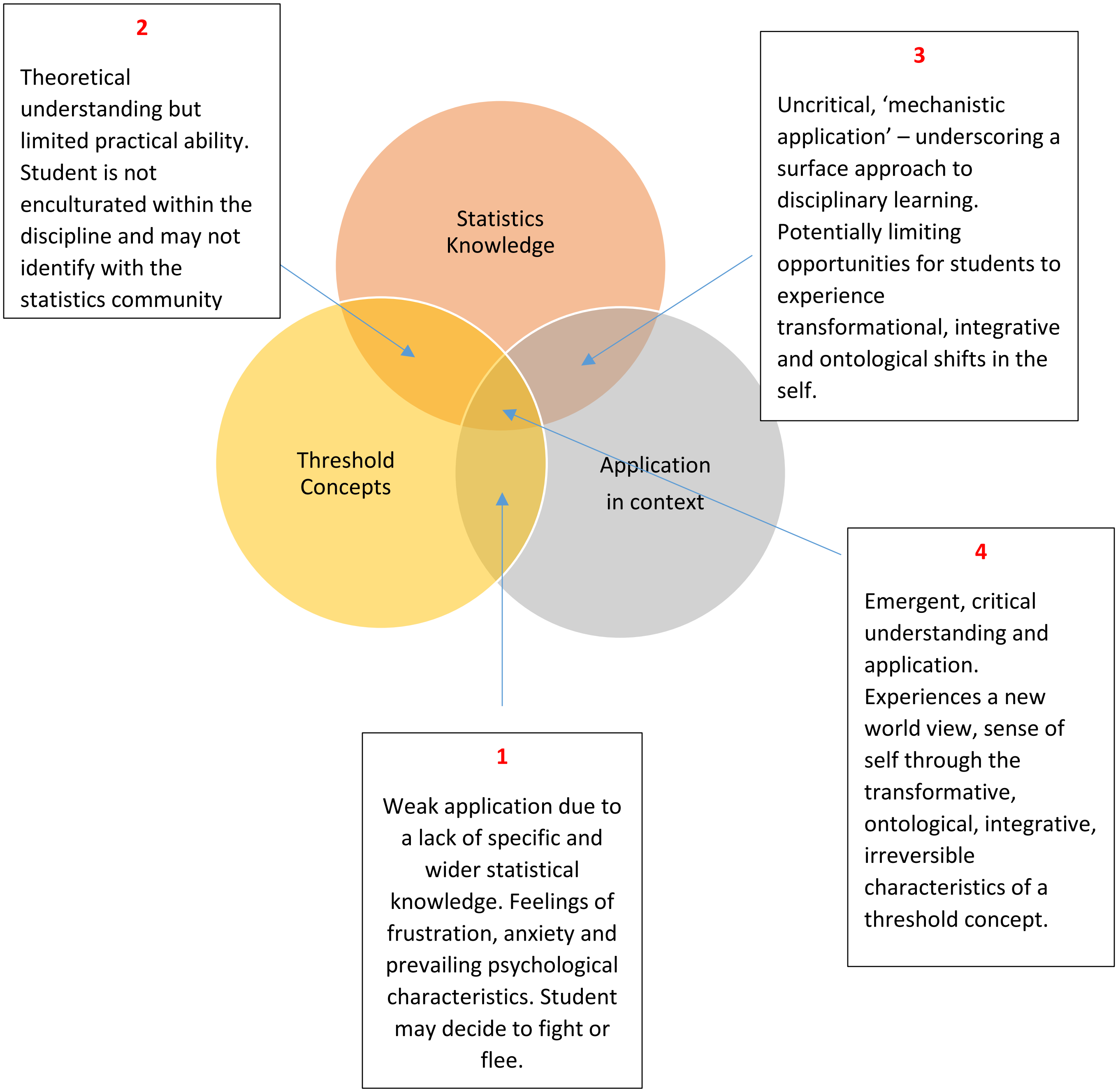


Figure 10: The TCITF from a statistics disciplinary perspective

(Adapted from (Baillie et al., 2012; HEReflections, 2015)

This study’s adaptation of the TCITF to the statistics discipline embraces the threshold concepts framework’s central idea of traversing the liminal space (Cousin, 2006a, 2008; Meyer & Land, 2005), enroute to conceptual mastery. Liminality may be described as “a suspended state of partial understanding” (Land et al., 2010, p. x), an “unstable space in which the learner may oscillate between old and emergent understandings”. While a threshold concept constitutes critical, albeit unfamiliar, discipline content (Schwartzman, 2010), difficulty in learning does not reside only in this content, where it cannot be separated from the learner, or the social context (Cousin, 2006). With regards to the above model, intersections 1, 2 and 3 represent a liminal state of being for the student in the various stages of learning in the statistics discipline.

In intersection 1, learning in this view has affective as well as cognitive elements: acquiring a new concept can involve uncertainty, anxiety, discomfort, and sometimes a sense of loss, as learners relinquish prior understandings (Land, 2016). In this stage, learners’ encounters with the unknown elicit responses that may be either reflective or defensive (Schwartzman, 2010). If the learner’s response is defensive, she will remain stuck, often projecting responsibility elsewhere (Schwartzman, 2010). By contrast, reflectiveness results when the learner successfully negotiates the liminal space and attains the intended understanding. Students’ responses to challenges in the liminal phase of learning may be characterised as “fight or flight” (Berg et al., 2016), and are impacted by features of the disciplinary and social contexts as well as students’ intrapersonal resources, viz. their affective and psychological characteristics (Rattray, 2016).

In intersection 2, the student has mastered disciplinary concepts, but, additionally, it is recommended that the enculturation of students into statistical ways of thinking and practice involves the “ability to philosophize [sic] over data, argue about perceived patterns, and suggest new avenues to explore [and this] depends on [both] sound statistical and contextual knowledge foundations” (Pfannkuch, 2011, p. 27). These ‘learning-experience-contexts’ facilitates the construction of learners’ knowledge and reasoning and cannot be separated when teaching statistical thinking (Cobb, 2007; Pfannkuch, 2011). Thus, intersection 2 of this model would imply that “[t]he raw materials on which statistical thinking works are statistical knowledge, context knowledge and the information in data” (Wild & Pfannkuch, 1999, p. 228).

Learning a threshold concept is characterised as a discursive process, involving "the acquisition and use of new forms of written and spoken discourse and the internalising of these" (Land, 2014, p. 2). In the suspended state of liminality, represented by intersection 3 above, understanding can approximate to a kind of mimicry or lack of authenticity (Cousin, 2006a). Despite the negative connotations, this may lead towards a path of deeper, integrated learning, although it also brings the danger that students' understanding may be arrested at this level of "ritualized [sic] performance" (Cousin, 2006a, p. 5); foregoing opportunities to experience the potential transformations that characterise deep learning and accompany threshold crossing.

Ultimately, learning is a transformative process that goes beyond conceptual or cognitive change (intersection 4). Mastery of a threshold concept entails an ontological as well as a conceptual shift, because it results in a changed worldview or a reformulated meaning frame (Schwartzman, 2010). The shift in perspective which learning brings about is also likely to have an affective component, "a shift in values, feelings or attitude" (Meyer & Land, 2006, p. 7). Such threshold crossing is commonly associated with the acquisition or development of "ways of thinking and practicing" in a discipline (Barradell & Kennedy-Jones, 2013). Identity shifts ensue because "learning always involves a process of becoming" (Cousin, 2008, p. 265).

9.2.4 Methodology

In pursuit of an in-depth, holistic understanding of statistics students' learning, I used a qualitative, interpretive approach and a case study design that would enable me to explore participants' experiences and perceptions of their learning. This aligns with the social constructivist orientation of the threshold concepts framework, which defines the essential features of threshold concepts from the learners' perspective. Case study research is strongly rooted in context, and my findings are specific to this case, beyond which I make no claims; nonetheless, they may offer some analytic generalisability (Yin, 2014) and have wider resonance with similar situations in statistics education research or broader threshold concepts theory.

A purposive sample of volunteers from BSTS 201 participated in a semester-long tutorial programme that ran alongside mainstream lectures. This could be likened to an arranged situation

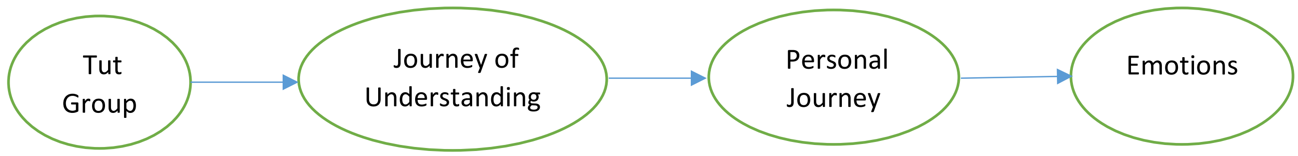
(Naidoo & Vithal, 2014), in which I was able to use cooperative learning pedagogies not available in the current mainstream situation but established in theoretical and empirical work as conducive to learning. Tutorial activities involved small-group discussion and analysis around structured tasks, which embed statistics threshold concepts in relatable examples and break the analytical task down into component steps. As a form of homework, I asked participants to write weekly reflections about their learning in statistics, and in turn wrote replies to those who submitted their writing to me. I expected these to have some intrinsic value in enhancing students' metalearning (Bargate, 2012; Ward & Meyer, 2010), as well as providing an additional data source for the study.

I created an online Blackboard classroom for the tutorial group, which featured a discussion board. I expected the discussion board to provide an opportunity for students to evolve into tutors as they offer advice to their peers and thus engage in a deeper form of learning and to encourage participation from less confident students, while I would be alerted to new and/or ongoing troublesome concepts characterised by the frequency by which these issues may be raised by individual students on the discussion board (MacDougall, 2010). I also planned on using the discussion thread messages to supplement my IQA data and offer an additional lens through which to look at the research questions. However, students did not engage with this medium of communication (for reasons outlined in Chapter 8). I then decided to create a WhatsApp group for the participants as another means of fostering a social constructivist environment for learning (Amry, 2014; Naidoo & Kopung, 2016). Students embraced this medium of communication, using it as a platform to share past year exam papers and posting positive messages of support and motivation to one another. From this experience, one may once again glean the support given to the cognitive and affective constructs of disciplinary learning through this pedagogical approach. These messages provided an additional data source for the study.

The larger part of my data was generated and initially analysed using IQA as a research method consistent with the interpretive, social constructivist paradigm of the study. IQA is a novel method that has, as far as I can determine, not been used in statistics education research. It resonates strongly with the emphasis the threshold concepts framework places on students' experiences, because participants are deeply involved in exploring their learning. Because the researcher plays a facilitative role in data generation and initial analysis, rather than being cast as the expert, IQA was also in harmony with the power relations that inhered in the tutorial programme where, as the group had been entrusted with responsibility for their learning, so they were entrusted with generating and analysing the data that represented their experience. The relationship I had formed with the group over the semester was important in securing their willingness to commit time and reflective effort to the IQA processes. IQA involves two main phases of data production, namely: focus groups and interviews. I had two focus group sessions at the end of the semester, in which participants generated a view of learning on the programme at group level. Following IQA protocols led me to represent the affinities (or themes) identified by the focus group into a Systems Influence Diagram (SID) depicting the group's conception of their learning. The focus group sessions were followed by semi-structured individual interviews, which added depth to the focus group data as participants elaborated on their personal experiences with regard to each affinity.

Because it is protocol driven and entrusts data generation and interpretation to participants, IQA has inbuilt mechanisms that enhance rigour. In foregrounding the students' perspectives and working with dismantled power relations, IQA assisted in mitigating possible issues around my influence in the research process, as the participants' lecturer and tutor as well as the researcher. IQA captures only what is said (or written during brainstorming) in the focus groups and interviews. Because the focus group aims at consensus, it is possible that the affinities may hide the silences of participants who disagree with the group view, and these would not necessarily be uncovered in the interviews, the scope of which is determined by the affinities. The written reflections and WhatsApp messages, which were not part of standard IQA process, could serve to offset possible shortfalls of the focus groups and interviews by offering participants an additional channel to express individual views. On analysing these, I was satisfied that the data therein was accounted for in terms of the affinities, and I was able to include appropriate excerpts in the composite quotes to supplement the interview descriptions.

9.2.5 Findings



(Taken from Chapter 5, Figure 5: SID: Students' learning in the threshold concepts-enriched tutorial programme)

The focus group identified four affinities — themes or components of meaning of their learning in the tutorial programme — and the IQA processes led me to construct the SID above, which captures how the group theorised the interrelationships among these affinities. The features of the SID as a whole suggest some insights regarding the group's understanding of their learning, which were substantiated by the thicker descriptive data from the reflective writings of the focus group brainstorming session, interviews, and written journal reflections. The primary driver of the system was Tut Group, which impacted on every other affinity. The Journey of Understanding was a secondary driver and Personal Journey was a secondary outcome, while Emotions was analysed to be a primary outcome.

Tut Group — the group interactions and processes arising through the multiplicity of pedagogical approaches adopted (small group cooperative learning, activities involving the analysis of real data, keeping of reflective journals, being provided with the solution to tasks, and instructor immediacy) in the tutorial programme — enabled and supported cognitive, metacognitive and affective aspects of learning. Through processes of discussion and articulation within the group, students constructed an understanding of statistics concepts. They recognised this understanding based on "knowing why" as being quite different to the mechanistic analysis they had tended to resort to in response to traditional lectured delivery. However, the progression in their understanding was difficult, and impasse was commonplace, where their primary source seemed to be in the abstract nature of many statistics concepts. Seeing their use through relatable applications facilitated understanding, and enhanced agency as students felt they were gaining worthwhile, empowering knowledge. Comprehending particular concepts and techniques was often experienced as a breakthrough that enabled the understanding of related ideas.

Cumulatively, these understandings constituted the development of students' *Journey of Understanding* — a statistics point of view, which afforded them a changed perspective on real-world events. Their changing conceptions of knowledge were reflected in deeper approaches to learning, and was accompanied by a sense of empowerment and capability, where before, many had felt self-doubt. These new conceptions of knowledge and learning, and of themselves as capable learners, were important metacognitive shifts that made up *Personal Journey*.

Emotions — affective responses, both positive and negative emanated from learning and engaging with content, from assessment, and from the learning environment. Persisting and progressing in learning made demands on students' psychological resources, such as self-awareness, self-belief, hope and resilience. Tut Group had a significant influence on Emotions: the sense of belonging, comfort and safety among peers and a sense of the teacher's immediacy in the tutorial group encouraged students to express themselves freely, and for many, facilitated the emergence of a clearer sense of self in relation to the discipline. Student's predominant feelings and emotions of their experiences of learning in statistics was one of a sense of achievement and accomplishment that translated into joy and love for the subject.

These findings are broadly consistent with the threshold concepts framework in highlighting that learning has strongly affective aspects entwined with the cognitive; that it might entail periods of stuckness and liminality; that particular concepts are likely to be both troublesome and — once mastered — transformative; and that disciplinary learning has implications for students' worldview and identity. Additional insights are suggested by participants' portrayal of the influential role of Tut Group in their learning. Peers, teacher immediacy, and the blending of multiple learning processes appear to hold significant potential for supporting cognitive, metacognitive and affective aspects of learning, and facilitating the emergence of a new sense of self in relation to the discipline.

9.3 Limitations

In contemplating the findings of this study, one should be cognisant of its limitations. My case study drew data from seventeen participants in one introductory statistics module, and from myself — the lecturer who was also the tutor on the programme in which learning was studied, as well as the researcher. Different groups of students, different modules in statistics, different years of study, or different tutors/lecturers may realise different results. The sample was small, and in effect, was made up of self-selected students who had volunteered to take part in the programme.

Given the nature and purpose of the study, my main concern was to attract students who would participate in the programme and subsequent IQA processes, and provide rich data. I did not attempt to select a representative sample, nor even to identify the dimensions across which representivity might be sought. The results are therefore not statistically generalisable beyond the scope of the case study. Students would have experienced learning in the programme differently, depending on intrinsic factors and individual biography, including, for example, academic abilities, home background, schooling history and contemporary learning experience, learning styles, and personality traits. I did not explore these individual factors and their impact in any detail, beyond the extent to which they came up in the journal writings, focus group and subsequent interviews. I did not specifically seek data regarding variation in students' levels of 'preparedness' for university study linked to their schooling — a significant question in the South African context — and therefore cannot explain in detail or with certainty the ways in which the difficulties students described may be more challenging for those with a poor schooling background.

Students' non-participation on the online discussion board deprived this study of a potentially rich data source. However, substituting the online discussion board with the WhatsApp group offered a novel insight into students' experiences of disciplinary learning. Due to time constraints,[57] the tutorial activities that I had planned to cover the topics of hypothesis testing and Chi-squared distributions, were not attempted by the participants. Although these topics were taught during the normal lecture periods, students did not mention them in their reflections of their experiences of learning statistics over the semester. I assume that students' limited their reflections of their experiences of learning statistics to the topics covered in the tutorial programme, and compared

[57] See researcher's reflections in Chapter 4 – section 4.8.

and contrasted this experience to their experiences of learning these same topics during the traditional lectures. Thus, I cannot offer further detail on how students' experienced learning the topics of hypothesis testing and Chi-squared tests.

The study drew on students' own perceptions of their experiences, and there may be potential bias in this self-reporting. Because I was interviewer and researcher, as well as lecturer and tutor on the programme, they may have held back from revealing information or opinions they thought might reflect negatively on them, and may have been inclined to respond in ways they thought would please me, despite steps I took to mitigate this. Participants may have also varied in how self-aware and how candid they were. I did not set out to evaluate students' learning as part of this study to see whether their self-reported experiences of having understood threshold concepts could be substantiated with evidence of improved analytical ability, nor did I track their assessment performance over the semester, or compare it with that of the rest of the class. This despite the fact that participants were very vocal about their improved test performance. In short, the findings of this study have taken participants at their word.

A strength of IQA is that data is generated and analysed by the participants themselves. This means, however, that the whole process may stand or fall on the focus group: the focus group is pivotal because it produces the affinities that structure and circumscribe the deeper exploration in the interviews. My confidence in the findings is enhanced by the fact that the focus groups were well-supported by the students, and that the themes that emerged from the reflective writing were compatible with and could be accommodated by the same set of affinities. Nevertheless, I note that a different method of generating and analysing data may have yielded different results.

The tutorial programme was tailored to my research requirements, to be a vehicle to study learning, and was very resource-intensive in terms of the time and energy it required from me. With current budgets and constraints on staffing, venues, and student timetables, it would not be feasible to roll out an equivalent intervention for the entire BSTS 201 class of a few hundred. However, the intention was not to test an intervention, but to draw insights that may deepen understanding of students' learning in statistics.

9.4 Implications

These findings suggest that generally, understandings of what it means to learn and to teach statistics in higher education, as reflected in dominant teaching practices and related research globally and in South Africa, are too narrow. Prior research using the threshold concepts framework has shown that effective learning in any discipline is a strongly affective, transformative process that involves far more than acquiring concepts and being able to replicate disciplinary techniques.

Teaching in introductory statistics still relies heavily on lectured delivery at DUT, and in most universities around the world, despite substantial and mounting evidence within statistics education research regarding its shortfalls (Aliaga et al., 2010). This traditional delivery may be responsible for the mechanistic and algorithmic display of disciplinary conceptual understanding (Moore, 2005). In response to Shulman's (2005) list of the significant hindrances to learning in higher education, namely passivity, invisibility, anonymity, and lack of accountability; the study findings suggest possible succour to these hindrances to disciplinary learning: engagement or commitment (due to finding context application activities meaningful and identity-relevant), self-efficacy and reassurance (linked to students' disciplinary knowledge capabilities), and feelings of being academically nurtured (related to the students' sense of the teacher's immediacy).

The study findings offer support and substantiation for calls within statistics education research for greater use of active, context-based, cooperative learning pedagogies. Additionally, the findings offer credence to the incorporation of reflective journal writing and social media applications to support the cognitive and affective constructs of disciplinary learning. Students ascribed to those processes by which they constructed conceptual understanding, as well as the aspects of affective support and personal development they experienced in the group. While it is not feasible to roll out a similar programme for a class of up to a couple of hundred; with further research, experimentation and reflection, it is possible to identify elements from the tutorials that might be leveraged to support and facilitate learning on a larger scale.

The mechanisms of discussion and articulation engendered by cooperative learning approaches would seem to offer some unexploited potential for bringing about deep and transformative conceptual learning. It is worth investigating and experimenting with ways in which we might provide and structure learning experiences within the mainstream that encourage deliberative verbalising, and move students from everyday talk towards comprehensible, conceptually rich articulations.

While a shift towards more active learning puts the onus on students, this does not imply abdication on the part of teachers, it may require intensified effort and care in structuring and facilitating learning experiences, and maintaining momentum and engagement whilst fostering students' sense of capability (Garfield & Ben-Zvi, 2007). If accommodating cooperative learning experiences within the mainstream includes the formation of small groups for the duration of the course, it may also harness the affective support which the tutorial groups offered students by initiating caring peer relationships (Johnson & Johnson, 2009) to provide a more emotionally supportive environment. It seems the peer group may be well placed to be entrusted with some aspects of emotional support, by virtue of their proximity to affective as well as contextualised aspects of learning. In a large class, small groups may offer an effective way of providing the emotional support that one lecturer would not be able to give. Further research is warranted to identify how this may be accommodated and facilitated at scale.

For the large proportion of underprepared students in South African higher education, the metacognitive and affective challenges of disciplinary learning are likely to be more pronounced. There are suggestions in the data that some students encountered greater challenges of this kind, for instance, many participants were outspoken about their anxiety towards learning statistics that stemmed from their high school experiences of learning mathematics, and had to learn to undo in order to make a legitimate attempt at understanding statistics. Learner biography is also implicated in the pervasive low-grade anxiety and self-doubt many participants conveyed. The intersection of learner biography, including school history and threshold concept learning in the South African context, is worthy of further investigation. More broadly, it is worth exploring how students may be supported to develop self-efficacy and other components of psychological capital with which to face liminal learning challenges.

Issues for further research emanate from the broad question of how to encourage a shift towards deep, rather than surface learning approaches. Findings suggest that students' orientation will be influenced by personal biographical factors and their intersection with the discipline as they experience it. The latter encompasses pedagogical approach, course content, and assessment practices (Biggs, 1996); if the discipline as experienced is meaningful and identity-relevant, students are more likely to develop and use deeper approaches.

In considering how the use and relevance of the discipline may be made more evident to all students, possibilities suggested by the study findings include providing opportunities for students to reflect on their learning, encouraging them to apply disciplinary ideas in their own lives, and to consider relatable real-world applications rather than sterile, contrived examples.

Making room for students to reflect on their learning includes developing their metalearning capacity, which has long been advocated within the threshold concepts framework (Ward & Meyer, 2010). Beyond this, encouraging them to reflect on the extent to which their longer term goals and career choices are personally meaningful may foster the development of goals consistent with their self-construals, rendering their studies more meaningful (Vogel & Human-Vogel, 2016). This is evidenced in this study by a student who articulated aspirations of becoming a statistics teacher, due to her positive experiences of learning statistics in the tutorial programme over the semester.

The meaningfulness of the discipline as experienced is strongly tied to questions of affect and values. Important areas for future research to inform practice centre on how statistics educators may account for and harness affect and values, in curricular as well as pedagogical choices, to enhance teaching and learning. The ways in which cooperative learning pedagogies may provide affective support to learners have been noted above as an area deserving further investigation. Including questions on real-world issues about which students care, into mainstream introductory statistics may enhance its meaningfulness and identity-relevance.

More broadly still, this question relates to students' "becoming" through the discipline. Further attention should be given to identifying, and exploring ways of fostering affective competences to complement cognitive curriculum goals in statistics. This in turn points to much bigger questions about the role of higher education, and the kinds of changes we hope to effect in students (Land, 2016).

Finally, any meaningful change in pedagogical approach is likely to entail some transformation on the part of teachers (Savin-Baden, 2016); teaching in higher education draws on knowledge of three areas, namely knowledge about one's discipline, generic principles and ideas about teaching and learning (Fry, Ketteridge, & Marshall, 2009); thus changing our conceptions of knowledge, learning and teaching may well be experienced as a significant threshold, with attendant troublesomeness.

Research into teachers' conceptions and experiences of teaching and learning in introductory statistics in South Africa was not considered within the focus of this study, but would be a useful complement to findings in future investigations. This line of research would include exploration and identification of enabling measures that may facilitate and support educators in building relationships with their students in the hopes that this would bring about the desired shifts in learners. After all, "[n]o matter how much pedagogy we know, no matter how many degrees we have, unless our students know that we care, they will not learn from us" (Kwon, 2017).

9.5 Towards a model of students' experiences of learning statistics in a threshold concepts-enriched tutorial programme

To realise deep, transformative disciplinary learning, students have to engage cognitive and affective constructs in the process. The multiplicity of pedagogical approaches used in the tutorial programme, supported cognitive and metacognitive shifts, as well as affective, conative and identity-related responses. The schematic in Figure 11 below offers a view of students' learning in the programme.

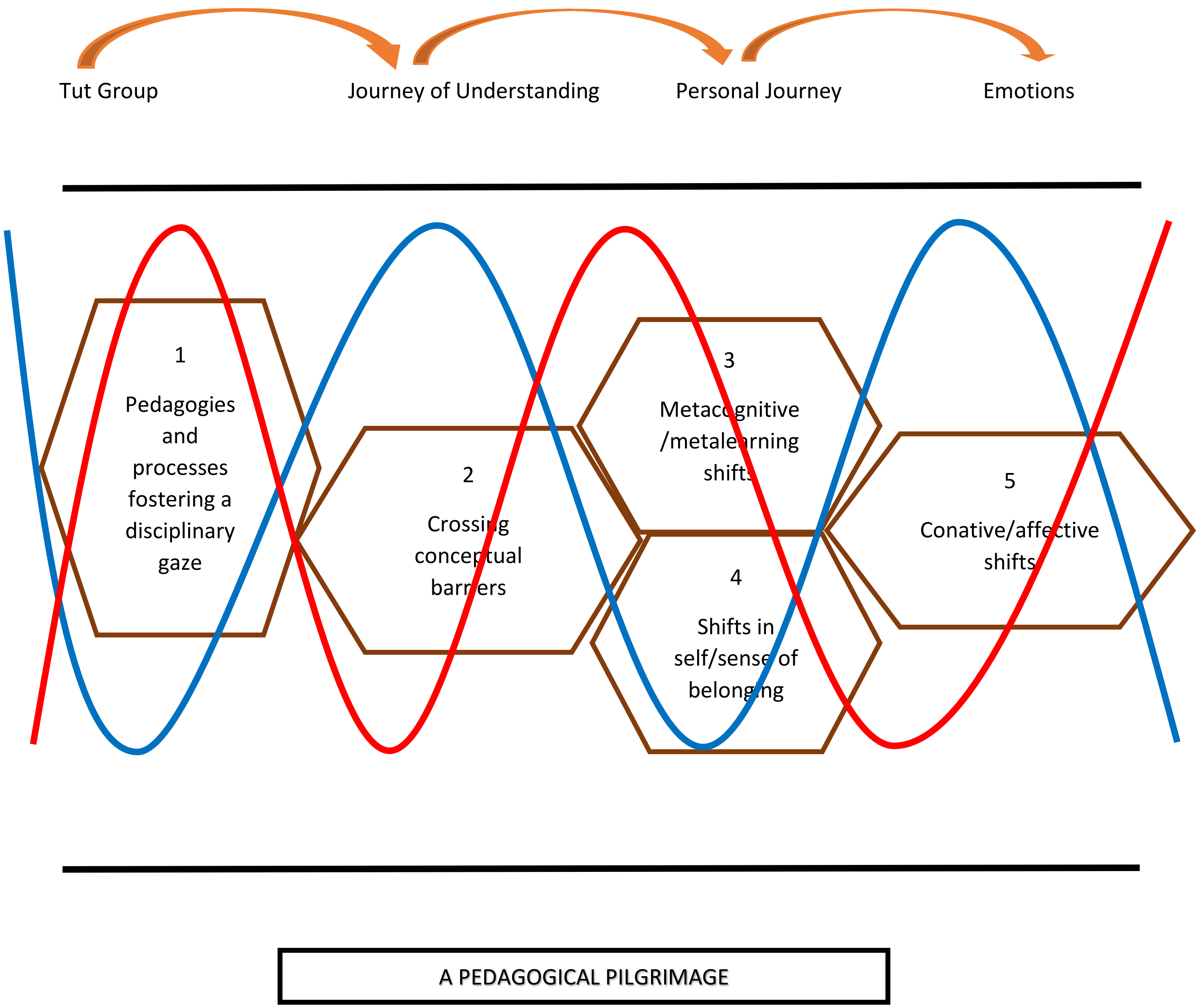


Figure 11: Pedagogical Pilgrimage: A model of students' experiences of learning statistics in a threshold concepts-enriched tutorial programme

The above model shows students' learning as comprising steps along a journey in a pedagogical pilgrimage. The schematic evokes a linear path, and recalls the structure of the SID representing participants' understandings of their learning, from which this tentative model is abstracted. The path of students' disciplinary learning journey may be depicted as being linear, but oftentimes students may have double-backed along the path only to move forward at a pace determined by their understanding and grasp of disciplinary knowledge and capabilities as well as by their emotions and psychological resources. As such, this linear journey encapsulates the double helix structure of DNA – a metaphor I have used in this study to characterise the inter-twining of the cognitive and affective constructs of disciplinary learning - which characterises students' learning journeys in this study.

Along this path shown above, are interrelated components or elements of learning and transformation, represented by the five hexagons (used to evoke the imagery of cobblestones along a pathway and/or the hexagonal structure of DNA). The path as portrayed shows that learning is anchored by the multiplicity of pedagogical approaches and processes (cobblestone/hexagon 1) that were adopted in the tutorial programme, and which influences students' learning journeys in a multitude of ways. The effects of their collective influences pervades the overall learning experience (cobblestones/hexagons 2, 3, 4 and 5 in the model).

Each pedagogical approach may vary in 'value' according to individual or context. Thus, an approach may be experienced as positive or negative, conducive or not, complete or partial. Optimal learning will be favoured if all approaches are deemed to impart a positive experience (as was the case in this study); on the other hand, variation in each can, in interaction, give rise to a multiplicity of different individual experiences and consequences of learning. Together, these pedagogical approaches and their effects may be used to explain the 'golden path'[58] of disciplinary learning in the programme. The constructs or elements of learning represented by the remaining four cobblestones, and their inter-relationships, are briefly elaborated in the paragraphs that follow.

[58] In keeping with the DNA metaphor of the cognitive and affective constructs of disciplinary learning used in Chapter 2, a golden path is a term borrowed from genome assembly, and is used to describe the mapping of a chromosome, by listing all of its components in order and specific location. Thus, the five elements of disciplinary learning and their inter-relationships depicted by order and location in Figure 11 above, is akin to the genetic mapping of students' disciplinary learning in this study.

The progress of disciplinary learning entails coming to understand particular concepts and techniques. This process may be characterised as crossing conceptual barriers (cobblestone/hexagon 2), as portrayed in the threshold concepts framework (Meyer & Land, 2003) due to the transformative, integrative and troublesome nature of reaching understanding. The discipline as experienced is determined, to a large extent, by teachers' curricular and pedagogical choices (hexagon 1).

In this case, students' encounters with statistics included both mainstream lectures and the tutorial programme, and the latter seemed to enhance the discipline as experienced for many students (reflected by the trajectory of the path-vector: Tut Group → Journey of Understanding). In the tutorials, processes of discussion and articulation allowed students to construct conceptual understanding, and prompted them to revise their conceptions of knowledge and learning. Many students viewed the activities given in the tutorial sessions as extra practice of disciplinary concepts and appreciated the opportunity to construct meaningful knowledge through this iterative process. The emphasis on application and use of relatable real-world examples allowed them to see the use of concepts in context, and thus experience their learning as meaningful. Cumulatively, these conceptual transformations give rise to a disciplinary gaze in the form of a transformed way of viewing and interpreting real-world events. Group discussion and articulation in the tutorial programme were key cognitive processes that facilitated students' (re)conceptualisations and understanding of statistics concepts and techniques. Learning in this way also promoted the use and mastery of the disciplinary discourse (language and symbolism), which was both a means for and an expression of learning. Students' reflective writings afforded an opportunity for them to integrate their life experiences into disciplinary learning, thereby centering them in the learning experience. Having access to the solutions to the exercises as a form of reference to check against their own workings, allowed potential misunderstandings/misinterpretations to be revealed and re-learned. This served to enrich the learning experience. All the pedagogies and processes used in the Tut Group served to enculturate the statistics student into the disciplinary ways of thinking and practice.

Embarking on deep disciplinary learning requires that students cross metacognitive thresholds (hexagon 3). The more students' understanding in the discipline improved, the more meaningful, personally significant and identity-relevant they will consider discipline-related outcomes. In the above model, this link is reflected by the trajectory of the path-vector: Journey of Understanding → Personal Journey. Effective pedagogy facilitated a learning experience that students found meaningful, valuable and congruent with their individual identity. Learning requires them to see knowledge not as a fixed body of disciplinary 'truth' to be absorbed and reproduced, but as being socially constructed. Accordingly, conceptions of learning shift from a focus on memorisation, to a process of understanding based on "knowing why", in which they are active and capable agents. In their transformative and enabling capacities, these changed views of knowledge, learning, and self as a capable learner may be characterised as metacognitive thresholds, which must be crossed if students are to further disciplinary learning.

The empowering pedagogical approaches amplified the sense of disciplinary self-efficacy that arose as they recognised their own progress in conceptual learning. The tutorials seemed to contribute to students' metacognitive shifts in several ways, including giving them time and reason to reflect, building a sense of capability and self-efficacy in the discipline, enhancing the relevance of the discipline as experienced, offering a safe environment to encourage and accommodate a mastery orientation, increasing motivation through a sense of common purpose, and fostering identification with the peer group and the emergence of a disciplinary identity.

Together with the enabling cooperative approach that transferred much of the responsibility for learning to the group, this fostered a view of themselves as capable learners, and this played a central role in motivating and guiding their learning choices, academic behaviour and achievements. By becoming aware, and taking control of their own learning processes, students were able to breach metalearning thresholds. This growing sense of self-efficacy in turn increased students' intrinsic desire to understand, and their readiness to engage with conceptual content (not only in statistics but also with other modules that they were studying), and seems to be an important reason why many experienced their learning in the groups as personally empowering.

Students' identity or self-concept and sense of belonging (hexagon 4) is affected by the progress of their disciplinary learning (again, this is reflected by the linking of the path-vectors Journey of Understanding → Personal Journey). The sense of common purpose and emerging disciplinary identity (belonging) within the peer group seemed to encourage students to embrace new perspectives and practices, easing incipient shifts in identity. The pedagogical approaches adopted in the tutorial programme encouraged students to release their long-held conceptions of themselves as incapable learners of mathematics (feelings that had developed from their past academic careers), by having their capability affirmed by the teacher (through the teacher's written responses to their journal writings), through their sense of collective capability, by their growing individual self-efficacy beliefs, and by the underpinning conception of learning as the social construction of meaningful knowledge, in which they are active agents.

The element of belonging in the context of students' learning represents the extent to which the learning environment fosters a sense of safety, comfort and community that enables the expression of their developing disciplinary understandings and emerging identities. The peer group and pedagogical approaches, along with students' appreciation of the teacher's immediacy, created an emotionally supportive learning environment in the form of a risk-free space in which to practice statistics, and to find their disciplinary voice.

This sense of self includes appraisals, values and aspirations originally formed by individual biography, which may evolve to include a stronger disciplinary identity in response to changing perspectives, personal growth and increased capacity for self-expression in academic and social domains. In the tutorial programme, the students' sense of belonging was instrumental in facilitating their 'becoming' with regard to the discipline. As they identified with the group of fellow statistics students (or in some cases with the wider community of statisticians), and became more proficient in the discipline and more confident of their own abilities, many appeared to experience an expanded and clearer sense of themselves.

A sense of belonging — within the peer group, the institution, or the discipline — supports affective, conative-related aspects of learning (hexagon 5). In the model above, this relationship is represented by path-vector: Personal Journey → Emotions. A range of emotions arise from the previously discussed elements of learning; these make demands on learners' psychological resources. Together, the interplay of affective responses and psychological resources constitute an important element of learning. Affect may be evoked by any aspect of learning, including the pedagogical approach, disciplinary content, assessment practices, teacher immediacy, and other features of the learning environment. Affective responses are widely variable, and may be strongly positive or negative. In the tutorials, students expressed strong emotions associated with the peer group and learning approach, the teacher's approach, their engagement with content, the processes and outcomes of assessment, their awareness of disciplinary mastery, and their own personal growth. Effective learning requires that students modulate the negative and harness positive emotional responses, drawing on their internal psychological resources in the form of the conative and affective intrapersonal constructs that sustain commitment to learning goals, and enable persistence in the face of difficulty. These might include fortitude, determination and resilience, self-belief, optimism and hope. Importantly, these resources are not fixed, and may be supported and developed in the course of learning.

In consideration of the above model, likely locations of systemic failure, manifesting as stuckness, defensiveness, or a flight response, exist. A few possibilities will be noted here. Students may not progress in disciplinary learning if they have not breached conceptual thresholds — in other words, if they fail to scale conceptual barriers of disciplinary knowledge.

Thus, this lack of conceptual and identity-relevance of the discipline as experienced would suggest that the vector-pathway linking the Journey of Understanding to Personal Journey would not be completed; and the cobblestones of metacognitive/metalearning shifts and shifts in self/sense of belonging would not be traversed to sustain and energise learning. Insufficient self-belief, resilience, academic biography, or other intrapersonal resources may be a further reason for students' learning engagement to fall short of its potential. Finally, if students do not feel a sense of community or membership but instead feel alienated or isolated in the discipline, or the course of study, their self-investment, commitment and learning achievements are likely to be curtailed.

Viewing students' learning in this way may suggest promising points for supportive intervention to enable and facilitate learning, some of which are noted in the implications discussed in section

9.4 above. The model accommodates the possibility of some scope for substitutability across some of the elements, which might ultimately enlarge the range of options for helpful intervention available to teachers, even in the face of relatively less tractable exogenous factors. For instance, a student may not feel strong identity congruence with the discipline as experienced, but could still be encouraged towards commitment and self-investment by virtue of the social integration the peer group affords and the reassuring presence of the propinquity of the teacher. The extent of this type of compensation across elements remains an open question.

Figure 11 depicts the system of learning as resting on the processes and interactions engendered by the tutorial group-based pedagogy, which supported and sustained both the cognitive and affective aspects of disciplinary learning. In reality, variation in individual biography and self-construal, as well as personal context, will affect how students engage with, experience and are transformed by disciplinary learning, so that the impacts of pedagogy may not be predictable or uniform.

Nonetheless, it seems reasonable to suggest that teachers, peers and pedagogy can enhance the meaningfulness and identity-relevance of the discipline as experienced for many students in the ways suggested here. This representation of students' learning may also be used to explore the impacts of different pedagogical approaches. For instance, if the pedagogy supporting learning in this case were to be replaced with a flipped classroom approach, we might speculate about the likely impact on the remaining constructs, exploring how each element in the system of learning as a whole might be affected by a change in the pedagogical basis.

9.6 Concluding reflections

The self-proclaimed transformations that participants' described and attributed to their learning in the threshold concepts-enriched tutorial programme seem larger than the questions that precipitated them. These transformations are an illustration of a qualitative view of statistics students' learning that goes beyond issues of disciplinary difficulty or local context. The model developed in sections 9.2.3 and 9.5 offers a conceptual and graphic representation of these tentative answers, in terms of which disciplinary learning may be understood as a challenging and transformative process. Crossing the learning thresholds that constitute disciplinary mastery requires a sense of capability, as well as self-investment, which in turn propels one's motivation to succeed. Thus, disciplinary learning engages students' cognitive, conative and affective resources. If the discipline as experienced aligns with students' values, identity and goals, learning is more likely to be experienced as meaningful, facilitating the engagement of intrapersonal psychological resources that sustain academic commitment and in turn enhance cognitive and metacognitive development. In the tutorial programme, the pedagogical approach contributed to learners' sense of autonomy and capability, supported cognitive processes of conceptual learning, and offered a sense of belonging and an emotionally supportive learning environment. It appears that for many students, this promoted discipline-self congruence, enhanced learning, and facilitated the emergence of an expanded and clearer sense of self — which may be viewed as a central objective of graduate attributes in higher education. As such, these emergent findings may draw our gaze to contemplating what it means to learn and teach in statistics and to achieve disciplinary maturation and enculturation.

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APPENDICES

APPENDIX 1: REQUEST TO CONDUCT RESEARCH

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

11 May 2017

Prof. S. Moyo

Director: Research and Postgraduate Support

Dear Prof. Moyo

PERMISSION TO CONDUCT RESEARCH

I am currently registered for a PhD study that examines students learning of Statistics at DUT. The title of the study is: "Cost and Management Accounting students' experiences of learning Statistics in a threshold concepts enriched tutorial programme".I wish to examine Cost and Management Accounting students' learning of Statistical concepts in the Business Statistics II (BSTS 201) course at the Durban University of Technology, Ritson and ML Sultan campuses.

The research will be undertaken by me, Mrs. Anisha Ananth, lecturer in the Department of Statistics in the Applied Sciences Faculty, to fulfil the requirements of a PhD in Education. My contact details are: Room AE 0009, Mariam Bee Building, ML Sultan campus, DUT. My office telephone number is 031 373 6800; email: anishas@dut.ac.za. Further information on the project may be obtained from my supervisor, Prof. S.M. Maistry, Edgewood campus, UKZN, office telephone 0312603457.

I request your consent to conduct a weekly 1 hour tutorial programme with a maximum of 20 students sampled from the Business Statistics II course. Participation in the programme will be voluntary and will be conducted during the entire duration of the second semester, 2017. Data will be collected from the participating students through focus group discussions and an individual interview with participants, and will also draw on the participating students' course-related written submissions (assignments and learning journal), to consolidate my study. The focus group, interview and journal writing will be about the students' views on learning Statistics concepts. The duration of the focus group and interview will be about 60 and 30 minutes respectively. Video and/or audio recordings will be made, and discussion will be transcribed and coded for study. The transcribed interview will remain confidential at all times, and the participating student's anonymity is guaranteed. This will be achieved through the use of codes and/or pseudonyms. The transcribed interview will be kept in a safe place within the School of Education as per research requirements. At the end of five years the transcribed interview will be destroyed by shredding.

This study will certainly be of benefit to our students as it has potential to reveal important insights into the teaching and learning of Statistics at DUT.

I will be grateful if you would consent to me undertaking this study at DUT. I will need a brief letter to this effect should my request be approved.

[redacted] 17 May 2017

SIGNATURE OF RESEARCHER **DATE**

APPENDIX 2: PERMISSION TO CONDUCT RESEARCH

DUT DURBAN UNIVERSITY OF TECHNOLOGY | DIRECTORATE FOR RESEARCH AND POSTGRADUATE SUPPORT

2 June 2017

Ms Anisha Ananth
c/o School of Education University of Kwa-Zulu Natal

Dear Ms Ananth

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

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 permission for you to conduct your research "Cost and Management Accounting students' experiences of learning Statistics in a threshold concepts enriched tutorial programme" at the Durban University of Technology.

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

[redacted]

____

PROF SIBUSISO MOYO
DVC (ACTING): RESEARCH, INNOVATION AND ENGAGEMENT
DIRECTOR: RESEARCH AND POSTGRADUATE SUPPORT

APPENDIX 3: ETHICAL APPROVAL

UNIVERSITY OF KWAZULU-NATAL™

INYUVESI YAKWAZULU-NATALI

17 July 2017

Mrs Anisha Ananth (993221552)
School of Education
Edgewood Campus

Dear Mrs Ananth,

Protocol reference number: HSS/1057/017D
Project title: Students' experiences of learning Statistics in a threshold concepts enriched tutorial programme

Approval Notification – Expedited Application

In response to your application received on 11 July 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

[redacted]

Dr Shamila Naidoo (Deputy Chair)

/ms

Cc Supervisor: Professor SM Maistry
Cc Academic Leader Research: Dr SB Khoza
Cc School Administrator: Ms Tyzer Khumalo

Humanities & Social Sciences Research Ethics Committee
Dr Shenuka Singh (Chair)
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Website: www.ukzn.ac.za

1910 - 2010
100 YEARS OF ACADEMIC EXCELLENCE

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

APPENDIX 4: INFORMED CONSENT

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

Dear Student

I am conducting research into students' learning of statistics concepts in Business Statistics II at the Durban University of Technology.

The research is being undertaken by me, Mrs. Anisha Ananth, Lecturer in the Department of Statistics, Faculty of Applied Sciences, to fulfil the requirements of a PhD in Education. My contact details are: Room AE0009E, Mariam Bee Bldg., ML Sultan campus, DUT. My office telephone number is 031-373 6800; email: anishas@dut.ac.za. Further information on the project may be obtained from my supervisor, Prof. S. Maistry, Edgewood campus, UKZN, office telephone number 031-260 3457.

I wish to obtain your consent to participate in a weekly tutorial programme and to conduct a focus group discussion and an individual interview with you and to draw on your course-related written submissions (learning journal and comments on the online discussion board) to consolidate my study. The focus group, interview, journal writing and online discussion board comments will be about your views on learning statistics concepts. The duration of the tutorial programme will be approximately 90 minutes and the duration of the focus group and interview will be about 60 and 30 minutes, respectively. Video and/or audio recordings will be made and discussion will be transcribed and coded for study. Your transcribed interview will remain confidential at all times and your anonymity is guaranteed. This will be achieved through the use of codes and/or pseudonyms. The transcribed interview will be kept in a safe place within the School of Education, UKZN, as per research requirements. At the end of five years the transcribed interview will be destroyed by shredding.

Please note that your participation in the study is voluntary and a decision not to participate will not result in any form of disadvantage to you. Participants have the right to withdraw at any stage and for any reason without any negative consequences.

DECLARATION OF CONSENT

I ………………………………………………………………………………………… (full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project and I consent to participating in the research project. I understand that I am at liberty to withdraw from the project at any time, without any negative consequences should I so desire. I hereby provide consent to:

Audio-record my interview and focus group discussion YES/NO

Video-record my interview and focus group discussion YES/NO

Use of my written work for research purposes YES/NO

………………………………………………………………………………………… ……………………….

SIGNATURE OF PARTICIPANT **DATE**

APPENDIX 5: TUTORIAL TOPIC LIST

Activity 1 - Simple linear regression and correlation

Police sometimes use footprint size as evidence to estimate the height of a suspect. Anthropologist, Paul Topinard, collected foot/height measurements and used it develop a rule that could estimate a person's height from their foot length.

For each student in class, measure the student's height (Y) in centimetres and shoe size (X).

(a) Test for a linear correlation between the variables.
(b) Identify the equation of the regression line (i.e. the line of best fit).
(c) Use the lecturer's shoe size to estimate the height of the lecturer.
(d) From the regression equation, if a person's shoe size increases by one unit, what is the corresponding estimated change in height?
(e) What variation in a person's height is determined by their shoe size?

Describe the correlation that exists between a person's shoe size and the person’s height

Activity 2 – Probability

1. Consider the following three pairs of statements and determine whether the events are mutually exclusive.
   a. Arriving late for your statistics class
      Arriving early for your statistics class
   b. Asking for a date through a Facebook post
      Asking for a date in French, the language of love
   c. Randomly selecting a survey respondent and getting someone who believes in UFOs
      Randomly selecting a survey respondent and getting someone who believes in Father Christmas

2. The weather channel reports that there is a 20% chance of rain in Durban today. Which of the following is the most reasonable interpretation?
   (a) $^1/_5$ of Durban will get rain today
   (b) In Durban, it will rain for $^1/_5$ of the day.
   (c) In Durban, there is a $^1/_5$ probability that it will rain at some point during the day.

3. This is the sample space listing the 8 events that are possible when a couple has 3 children:
   {bbb; bbg; bgb; bgg; gbb; gbg; ggb; ggg}
   a. Find the probability that when a couple has 3 children, there is exactly 1 girl.
   b. Find the probability that there are exactly 2 girls.

4. Consider the random experiment of tossing a coin. There are two possible outcomes for this experiment, namely a head (H) or a tail (T).
   a. Repeat the random experiment five times, i.e., toss a coin 5 times and record the information in the following table:-

Toss	**Outcome**	**Number of heads**
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		
13.		
14.		
15.		
16.		
17.		
18.		
19.		
20.		

   b. Based on your first 5 tosses, what estimate would you give for the probability of a head when this coin is tossed?
   c. Now toss the coin 5 more times and continue recording in the table so that you now have entries for tosses 6-10. Based on your 10 tosses. What estimate would you give for the probability of a head when this coin is tossed. Explain your answer.
   d. Now toss the coin 10 more times and continue recording in the table so that you now have entries for tosses 11-20. Based on your tosses 1-20, what estimate would you give for a probability of a head when this coin is tossed. Explain your answer.

5. Fill in the following frequency distribution table showing the number of male and female students in the tutorial group:-

Gender	frequency
Male	
Female	
Total	

Two students are selected at random from the class.

a. The first student selected does not return to the class for possible reselection, i.e. sampling is **without replacement**. Let
F_1 = the event that the first student selected is female and
M_2 = event that the second student selected is male
Then, $P(F_1 \cap M_2) =$

b. If sampling is **with replacement**, then calculate $P(F_1 \cap M_2) =$

Activity 3

1. When an adult is randomly selected there is 0.85 probability that this person knows what Twitter is. Suppose that we want to find the probability that exactly 3 of 5 random adults know what Twitter is.
   a. Does this procedure result in a binomial distribution?
   b. If this procedure does result in a binomial distribution, identify the values of n, x, p and q.
   c. Calculate $P(X = 3)$.

2. Assume that random guesses are made for five mcq's on a statistics test so that n = 5, each with a probability of 0.2 of being correct. Find the probability:
   a. The number of correct guesses is at least 3:
   b. The number of correct guesses is less than 3:
   c. The probability of no correct guesses is:
   d. The probability that all the guesses are correct is:

3. The brand name of McDonald's has a 95% recognition rate. A special focus group consists of 12 randomly selected adults are to be used for extensive market testing. For such random groups of 12 people, find the mean and standard deviation for the number of people who recognize the brand name of McDonald's.

4. The average number of major storms to hit your city in a year is 2. What is the probability that exactly 3 storms will hit your city next year?

5. Here is an example where the Poisson distribution was used in a maternity hospital to work out how many births would be expected during the night.
   The hospital had 3000 deliveries each year, so if these happened randomly around the clock 1000 deliveries would be expected between the hours of midnight and 8.00 a.m each year. This is the time when many staff are off duty and it is important to ensure that there will be enough people to cope with the workload on any particular night. The average number of deliveries per night is 1000/365, which is 2.74. From this average rate the probability of delivering 0,1,2, etc., babies each night can be calculated using the Poisson distribution. Some probabilities are:
   a. $P(X=0)=\frac{e^{-\lambda}.\lambda^x}{x!}=\frac{e^{-2.74}.2.74^0}{0!}=0.065$
   b. $P(X=1)=\frac{e^{-\lambda}.\lambda^x}{x!}=\frac{e^{-2.74}.2.74^1}{1!}=0.177$
   c. $P(X=2)=\frac{e^{-\lambda}.\lambda^x}{x!}=\frac{e^{-2.74}.2.74^2}{2!}=0.242$
   d. $P(X=3)=\frac{e^{-\lambda}.\lambda^x}{x!}=\frac{e^{-2.74}.2.74^3}{3!}=0.221$
   e. $P(X=4)=\frac{e^{-\lambda}.\lambda^x}{x!}=\frac{e^{-2.74}.2.74^4}{4!}=0.152$

   On how many days in the year would 5 or more deliveries be expected?

6. The social organization Tall Clubs International has a requirement that women must be at least 1.7m tall to join. Given that women have normally distributed heights with a mean of 1.63m and a standard deviation of 0.26 metres, find the percentage of women who satisfy the height requirements.

Activity 4

Normal Distribution

1. **Window placement** – The standing heights of men are normally distributed with a mean of 1634mm and a standard deviation of 66mm.
   a. If a window is positioned so that it is comfortable for men with standing eye heights greater than 1 500mm, what percentage of men will find that height comfortable?
   b. A window is positioned to be comfortable for the lowest 95% of eye heights of men. What standing eye height of men separates the lowest 95% from the highest 5%?
2. **Ability grouping** – Some educators argue that all students are served better if they are separated into groups according to their abilities. Assume that students are to be separated into a group with IQ scores in the bottom 30%, a second group with IQ scores in the middle 40% and a third group with IQ scores in the top 30%. The Weschler Adult Intelligence Scale yields an IQ score obtained through a test and the scores are normally

distributed with a mean of 100 and a standard deviation of 15. Find the Weshler IQ scores that separates the three groups.

Activity 5 – Sampling Distribution

Divide into groups of 3 or 4 students. Use a coin to simulate births, each individual group member should simulate 25 births and record the number of simulated girls. (If coin lands Tails then it is a girl).

Each group should fill in the following table:-

n = total no. of births	***x = no. of girls***
$n_1 = 25$	
$n_2 = 25$	
$n_3 = 25$	
$n_4 = 25$	

Calculate the mean no. of girls for each group as follows:-

Sample mean: $\bar{x} = \frac{\sum x}{n}$

Combine all the group results for the *n* batches of births as follows:-

Group 1	$\bar{x}_1 =$
Group 2	$\bar{x}_2 =$
Group 3	$\bar{x}_3 =$
Group 4	$\bar{x}_4 =$
Group 5	$\bar{x}_5 =$
Group 6	$\bar{x}_6 =$

Compute the mean for the sample means of girls, i.e. calculate $\mu_{\bar{x}}$

Is this simulated result unusual? Explain.

APPENDIX 6: REFLECTIVE WRITING PROMPTS

Reflection 1

Tell me about your initial feelings/impressions of the Business Statistics course and about your decision to participate in this tutorial programme.

Tell me about your academic career thus far and any problems/challenges you anticipate facing in your learning in Business Statistics.

Reflection 2

Tell me about your experiences in the first tut group session.

How did you feel about working in a group, collecting real data and applying the data to real world problems?

Reflection 3

I would like you to reflect on today's tutorial – what are your thoughts on probability distributions and modelling? How have you experienced the process of learning these techniques thus far?

Reflection 4

Tell me about your study preparation for test 1 and your reflections on your results.

Tell me about any aspects of the tutorial group that you may be finding difficulties with and/or aspects that you are enjoying.

Reflection 5

Tell me about your preparation for test 2.

Has the tut sessions helped towards your studying of test 2?

Reflection 6

Please tell me about a learning experience when you "got" something in Statistics. What factors are making it harder or easier for you to learn statistics: attitudes, language, previous schooling, etc.

APPENDIX 7: FINAL ISSUE STATEMENTS

Issue Statements for IQA focus group

During this group session I would like you to share your experiences of learning statistics in this threshold concepts-enriched tutorial group.

Before we begin I would like you to:

- Try and get as comfortable as possible.
- Close your eyes, take a deep breath and relax.
- Now I want you to cast your mind back to the beginning of this semester. Coming back to campus after the holidays and seeing that Business Statistics is one of the courses you will be taking this semester.
- Now imagine yourself learning Statistics through the semester and your joining this tut group. Your reasons and feelings for joining the group.
- Recall our first meeting and our first activity working as a group and your writings in your reflective journals

Reflect on your experiences of learning new knowledge. Please tell me about your overall experiences of learning in Business Statistics 201 and this tut group this semester.

Tell me about your journey of learning

- How have you come to understand the new knowledge taught in Business Statistics this semester?
- Tell me about your “aha” moments and when and how did you “get” it and you knew you “got” it?
- What aspects of the tut programme helped you in your learning?
- What aspects did you find difficult or challenging and why? If so, how did you overcome your areas of “stuckness”?

Tell me about what you got out of your learning

- Do you have a working grasp of the statistical concepts such as probability, simple linear regression, sampling distribution, etc.
- Can you describe personal attributes, skills and knowledge that you have developed through working in this tut programme.
- Has learning in this tut programme changed the way you viewed the statistical concepts
- Did your understanding of your own learning and thought processes change by being a part of this tut programme?

Tell me about your feelings towards learning

- How did it feel to learn Statistics this semester?
- How did you deal with negative emotions or challenges in your learning?
- How did you feel about this tut group?

Tell me about what you learnt about yourself in this process

- What elements of your own particular background, personality or circumstances have affected your learning journey or your feelings about learning Statistics?
- Has learning Statistics or being in this tut programme changed you as a person or the way you see yourself or the world at large?

Now tell me about your learning of Statistics in BSTS 201 and this tut programme throughout the semester. Reflect on all the thoughts you had about learning Statistics. You are the expert and I want to tap into your experiences of learning statistics in BSTS 201 and this tut programme.

Write these thoughts down on your cards.
Write one thought or one experience per card – using words, phrases, sentences or pictures.
Write as many thoughts as you can – one thought per card - until you have run out of ideas or until I ask everyone to stop.

(Task time – approx. 15 minutes)

APPENDIX 8: FOCUS GROUP AFFINITY GENERATION

Below are the responses participants generated, clustered into affinities and named in the first focus group session. Index cards were typed up verbatim. Affinities were checked and affinity descriptions (presented in chapter 5) confirmed in the second focus group session.

TUT GROUP

- Working in groups, having the ability to voice your opinion either through writing or just by talking
- Giving myself enough time to study and, joined the tut group, really helped me a lot
- My reason for joining this group was because I knew that I was going to benefit from it. I wanted to improve and change my thoughts (negative) about some of the topics covered in statistics
- The tut session was very helpful cause when there is a problem you faced regarding business statistics you just ask for help from your tut group members using communicating channels provided in the tut session
- The aspect which I find difficult was understanding the topics, but as time progress and engaging with the group for business statistics tut, it real help me a lot to overcome my difficulties and help me improve my marks
- I found with enough practice it all made sense
- The tut program has been a great experience and I wouldn’t mind learning more about statistics. It is very interesting especially when it comes to real life experiment
- The time consumed by the tut was worth it as every tut was progressive and very helpful in learning
- Being part of this tut did not change me that much or made me see the world differently at large but it has thought me how to tackle challenges differently from a different aspect and perspectives
- I have an increased hunger to learn ever since I joined this group. More hunger for knowledge
- Before I used to stress about 5 modules but now I only stress about 4 modules. I don’t regret my decision on joining the tut group. I hope that you may also succeed in your PhD because you have made us succeed in our module ☺
- It really helped me to join the class because I had a chance to tackle exercises by myself or with a peer and that really helped me to learn the work. I also had a chance to get help from the lecturer if I didn’t understand a concept in class
- It is very easy to fail statistics and in seeing that I knew that joining the tut sessions would really be of help because it is where you get a clear understanding of statistics and all the topics we had to cover, of what to do and how to do it

- At first the group did not seem active at all, everyone was quiet but as time went by, everyone was comfortable and able to provide and ask questions that were helpful to us
- Being given a chance to attempt a question really help myself to see where I am lacking, what I should study
- TUT GROUP (image of two hands high-fiving, formula for standardizing a Normal variable))
  - Knowledge
  - Friends
  - Constructional, and
  - Food ☺ (not that it's the most NB! aspect)
- In the tut sessions we were given questions to ask and then the solutions of the tasks to see where you went wrong
- Going to school on Saturdays, having a study group also helped to better my understanding and achieve good results
- ☺ I wish all module should be the same because this really improve my learning and I gave me hope. It has show me that I can do things that other people think I won't be able to do with the help of this group. I did better. Why this didn't happen when I was doing my first year because I didn't thought I will be able to study with a group of people
- Well to be honest I would advise anyone doing stats to join the tut, as it may help them to improve their statistics knowledge
- I feel very well about this tut group as its helpful
- I have my own skills of I have developed in this tut programme that helped me in doing better on my tests
- Happy with each tut
- Tut group was useful and it helped me to understand some aspects
- When I was doing my first year, I had people/other students who were doing 3rd year and BTechs talking about this module. Honestly they didn't speak nicely about it. They were always saying that it is the most difficult module in DUT especially if you are doing it without any background of pure maths (if you didn't do it in high school). I kept that in my mind. But I was always telling myself that I would be able to do it. Here come the day of registration, it appears on my proof of registration, this thought come back in my mind. It was like it has been put on repeat, cause I couldn't stop thinking about it. When I heard about this tut, I joined it and now everything has change. This group teach me not to listen to other people.
- Doing my exercises helped me to understand stats.
- I learned that I am not as good as I thought in solving problems alone, but with group work I'm even more productive and excel.
- This tut group helped me understand the new knowledge about statistics because of the activities that we did together
- I think it helps working in groups than individuals when practicing business statistics
- Through all the tuts, hard work and commitment, I now see things differently. I enjoy doing statistics now, unbelievable but true.

- My personal attributes, skills and knowledge for this tut programme, was being able to communicate with other students when needing help and also gain much knowledge from the student in the group on how to tackle some question in the statistical way.
- The learning in this tut programme has real changed the way I viewed statistical concepts because we in the group help each other and by linking the statistic with the real world was interesting and I enjoyed it.
- This group teaches me something that I didn't thought I will ever do. Speaking with a lecturer. YO! YO! I am a very shy person. I never thought that I will ever ask a lecturer a question but now. Hey ☺
- Tut programme helped me to give me more understanding when we do activities.
- Learning in this tut programme has changed the way I view statistical concepts. E.g. the storm that has been few days ago. It is confirmed that damages are 30 million of which I believe that Statistics South Africa had to confirm that.
- Now talking about the tut session as a whole, I had fun with it and our tutor/lecturer not sure what to call her !!! LOL, always had the thing called Ubuntu brought us food every time we meet ☺
- Joining the tut sessions was a really good move because we were put into groups where we all had to work together and it is sometimes easy to understand something when you hear someone explain it clearly to you, and how they think it should be done plus it was always fun too.
- I was afraid to join the tut group because I thought I won't get what I want. But hey ☺ I get more than what I expected.
- I feel very happy about this tut because it helped to understand better what I missed during the lecture. Statistics taught me that every time I am doing something, I should know that there possible chances. Either it happens or not, either it comes out good or bad, etc.
- In order for a person to master business statistics you need a lot of practice.
- By learning statistics really changed me as a person and also to be able to view other things different than before learning statistics.
- I feel like the tut helped me more in preparing for my tests because I would also try to use my own real life experiments to try and understand the work better and it did help me understand the work.
- TUT GROUP WAS HELPFUL
- For being part of this group at first it was intimidating, but as time progressed …. I felt at home and relaxed and enjoying being part of it.
- Learning of BSTS 201 and this tut programme is the best thing ☺
- Yes I do have working grasp of the statistical concepts especially sampling distribution, non-sampling distribution, sampling with replacement and sampling without replacement.
- WORKING IN GROUPS (picture of two girls smiling and a test paper with 96% written on it)
- I deal with challenges by doing more practice on what is challenging me
- PRACTICE MAKES PERFECT ☺

- WITHOUT THE TUT GROUP I WOULDN'T HAVE:
    - Learned that we can use stats to predict future occurrences in real life
    - Known that stats is also for dummies (not just the smart ones)
- My feeling about this tut I am very happy, it helped me score more in my tests
- The feeling I had joining this group was that it would make Statistics easier for me cause more heads will be joined together in finding solutions than just me alone
- Reason for joining this group as because I wanted to learn more about stats and how its used in the outside world
- The tut programme helped me get more practice in the work since in class we would only do the example in the book
- I would regard this tut programme as extra lessons I had which provided useful information, cause whatever I couldn't figure out in class, the reflection activity/activities would come in hand and assist me
- Learning and participating in group exercises has helped me in understand statistics better and also helped me to work as a team and not always individually.
- Being in this tut group helped me, improve my individuality and group work, not just to be taught only, but to learn to learn it yourself
- If I were to rate the tut I would say 11/10 ☺ If it were a hotel I would say it's a 6 star hotel lol!!
- Stats is not as bad as they claim (pic of a dancing lady)
- No regrets ☺
- I really was not excited about doing stats, I just wanted to do it and get it over and done with
- I feel great about the tut group, it has helped me a lot and I have no regrets of joining it, it has been an awesome experience in learning.
- In the tut group we were provided with activities that helped us a lot when we studied for the test and with the help of our lecturer who made everything manageable for us
- I liked the idea of having a journal so we'd get feedback from some of the thing I didn't understand in class. Also to give my point of view on or after the activity
- Our first meeting and activity as a group at first was intimidating, but reflective journals was good on what I thought and enjoy, but as time goes on, I enjoyed the group and felt at home
- The first activity we did, where we were measuring height and shoe sizes was very interesting as I found it to be practical and was a real life example

JOURNEY OF UNDERSTANDING

- The negative emotions in my learning, I deal with it by giving the learning the time to try and practice more and also seeking help from others
- Just a bit but its still calculations at the end of the day. So you still see statistics and remember high school with pure maths
- (Random scattering of the words Binomial, Poisson, Normal and formulae)
- I think so
- When I understood statistics my world became so much better ☺. I give credit to my lecturer, she was committed and patient to us students, it really helped having her around. She made everything better.
- Learning statistics it good for me because I like challenges
- Everything was still very fuzzy especially during simple linear regression and sampling distribution but the tut sessions really did help together with hard work
- Before I knew that statistics is difficult to understand and pass it so that affect me because I came with that belief
- Pretty much statistics is not an easy module it needs time and commitment. But through hard work and dedication it becomes easier and even fun especially during tut sessions
- When I struggled to understand something the tut came in handy as I would either ask our lecturer or tut group mates which made things even easier for me than to go over hours trying to figure something on my own.
- My knowledge of my own learning did change by being in this tut group because I learnt new things and found ways to understand stats by even using everyday problems
- The difficulties I experiences in learning stats are when I didn't know what formulas to use for each example given to us.
- Probability is the one topic that got me stucked like no other. Tjoh it was just too much I guess
- I have come to understand that every information presented in numbers has been accounted/obtained through statistics. So this semester most of the things I would be doing in statistics pertain real life situations.
- First test was challenging ☹
- Tests are rather painful when you confuse one component or info u feel like you might get 25/40 at times.
- The most challenging part was to actually understand the question and figure what was expected of me. I never gave myself time to practice on my own, I would only hear things from class. I overcame this by bringing this matter in the tut group and find more practice and practice
- The knowledge taught in Business Statistics make us understand the outcome of it when linking it with the things happening in the real world. For example how statistics predict the spreading of HIV & AIDS in South Africa using samples.
- The thing that simplified everything for me was that although statistics required a lot of formulas, most of it was in the calculator so it made life easier.

- Yes before I join this group I thought statistics is so it makes it easily to understand most of the things since it done practical
- I don't think that stats will ever be an easy subject but it gets better with time, depending on just how much you want to know.
- I understand by focus while lecture is explain.
- Statistics is a module you must start understanding from the beginning, just so you can understand it better. It is not a subject that you can just rush now that exams or tests are around the corner
- I overcame the "stuckness" by understanding the concepts of each chapter and what was expected by the question asked
- By learning at home, in class and in the tut I came to understand the new knowledge taught in Business Statistics because I could solve my problems faster and get ready for my tests better.
- Economist often predicts that petrol price will increase or decrease in next quarter or next month, which I feel statistics play a major role towards their predictions.
- The way I overcome my stuckness was that since I did maths in high school and figured I did get through statistics in maths I should apply same knowledge I got, especially in probability.
- I understood my own learning after I attend this tut group.
- AHHA!!! P and q are constant * I never noticed that until I got it in the group tut
- I thought binomial distribution was hard coz I wasn't getting the answers everyone was getting only to find its coz I wasn't I don't know what do when P(X<1) or P(X>1) after I understand it was smooth sailing.
- After taking time and re-doing what was done in the class, it all made sense as I understood the purpose and use of regression, then I felt little bit relieved.
- I asked questions that related to my confusion which helped me understand and also brought some of my aha moments as well as stuck (picture of lightbulb) were brought.
- (Picture of a person looking worried and frustrated written beneath it then and arrow points to a person reading a book and tried to study written beneath this picture and then an arrow pointing to another picture of a person smiling with the word understood written beneath it).
- Well judging from what we did in Business Calculations I thought statistics will be much harder since it is advanced maths
- One day I would like to be a teacher I will now consider teaching statistics and make my learners like it and understand it nice and more than myself
- My reason for joining this tut group was to gain more knowledge and understanding of the course.
- I have come to an understanding that I can relate what I am learning into reality. Working in groups helped me to have more understanding where others come up with ideas that make it easy to answer questions.
- PERSONALITY "FAKE IT TILL YOU MAKE IT" using that saying played a huge role in me giving answers like I actually understand until I actually understood through time

- Through commitment to the tut and paying attention in class, I could understand more about the subject
- I do not want to lie learning statistics this semester was stressful
- Complex
- The moments we had to use the binomial formula for more than one trial as well for less than was interesting. Or the Poisson formula and figured it used average or that sometimes I would use a figure above the needed # in the Z table
- AHA moments come when we are surprise of something that seem to be new.
- AHA moments: (picture of a person thinking about this)
- Dealing with negative emotions, was not easy I must say. I had to tell myself every time I opened that book, that I'm going to this only to find some other days it happened that I couldn't understand some notes, but slowly I am getting there.
- STUCKNESS → into → AHA
- A very challenging subject that wants you to learn to think for yourself. Solving for x's was never one of my strong points and I think I accepted that during my high school days but I'll say until now.
- Is there any??? I am not sure really.
- Using probability when trying to see if I should sell a lot of produce or when I should go to the library with the probability of it being full or probability of me finding a book I need.
- My understanding of my own learning and thought changed by being a part of this tut programme in a good way
- I have a broader understanding of the topics that we studied in class and the tut because the class was more theoretical and the tut was based more on practical and real life examples, which helped me view statistics in a wider angle.
- They are somethings that I didn't understand in class but I didn't ask because I was afraid that my class mates would look at me. I get a chance to ask my questions in a tut group.
- At first, probabilities were challenging. But because this programme has my back "AHA" ☺, they are not a problem at all.
- It took me time to adjust to Business Statistics cause I'm used to straight mathematics which is what we did in BCAL but with stats it seemed different.
- The aspects I found difficult were that in statistics a lot of formulas are used and they seem to be very alike/similar so it gave me difficulties in understanding which one belongs to this and which one belongs to that
- Business Statistics have helped me understand the real world problem solving, the linear regression very well. Thanks to the tut group. Now I can bet using probabilities pity I haven't won any ☹
- I realized how important statistics is by learning some aspects of it, I was tempted to say to myself "Oh Stats SA uses these things were learn to make some statements and predictions".
- Business Statistics has a lot of formulas which makes it hard for you to remember which formula to use when doing your calculations.

- Calculations are always the best but theory part.
- Learning in groups was difficult for me as I prefer working alone, that way I find myself at most comfortable, but coming to the tut helped me see that groups can at some points be more productive than working alone.
- So throughout I would say studying statistics has helped me understand how other things came into existence, how data is collected and calculated.
- I remember in the past years I was always told that stats is the most difficult module in second semester, only to find it is not as bad as they say I'm handling it just fine.
- PROBLEM SOLVED
- It's interesting yet frustrating cause you would think you understood in class do it at home, you end up with question marks. But as the semester went on we or shall a say began to understand with a few hiccups here and there.
- Things are so much different now, I look forward to attending statistics every day. I enjoy it more.
- Overall I loved and hated the subject understood it more with tuts and being comfortable in the class. I joined the tut so I understand the content so I am happy I did.
- Negative thoughts into positive thoughts – improvement
- Learning statistics this semester has been great because it is a module that is easy to understand.
- It did change the way I learnt as there were people who you would discuss the content with and it made it easier to understand. It made it more fun. ☺
- I knew I got it when I started getting 80% of the questions right
- More than anything I have enjoyed having Mrs. Ananth as a lecturer. She has taught me:
    - Stats (well obviously ☺)
    - Kindness
    - Ability to use my intuition
- The topic I loved most was sampling distribution cause it has formulas that are straight forward, all you have to do is to determine the distribution that is use and apply your formula
- Probability has always giving me a problem since high school, but this tut session helped me understand it better, though I haven't achieved 100% level of understanding it
- I always asked myself how do weather forecasters, forecast weather, and turned to be really true sometimes, now I understand that stats is involved and probability
- STATISTICS "EXPERT"
- I understand the working concepts of most but hated having a lot of info to study or understand about the type of samples
- Yes, at first I was worried, how am I going to understand stats whereas I escaped maths during high school and engaged with maths lit.
- There is nothing much difficult
- It was difficult at first I felt the load but I then got familiar with it and I think it's better now

- Test 2 was a nightmare, but I believe it's not as bad as I think. What I found difficult in test 2 was chapter 5. The theory!!! I won't be beaten twice exam is my day to avenge myself.
- Yes, I have come to understand a lot about statistics than before I did Business Statistics class. I really didn't see the use of statistics and how they affect our lives. But now I have come to see how we can predict future occurrences by using the frequency of past occurrences. After all, we all watch the weather after the news ☺
- Understanding is important but in business statistics I just not understanding what and why I am calculating.
- When Mrs. Ananth requested us to assist her in her tut programme, I didn't hesitate to join the tut group as I had a hope that maybe it will help me understand Business Statistics
- The other way I overcome my areas of stuckness was that since we are asked in a MCQ way, I would simply work around the given answers till one satisfies the question, especially in calculations

EMOTIONS

- The moment I saw that I will be taking Business Statistics this semester, I trembled, frightened and scared since I heard rumours people saying the worst is yet to come. Stats gonna show us flames.
- My initial thought about statistics was that it was very difficult, I had a skeptical view, wasn't even sure if I will pass the module
- ☺ I wish I learned it when I was doing my first year
- It has been an amazing experience
- Figuring out how to calculate an equation is the most AWESOME feeling
- ☹
- Learning statistics this semester made me feel excited because I love working with numbers. I was certain that it was a module that I will definitely enjoy. ☺
- My feelings of learning statistics changed from feeling bored to excited about learning statistics because of the tut and seeing how it is applied in real life circumstances
- Second test was actually fun and exciting …. ☺ wish I wrote all my tests like that
- In over all I'm very happy and I think I have fallen in love with this module as it changed the way I see the world as a whole.
- I feel good about learning statistics this semester. At first I thought it was going to be a jolly ride and all but when it I started doing it it looked harder than I thought
- Fun and informative (my experience ☺)
- Right now I'm ☺ happy
- Best decision ever
- Oh my word learning stats is like "Boom" (picture of explosion) but after some time you like it.
- Before (picture of frustrated person and formulae) After (picture of smiling person and formulae)
- So much fun
- I (Heart) statistics now yipeee
- Theee Best
- 80% → test one – 90% → test two – (picture of balloons with A's written in them) → exam (final)
- Yes
- I wish I only did statistics
- Binomial distribution (heart) fav (heart)
- (picture of smiling face dreaming with hearts)

PERSONAL JOURNEY

- At first learning statistics this semester, I was scared of it, but after test 1, I real enjoy it
- The more classes I attended, the more I started to have interest in mathematics
- The responses I received from ma'am were very encouraging and helpful
- Mrs. Ananth's positivity and constant patience has helped me deal with negative emotions/challenges
- It had its pros and cons, like anything else would, but it was fine we encounter new things as we grow in life
- (A mind map with the word statistics in the middle and arrows radiating out of it pointing to the words → fail → actual work → maths → takes time→ y do we have x →formulas, formulas, formulas, why??? → DUT → nice when you understand → tests = stress → emotional → frustration)
- First time I attended Statistics 2 I was not excited at all because I don't like maths
- Learning stats for the first time this semester felt like here we go again, what is maths doing now. We never became friends with maths. But look at me now. Who knew I would get 70% on stats. Lol!!
- At first I had problems of identifying the suitable formula for the question
- I used to think DUT never loved us coz this maths but you can actually use it wherever you go so it's all good.
- Recalling the first activity we did working with the group, where we had to measure each other's heights and shoe sizes. It left with the question "is statistics correct?" The answer to that question is that it is approximately ($\approx$) I liked the idea of using this method (reality problem solved)
- When I started the module it wasn't as bad as I thought, the concept were more easier than expected. The extra class I joined to better my understanding about statistic and indeed I did.
- Learning statistics wasn't optional (this semester). At first I would have never chose the module, but now I can even study it next year
- It felt like I was hit by a bomb. I mean it was brought to use when used (CPF) in the first year (Cram Pass Forget = CPF)
- When I first saw that this semester I'll be doing Business Statistics I panicked because I knew that probability would be done during the module and I was never good with probabilities
- As at the beginning statistics looked hard when I started doing it, it become easier and more exciting to study because of the tut sessions
- First lecture begun, where scary fomulaes appeared, then I started panicking and wondered if I will make it
- Learning statistics did change the way I thought about the world. Yes it did. I never thought that they are people who are not from your family who could help you to do better each and every day. Who can help you reach your goal.

- My group working skills have improved because most of the time the experiments we did in the tut required us to work in groups.
- You can achieve anything if you put your mind into it
- School life hasn't been easy but the journey has taught me perseverance and not to be afraid to aim high and work very hard to achieve and to reach full potential
- Inspite of being terrified by people about how difficult business Statistics is, I said to myself "I will fight, I am not a loser, everything has got its limitations". I had a hope that I will overcome any unforeseen obstacles in Business stats
- I wouldn't say much about background and personality but there definitely was a time where circumstances affected my learning not specifically stats but my learning in general
- The only people who believes in me are my family but not the rest of them only my mom and my grandmom. Each and every day I always want to do something that will make them proud of me. I really don't like the way I was raised. I was raised by my grandmom. I was not staying with my mom. My background is the only reason why I work hard.
- In this tut programme I learnt to work with my peers which is something I was not used to as I preferred studying/working on my own before
- This module has made me question how the stats we see on TV, newspapers, etc. were calculated/compiled
- Yes it change me
- I finally found the use of those extra buttons on my Casio calculator because of Business Statistics
- My background and my personality affected me in my learning journey by understanding certain things on how did they come about it, but after learning the statistics it made me really eliminate certain things in my personality
- My own learning and thought processes actually improved by being part of this tut programme
- Yes it did. My understanding did change → ☺
- I've learned to be fast and communicate with other people. Ask questions when I have. I engage with other learners.
- The way I dealt with challenges was that if I get stuck, Mrs. Ananth is here to simplify things so I would seek help in the tut session. Then that helped take the negative thoughts I had about stats being hard away.
- I have learned to be persistent
- What I learned is that if I set goals for myself, I put in the effort and I work tirelessly I will achieve what I want to achieve and I'll succeed in whatever I put my mind to
- I have a better opinion about learning as a whole and how stats can be useful in our daily lives
- Being the inquisitive person I am I have learned that I enjoy statistics a lot because I always want to question the knowledge I am given. I've also learned that maths is not so bad if you practice
- Not too bad!!! ☺

- I focused on the positive emotions and challenges in my learning of the tut because all the negative would have just driven me away and I wouldn't have all the knowledge that I have now on statistics
- From the first day I attend this tut, I saw that something good is coming but the other part of my mind told me that I won't be able to do it because people told me that stats is not for people who did maths lit. at school. But I set myself down and speak to myself, just the two of us, me, myself and I and I ask myself, why you are here? What makes you to come here? My answers was it because I believed from the first day, when I got my matric results that I can do something better in life. I just believe in myself and now I am still does
- Hardwork dedication commitment
- Solving real life problems opened my mind and I started understanding some of the things I never understood
- Learning statistics has helped me to see myself at large, it made me believe that there are changes for me to become a better person in future. It made me believe there is a 95% for me to leave a mark in this world
- The one thing I learnt from this tut group and statistics 201 is that you can achieve anything you set your mind to

APPENDIX 9: SUPPLEMENTARY GRAPH

The graph below is supplementary to Chapter 5 and offers an alternative way of expressing the Pareto Principle for determining the optimal number of affinity relationships to include in the Inter-relationship Diagram. This is a graphical illustration of the arguments in the paragraph immediately following Table 1 in section 5.2.2.2.

Figure 12 plots power against the total number of relationship pairs; again it its evident that power is maximized at 6 relationships.

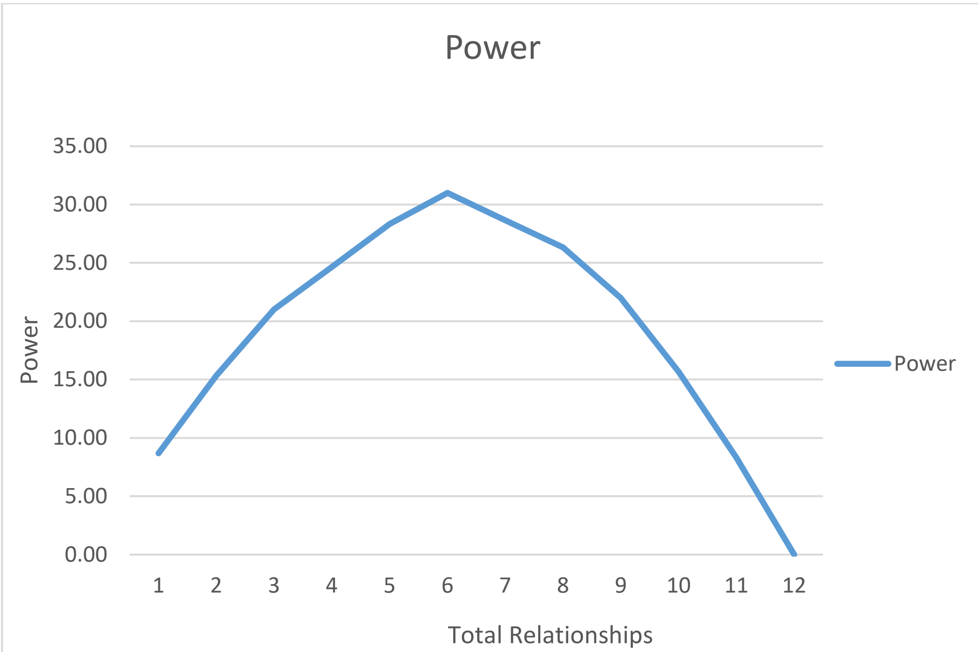

Figure 12: Power to total relationships

APPENDIX 10: INDIVIDUAL INTERVIEW PROTOCOL

1. Thanks - confidentiality of the interview - will be recorded, & I will later transcribe it but you won't be identified by name in any parts I use (will use a pseudonym if names are used).

2. Outline my study in general & recap affinities identified by focus group.

3. Start audio recording.

4. Axial interview: Experience the student has had with each of the affinities? (Making sure the experience is clearly and thoroughly expressed. Probing questions may allow for a richer or more in depth account.)

5. Theoretical interview: Relationship or connection between each pair of affinities? Refer to their filled in forms. Discuss all pairs, relationship or not.

6. Ask if they have any final thoughts.

7. Thank interviewee for their time & participation.

Interview protocol: Axial interview

The focus group identified several common themes or affinities that describe their learning of statistics in BSTS 201 and the threshold concepts-enriched tutorial group. Let's look at each of these themes one at a time, and you can tell me about your experiences with each. (Please be honest – I'm hoping to deepen understanding of how students learn so I'm looking for real reflections, & I won't mind if some of it is not positive ...)

1. Tut Group
This describes the teaching and learning methods used in the tutorial programme. Tell me about what your experiences with the tut group – what it has meant to you.

2. Journey of Understanding
This affinity is about your progression or path in learning statistics. Tell me about your experience of the journey of understanding.

3. Emotions
This affinity refers to the range of emotions students experienced while learning BSTS 201 and participating in the tuts. Tell me about your feelings over the semester.

4. Personal Journey
This affinity is about the personal growth or development students described as resulting from their participation in the tuts. Tell me about your personal outcomes.

Interview protocol: Theoretical interview
Many of the themes or affinities identified have some kind of relationship; one affects or causes the other. Tell me about your experiences with such relationships. Let’s look at each theme, and you tell me more about if or how it relates to each other theme, for you. For each relationship, please give me a specific example of how the relationship has affected your experience in learning statistics this semester.

AFFINITY NAMES
1. Tut Group
2. Journey of Understanding
3. Emotions
4. Personal Journey

Possible relationships

A → B (A influences B)
A ← B (B influences A)
A <> B (no relationship between A and B)

AFFINITY RELATIONSHIP TABLE

Affinity pair relationship	
→/←/<>	
Tut Group	Journey of Understanding
Tut Group	Emotions
Tut Group	Personal Journey
Journey of Understanding	Tut Group
Journey of Understanding	Emotions
Journey of Understanding	Personal Journey
Emotions	Tut Group
Emotions	Journey of Understanding
Emotions	Personal Journey
Personal Journey	Tut Group
Personal Journey	Journey of Understanding
Personal Journey	Emotions

APPENDIX 11: TURNITIN ORIGINALITY REPORT

Turnitin

Turnitin Originality Report

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By Anisha Singh

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