The Relationship between the Philosophy of Scientific Knowledge and Curriculum in Molecular Bioscience teaching at a tertiary learning institution

Derryn Audrey Legg-E'Silva

0111830P

A research report submitted to the Faculty of Science, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Masters in Science Education.

Johannesburg, 2017

DECLARATION

I declare that this research report is my own, unaided work. It is being submitted for the Degree of Master in Science Education in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

Derryn Audrey Legg-E'Silva

March 2018

ABSTRACT

The relationship between teacher beliefs about the nature of science and scientific knowledge and pedagogical practice has been well studied. However, this has mainly been for teachers at school level. This study examined this relationship, in lecturers, at a university level where a single course is taught by multiple lecturers, each with their own beliefs and teaching practices. Anecdotal evidence suggests that science students are receiving mixed messages about the nature of science and scientific knowledge, these are contradictory to what they should be learning in order to think and reason like true scientists. Data was collected from four lecturers who lecture across the same Molecular Biosciences course in the form of interviews, classroom observations and text analyses in order to ascertain the relationship between the beliefs, practices and assessment approaches of each lecturer. The findings indicate that coherence exists between lecturers' beliefs and practices and is in agreement with previous research. However, this coherence does not occur between the lecturers. One lecturer was found to be positivist, two lecturers transitional and one lecturer reform-based in their beliefs and teaching approaches. An interesting finding with regards to assessment was revealed and provided an explanation for mixed messages science students may be receiving regarding the nature of science and scientific knowledge. It can therefore be concluded that lecturers' beliefs about the nature of science and scientific knowledge are mirrored in their practices. This information may be useful for lecturer and teacher training and can be included in university and school discussions about views of teaching and assessment.

ACKNOWLEDGMENTS

I would like to thank the following people:

Professor Elisabeth Brenner for igniting my interest in education, for discussions about the research idea and design, for constructive criticisms of the research report and for being an inspiration and friend.

The School of Molecular and Cell Biology, University of the Witwatersrand for affording me the time I needed to attend the course components.

The 2015 2nd and 3rd year Molecular and Cell Biology students and staff, for agreeing to participate in the research.

Professor Jaya George and the National Health Laboratory Services, for authorising my study leave, enabling me to complete the research report.

Mrs Funani Makhanya and Dr Ike Achilonu for their assistance.

Dr Carolyn Podoa, Dr Eleanor Cave, Mrs Katherine Prigge and Miss Lungile Khambule for spending much of their precious time checking transcriptions and coding.

The University of the Witwatersrand for financial support.

My husband Elio, my son Edward and my family for cheering me on and picking me up when I needed it most.

TABLE OF CONTENTS

DECLARATION i
ABSTRACT ii
ACKNOWLEDGMENTS iii
TABLE OF CONTENTS iv
LIST OF FIGURES vii
LIST OF TABLES vii
ABBREVIATIONS vii
CHAPTER 1 1
INTRODUCTION 1
1.1 The Purpose of the Study 1
1.2 Background to the Research Problem 1
1.3 Research question and sub-questions 2
1.4 Significance of the Study 2
CHAPTER 2 4
LITERATURE REVIEW 4
2.1 Introduction 4
2.2 Theoretical and Conceptual Framework 9
CHAPTER 3 17
RESEARCH DESIGN AND METHODOLOGY 17
3.1 Overview and justification for the research design 17
3.2 Research population 18
3.3 Methodology 19
3.4 Data collection and analysis 21
3.4.1 Observation data 21
3.4.2 Interview data 22
3.4.3 Text analysis data 28
3.5 Reliability and Validity 30
3.6 Ethical considerations 31
CHAPTER 4 31
RESULTS 31
4.1 Dr Alpha 36

4.1.1 Practices 36
4.1.2 Beliefs 37
4.1.3 Assessment 38
4.2 Professor Beta 39
4.2.1 Practices 39
4.2.2 Beliefs 40
4.2.3 Assessment 41
4.3 Dr Gamma 41
4.3.1 Practices 41
4.3.2 Beliefs 42
4.3.3 Assessment 42
4.4 Professor Delta 43
4.4.1 Practices 43
4.4.2 Beliefs 44
4.4.3 Assessment 45
CHAPTER 5 46
DISCUSSION 46
5.1 Traditional view 49
5.2 Transitional view 52
5.3 Student-centred view 55
5.4 Closing 58
CHAPTER 6 59
REFERENCES 59
CHAPTER 7 67
APPENDICES 67
7.1 Classroom observation coding 67
7.1.1 Observation of Dr Alpha 67
7.1.2 Observation of Professor Beta 76
7.1.3 Observation of Dr Gamma 79
7.1.4 Observation of Professor Delta 83
7.2 Interview questions 87
7.3 Interview coding – lecturer beliefs 88
7.3.1 Doctor Alpha Beliefs 88
7.3.2 Professor Beta Beliefs 90

7.3.3 Doctor Gamma Beliefs 91
7.3.4 Professor Delta Beliefs 92
7.4 Texts for analysis 93
7.4.1 Class test questions - Doctor Alpha 93
7.4.2 Class test questions - Professor Beta 95
7.4.3 Class test questions - Doctor Gamma 100
7.4.4 Class test questions - Professor Delta 101
7.5 Text analysis 107
7.5.1 Class Test Coding – Doctor Alpha 108
7.5.2 Class Test Coding – Professor Beta 109
7.5.3 Class Test Coding – Doctor Gamma 109
7.5.4 Class Test Coding – Professor Delta 110

LIST OF FIGURES

Figure	Title	page
1	Flow diagram of the theoretical/conceptual framework underpinning the study	10
2	Constructivist Learning Environment Survey (CLES)	22
3A & 3B	Interview coding maps for markers 1 and 2	25
3C & 3D	Interview coding maps for markers 3 and 4	26
3E & 3F	Interview coding maps for markers 5 and 6	27
3G	Interview coding maps for marker 7	28
4	Triangulated data for Doctor Alpha	32
5	Triangulated data for Professor Beta	33
6	Triangulated data for Doctor Gamma	34
7	Triangulated data for Professor Delta	35

LIST OF TABLES

Table	Title	page
1	Participants' experience, qualifications and level of course	19
2	Framework used for analysis of class test questions	29

ABBREVIATIONS

CLES	Constructivist Learning Environment Survey
F(1-3)	Factual level (1-3)
DBE	Department of Basic Education
C(1-3)	Conceptual level (1-3)
P(1-3)	Procedural level (1-3)
SA	South Africa
SPS	Science Process Skill

CHAPTER 1

INTRODUCTION

1.1 The Purpose of the Study

The purpose of this study is to investigate whether individual lecturer's philosophies of scientific knowledge and the nature of science are reflected in the way in which they teach, design curricula or set assessments in the Molecular Biosciences.

1.2 Background to the Research Problem

Owing to the large numbers of students currently registered for Science degrees, it has become normal practise for several lecturers to share the teaching in a course. However, there is concern that differences in their teaching philosophies, views of knowledge, and ideas of what students need to learn might result in mixed messages being conveyed to students, which, in turn, could impact on their learning.

In the first instance therefore, it will be valuable to define what is referred to in this study as an individual lecturer's philosophy with respect to scientific knowledge. Philosophy can be defined as the most fundamental beliefs, concepts, and attitudes of an individual. This can be aligned with what has been referred to as the *nature of science*, defined as "an individual's ideas, beliefs, views, perceptions and assumptions about scientific knowledge – the facts, principles, laws and theories making up the body of knowledge called science" (Vhurumuku and Mokeleche, 2009, p. 47). Lederman (2007) defined the nature of science as the theory of science and the ideals and philosophies that are integral to scientific knowledge and its advancements.

Since individuals may have differing conceptualisations of the nature of science, I am interested in establishing how individual lecturer's views impact on what and how they teach as well as on the way in which they assess their students. This is because it can be expected that student's views on the nature of science will be influenced by those of their lecturers. This is important because there are many studies that report that student's views of the nature of science impact on the way they learn science (Lucas & Roth, 1996; Ryder & Leach, 1999; Ryder *et al*., 1999 & Lederman, 2007), which highlights the importance of establishing the views of their lecturers. Therefore this study will yield valuable information

that may lead to recommendations on how science is taught at a tertiary level with respect to the selection of lecturers sharing courses.

1.3 Research question and sub-questions

This study will investigate how the views of individual lecturers on the nature of science and scientific knowledge impact on the curriculum, their teaching and mode of assessment in the Molecular Biosciences.

In order to answer the research question the study will investigate the following sub-questions:

- What are the views of a purposely selected group of molecular bioscience lecturers, with different backgrounds, of scientific knowledge and the nature of science?
- Does a molecular bioscience lecturer's view of scientific knowledge influence their curriculum design?
- Does a molecular biosciences lecturer's view of scientific knowledge influence their pedagogy?
- Does a molecular biosciences lecturer's view of scientific knowledge affect the way in which they assess their students?
- What do molecular bioscience lecturers think science students need to know and do with respect to the scientific knowledge domain?

1.4 Significance of the Study

Scientific knowledge, which to a large extent results from observations, is subject to change, is subjective, involves human deduction and is socially and culturally rooted (Lederman, 2007). It has also been explained as being created by humans instead of being revealed as a series of truths (Yoon & Kim, 2016). An example that may be used to illustrate this point is that since Democritus proposed the concept of an atom during the 5th century, it has been a common belief that the atom is the smallest known entity and so this is what has been taught in schools and universities. However, subsequent to the discovery of the atom we have now learnt that the atom is not the smallest known entity. We now have evidence of quarks and leptons and more recently, the Higgs Boson particle (CMS Collaboration, 2012). Therefore, in general, within the scientific knowledge domain, as new experimentally based evidence is discovered, previously accepted "facts" are revised and replaced.

In light of this, one might envisage that the approach to teaching science should take into consideration that scientific knowledge is ever changing, especially since scientists are constantly making new discoveries and testing old theories and concepts. Moreover, in an ideal situation, science students should be able to think and reason like scientists if they, in turn, are to help advance our country through innovative thought. This highlights the importance of the way in which science curricula are designed and the way in which students are taught. This study therefore will examine how science lecturers interpret the concept of scientific knowledge, and how this knowledge is "transformed" to students and how this "knowledge" is assessed. The findings will thus contribute to the field of science education.

Furthermore, the study is important to me as an educator in the field because as a scientist and a lecturer, I need to take into consideration the impact of my own beliefs regarding scientific knowledge and the nature of science on my own teaching. From a personal point of view, I want to be able to teach science effectively so that all my students comprehend what it means to be a scientist, and are guided to think and reason like a scientist and to practice like a true scientist.

Lastly, the study is also important for South Africa (SA) especially if one takes into consideration that over the last few years education in Science and Mathematics in SA has been prioritised (Mbeki, 2005). This has mainly been due to a need to keep up with the education standards from around the world. In an attempt to enhance their economic development and thus advance the quality of the lives of its people, developing countries, such as SA, have spent huge amounts of money on science education (Coll & Taylor, 2012). Koh *et al*. (2008) point out the political aspect and the value it places on science education is linked to economic (as well as technological) transformation of developing countries. This ideal of the South African government has been reiterated by the Academy of Science of South Africa (Grayson, 2010) who highlighted a critical need to increase the number of students who are appropriately skilled in mathematics and science, the South African Department of Basic Education (DBE) stressed the importance of developing science process skills (SPS) (Molefe *et al*., 2016). These skills are defined by Aydogdu (2015) as the activities that scientists perform to obtain information about the world around us. This can be viewed as an attempt to expose students to the everyday activities of scientists so that they may

one day be able to think, act and reason like a true scientist. However, despite the emphasis that has been placed on developing SPS, research shows that South African students, in general, have misconceptions with respect to these skills (Molefe, 2011). It is thought that this may be due to teacher-centred practices that limit the opportunities for students to engage with different scientific methods that enable the development of SPS (Rambuda & Fraser, 2004). Coil *et al*. (2010) reported that this problem persists at a tertiary learning level, owing to the fact that these skills are not taught. Furthermore, notwithstanding reforms in South Africa with regards to skills, teachers continue to emphasise content over SPS development (Ambross, Meiring & Blignaut, 2014). So even with the prioritisation of science education in the country, and science teacher education courses that promote constructivist philosophies, student-centered and inquiry or problem based teaching (Jones & Carter, 2007) few educators utilize these practices on a frequent basis (Sickel, 2015). Furthermore, anecdotal and published evidence suggests that students still arrive at university used to standardised tests and rote learning facts covered in class (Flint, 2016). Many lecturers attempt to rectify the situation but again anecdotal and published evidence suggests that some maintain the status quo and expect students to continue to learn facts (Miyazaki, 2016; Rice & Foster, 2016; Isiksal-Bostan *et al*., 2015; Meyer *et al*., 2013; Umugiraneza & Bansilal, 2017). This leads one to question to what extent development of SPS is dependent on the mind-set of lecturers.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

For many centuries the exemplar of the scientific materialist world view was known as the positivist paradigm. However, over recent years, this paradigm has been criticised by philosophers of science and critical pedagogues (Vygotsky, 1978; Burbules & Linn, 1991, Kincheloe and Tobin, 2009).

Positivism has an ontology that views reality as being out there, ready to be discovered and comprehended, and an epistemology that sees the world as ordered and that knowledge is absolute (Hatch, 2002). The teaching of science according to a traditional positivist paradigm has been associated with these inert views of scientific knowledge that see knowledge as

being absolute and unchanging (Burbules and Linn, 1991). This has led to teaching practices that require little more than the rote learning of facts and the memorisation of technical vocabulary that are, in my opinion, synonymous with surface approaches to learning and teacher-centred teaching. Briefly, surface approaches to learning utilise low cognitive-level activities such as memorisation when understanding is required and listing facts when formulating an argument is necessary etc (Biggs and Tang, 2011). These types of activities isolate facts and treat concepts independently of each other thereby, making no difference between new ideas and existing knowledge (Fry *et al*., 2009; Biggs and Tang, 2011). In other words, students who display surface approaches to learning accept new facts and concepts uncritically and deposit these as unique and separate matters (Houghton, 2004).

The view that learning instructions are merely a means for students to gain scientific concepts has been frowned on by many (Talyzina, 1981; Davydov, 1990; Bruer, 1993; Karpov, 2003). However, this view of learning instruction was supported by those such as Hirsch (1987) who felt that the gaining of scientific concepts and other verbal information should form the main body of the content of school learning. He later stated that "Words refer to things; knowing a lot of words means knowing a lot of things" (Hirsch, 1988 p. 24). Vygotsky (1978), on the other hand, stressed the importance of learning scientific concepts since he believed that scientific knowledge allows students to conciliate subject domain-thinking with problem solving (Karpov, 2003). Subsequently, Vygotsky recognised that scientific knowledge could not just be simplified to verbal definitions of scientific concepts but would also require procedural knowledge that was applicable to the scientific concepts themselves. He therefore, emphasised that scientific concepts should not just involve factual information and that concepts cannot be learned purely by memorization (Karpov, 2003).

Over the last couple of decades, views on learning have shifted towards a cognitive perspective (Vygotsky, 1978; Driver & Odham, 1986; Von Glasersfeld, 1991; Piaget 1964, 2003; Kirschner *et al*., 2006; Weston, 2014; Sickel, 2015). Basically, this view of learning recognises that students construct 'models' or 'schemes' which are drawn upon in order to interpret their experiences (Vygotsky, 1978; Driver & Odham, 1986; Piaget, 1964, 2003). Therefore, this view of learning is nested in the paradigm of interpretivism (Gallagher 1991)

and hence, constructivism and these paradigms have helped to re-shape the thinking of science education researchers (Keser & Akedeniz, 2010; Alhammad, 2015; Hang *et al.*, 2015). Interpretivist paradigms involve the production of context-based comprehensions of students' views, values, beliefs and related social behaviours and as such, have a social constructivist epistemology (Taylor *et al*., 2012).

According to the ontology of the constructivist paradigm, what is out there is a world of unknowable realities. Reality, in turn, is the interaction of an individual with the environment or experience; it is always changing and therefore, multiple and unique realities exist (Hatch, 2002). Constructivist epistemologies contend that knowledge is constructed by individuals, and results from experiencing scientific methods and by interacting and communicating with others. For this reason knowledge is considered to be co-constructed (Hatch, 2002). Therefore while positivism embodies surface teaching approaches, constructivism might be considered to be synonymous with the so called deep teaching approaches that have been associated with student-centered, inquiry or problem based teaching (Prosser & Trigwell, 1999). This idea is supported by Altinyelken (2010), Merrill (2012), Van Merrienboer & Kirschner (2013) and Dolmas *et al.* (2016). Deep approaches to learning require higher level cognitive abilities (Biggs and Tang, 2011). From this perspective, the intention is to engage with tasks appropriately in order to bring about comprehension and meaning so that students are able to link concepts to understanding and to differentiate between new knowledge and existing knowledge, and ultimately to learn facts in the context of meaning (Fry *et al*., 2009; Biggs and Tang, 2011).

While a constructivist viewpoint might seem intuitive to most scientists, there are however, those that do not advocate constructivist views of teaching and learning. Von Glasersfeld (1991) pointed out that "the notion that, as far as knowing goes, we are unconditionally trapped in our own ways of seeing and conceptualizing irks a lot of people" (p.3). Mayer (2000), and Kirschner, Sweller, and Clark (2006), criticised constructivist teaching methods by reporting that empirical evidence does not support the constructivist teaching technique of pure discovery and preferably advocated guided discovery. Furthermore, and more recently, constructivist and social-constructivist pedagogies have been criticised for establishing minimal evidence of their usefulness but have been shown to be more

multifaceted when compared to traditional transmission modes of teaching (Barron & Darling-Hammond, 2010). Additionally, their effectiveness is dependent on the skills and knowledge of the teachers involved (Barron, Darling-Hammond, 2010). This leads one to conclude that not everyone considers constructivism to be a superior learning theory.

Despite criticisms of cognitive constructivism, the constructivist approach has provided many benefits to science classrooms and facilitated the understanding of learning processes in students (Giest & Lompscher, 2003). However, decades after Joseph Schwab's (1962) introduction of the notion that science should be taught as an 'enquiry into enquiry', and more than a century after John Dewey (1916) promoted student-centred classroom practices, these constructivist "procedures" are yet to be fully and correctly incorporated into science teaching. This finding has been highlighted by the studies of Duschl & Osborne (2002), Miyazaki (2016) and Molefe *et al*. (2016) whose research although markedly different and ranging from argumentation discourse in science education to complexities of pedagogical change to science process skills, all basically concluded that constructivist, student-centred teaching approaches and associated activities are not yet fully understood and/or implemented by teachers.

Recent studies (Markic & Eilks, 2012; Belo *et al*., 2014; Jogi *et al*., 2015; Miyazaki, 2016; Rice & Foster, 2016; Isiksal-Bostan *et al*., 2015; Meyer *et al*., 2013) have illustrated that positivist practices as observed by Burbules & Linn, (1991) are still rampant. Similarly, there are other reports stating that traditional classroom teachers feel that students learn by memorizing scientific rules, theories, classifications, or theorems (Karpov, 2003; Belo *et al*., 2014). This is disturbing as it confirms the continuance of practices in which researchers describe lessons that they have observed to be directed by teacher talk, with stress placed on memorization of facts (Gallas, 1995; Lemke, 1990). Bruer (1993) and Davydov (1990) report that under traditional instruction, students are frequently taught rote skills and verbal definitions of scientific concepts rather than actual scientific knowledge (conceptual and procedural knowledge). Currently, universities are required to educate students to become life-long learners and resourceful experts in their individual fields (Dolmas *et al*., 2016). Adopting and motivating the development of life-long learning skills, such as; critical thinking and problem solving, has become an urgent goal of higher education in the 21st century (Dolmas *et al*., 2016). The Bologna declaration states that successful learning in higher education should

involve students in deep learning (Asikainen, 2014). Accordingly, in terms of this study, the major question that arises is, what approach is adopted by science lecturers at a top South African University. This question is even more important if they are all teaching a particular course. Specifically, I would like to investigate their beliefs on the nature of science and their philosophy of scientific knowledge and probe how these influence their curriculum design, teaching and assessment practices. In particular, it would be interesting to establish whether they adopt positivist or the more widely accepted constructivist approaches and whether these reflect their beliefs about the nature of science.

From this perspective, there are many publications that report that educators feel, or have shown, that their beliefs do affect their instructional practices (Nespor, 1987; Pajares, 1992; Tsai, 2002; Luft & Roehrig, 2007; Tsai, 2007; Caudle & Moran, 2012; Belo *et al*., 2014; Anderson, 2014; Sickel, 2015; Rice & Foster, 2016; Tursucu *et al*., 2017). Research on the beliefs of teachers has developed into one of the main research areas of teaching and teacher education (Tsai, 2002). Some examples are Maor and Taylor (1995) who found that, even in computerised classroom environments, teachers' views of knowledge play an important role in determining the quality of student science learning. They concluded that teachers' conceptions of knowledge are principally related to their pedagogical practices. Donnelly (1999) showed that science teachers believe that scientists emphasise more established knowledge and see uncertainty or the unknown as intimidating and off- putting. Furthermore, science teachers in the study by Tsai (2002), Belo *et al*.(2014) and Sickel (2015) also appeared to adopt traditional transmission teaching and this corresponded well with their beliefs. Other noteworthy publications on teacher's beliefs are those by Postareff *et al*. (2008) who showed agreement and disagreement between some university lecturers' beliefs and practices. They concluded their study by saying that disagreement happened as lecturers changed from content- to learning-focussed beliefs. This was also one of the findings of the study by Malkki & Lindblom-Ylanne (2012) that showed that teachers either alter their beliefs and practices simultaneously or they alter their practices prior to changing their beliefs. When practices were changed prior to beliefs, discourse was also observed to occur. Since it is not easy to change the inherent beliefs of teachers, as will be discussed, one may expect some dissonance during transitions from one belief to another and so the above findings are reasonable. To complicate matters further, there are those teachers who

hold more than one belief at a time (Song and Looi, 2012) and those who may apply different beliefs and practices to different situations or contexts (Lameras *et al*., 2012).

There are many explanations that have been proposed to account for the relationship between teachers' concepts of knowledge and pedagogical practices. For instance, the reality that teachers maintain traditional views of teaching and learning science, as well as, the nature of science, may be due to problems they had during their own school science experience (Tsai, 2002; Shulman, 2005; Yoon & Kim, 2016). Or perhaps the science classes and laboratory exercises in teacher training programmes underpin traditional positivist views and practices or fail to enforce conceptual constructivist practices (Tsai, 2002)? It has also been reported that teachers did not develop constructivist views and practices about teaching and learning because they felt they had been successful by using the existing traditional positivist approach (Trumbull and Slack, 1991; Hamilton, 2017).

The majority of the studies in the aforementioned literature were undertaken at school level and for this reason, were based on science teachers who were not scientists. This reveals a gap in knowledge with respect to the teaching of science at a university level by scientists who are active researchers. The question that arose was whether scientists would have different views of scientific knowledge from school science teachers. The question could be extended to whether differing educational backgrounds would influence scientists' views of scientific knowledge?

2.2 Theoretical and Conceptual Framework

There are many theories and concepts that frame this research, a summary of which has been illustrated in figure 1. These include philosophies of knowledge and theories of paradigms such as positivism, learning theories and approaches such as cognition, constructivism and deep or surface approaches (discussed in section 2.1) and concepts of curriculum and assessment, amongst others. I will discuss how philosophies, psychologies and sociologies of educators (lecturers, in this study) and their role as curriculum developers, define the goals of tertiary educational systems. These direct the design of the curriculum and the underlining theory of learning that is selected, and this determines the curriculum program that is to be implemented and defines how assessment is approached based on the goals of the curriculum.

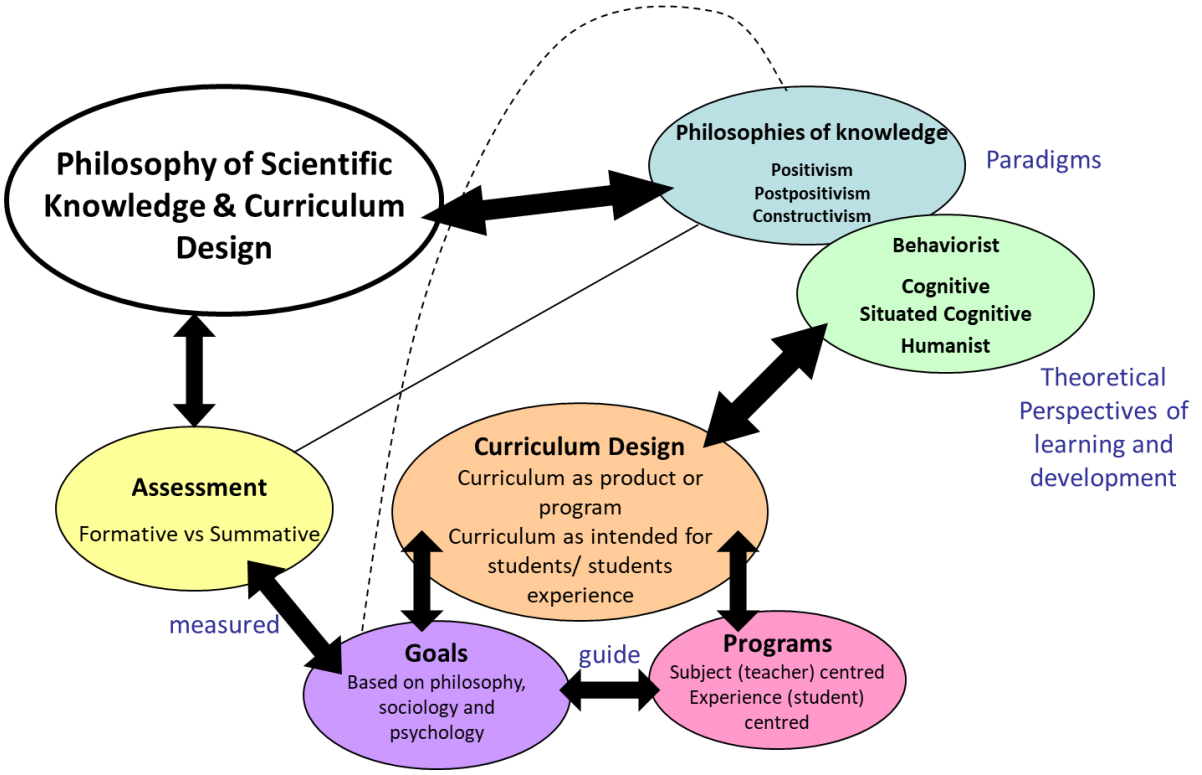


Figure 1: Flow diagram of the theoretical/conceptual framework underpinning the study.

Planning a curriculum is a very complicated process that depends on many factors. Curriculum planning comprises construction and design, development, implementation and evaluation (Zais, 1976). Beane *et al*. (1986) define curriculum development as "the curriculum planning process that results in broad and specific curriculum plans" (p. 356). Therefore, one can say that curriculum development is the planning of what is taught and learnt and is indicated in units of study and educational programs (Parsons & Beauchamp, 2012, Kattington, 2010) and this is ultimately determined by the definition of curriculum itself.

Generally, a curriculum is a collection of ideas, abilities, ideals and traditions that are accessible within a society (Lovat & Smith, 1995) or in the context of this study, within an individual lecturer. These will depend on the ideology, philosophy, sociology and psychology of that society or lecturer and will ultimately determine the goals of that society or lecturer and hence the goals of their educational systems. These goals will not only dictate the curriculum model, but also the curriculum program/design, curriculum implementation and

evaluation approaches and these will in turn dictate the role of educators (and students) within these curricula. Beane *et al*. (1986) said that all aspects of a curriculum should incorporate and be influenced by the fields of philosophy, sociology and psychology, since these three factors form the foundation of a curriculum and will ensure that all learners "grow and develop so that they may lead satisfying lives within the context of society" (p. 73).

Briefly, philosophy entails "the nature and meaning of life" (Beane *et al*., 1986). The philosophy of an individual lecturer will determine how they perceive philosophical notions of knowledge, truth, worth and value. In other words, the philosophy of an individual lecturer will determine what they think is valuable and worthwhile knowledge. Tanner & Tanner (1995) propose five philosophical considerations for a curriculum; perennialism, essentialism, experimentalism, reconstructionism and progressivism. These considerations play an important role regarding what sociological factors need to be addressed in a curriculum. Sociology involves the study of society and its past, present and future issues (Beane *et al*., 1986). Societal issues include; identity, values, technology and socioeconomics (historical, current and potential), all of which need to be addressed by curriculum developers in order for educational institutions to provide valuable knowledge that meets the needs of society. Psychologists have proposed different theories of learning, behaviourist, cognitive and humanist. These theories have been used when planning and developing a curriculum and influence the teaching-learning process. Tanner & Tanner (1995) propose that learning theories are selected based on the goals of a curriculum. Moreover this depends on the goals of individual lecturers and their definition of curriculum.

Most of the definitions of curriculum lie within one of the following groups:

(1) Curriculum as product originates from the idea that a curriculum is a document that describes the course of events of the educational institution and is the result of the planning and development of the curriculum (Beane *et al*., 1986). This form of curriculum often stipulates what students will learn (educational goals) and how this will be achieved. For this reason this definition of curriculum has been compared to the objectives model where education is viewed as a means to accomplish pre-determined goals (Hirst, 1969,

Stenhouse, 1975). Philosophically, Tanner & Tanner (1995) refer to this curriculum as both perennialist and essentialist where knowledge is truth and is unchanging. This type of curriculum would be considered a subject-centred (teacher-centred) program, since it centres around the notion that various subjects comprise "essential" knowledge and that the mastery of this "essential" knowledge is what enables one to be "educated" (Zais, 1976). Furthermore, as mentioned previously, this type of design and program is influenced by positivist philosophies that view knowledge as absolute and is seen as timeless, objective and unrelated to people's contexts (Kelly, 2004).

(2) Curriculum as program represents the course of study that is proposed by the educational institution and is the learning that takes place in all aspects of the institution (Beane *et al*., 1986) including non-academic activities such as sport and cultural events which offer learning within a different context. This type of curriculum is also rather prescriptive because it assumes that what is written in a curriculum is precisely what the students will learn. It is based on positivist epistemologies and is viewed as perennialist and essentialist and once again follows the design of a subject-centred (teacher-centred) program.

From a psychological perspective, curriculum as product and curriculum as program, can be considered to be aligned with behaviourist theories of learning. This is because behaviourist learning theories view the mind as a blank slate and focus on learning as a change in behaviour that has resulted from stimulus-response behaviour (Kruse, 2009). This abstract outlook of learning can be "easily applied to curriculum objectives and sequencing of subject matter" (Tanner & Tanner, 1995, p.274). These attributes are apparent in curriculum as product and curriculum as program by which a set of documents dictate what is to be taught and how and where "the course of study offered by the school" can be used to achieve its goals (Beane *et al*., 1986).

(3) Curriculum as intended for students is the intended knowledge or content, skills, characteristics, and behaviours to be learnt (Lovat & Smith, 1995). It differs to that of curriculum as product and program in that it does not stipulate how the intended knowledge should be taught. Knowledge however, is still considered to be absolute and is still prescribed (by dominant groups within the society or lecturers themselves). However,

context is taken into account particularly at the level of instruction. Therefore, curriculum as intended for students could be correlated to the cognitive theory of learning. Unlike behaviourism, cognitive learning theories are more concerned with the mental processes of learning (Kruse, 2009) such as reasoning, planning, solving problems and comprehending language (Greeno *et al*., 1996). According to cognitive learning theories, as mentioned previously, students already possess concepts and thinking patterns and these are used to construct and accommodate new facts and experiences into conceptual frameworks (Slavin, 2003). Therefore, curriculum developers and/or lecturers, need to be aware of the cognitive abilities of students in order to "design instructional activities encompassing a wider range of cognitive learning" (Tanner & Tanner, 1995, p. 277).

(4) Curriculum as experiences of the student is based on the notion that what is planned, may not always be realised and so the curriculum exists only in the learning that students deduct from their experiences (Beane *et al*., 1986). These learning experiences occur in a social context and because they are individual learning experiences, learning and hence knowledge, is not considered to be absolute. This curriculum program is considered to be student-centred (also known as experience-centred, problem-centred or inquiry based) since these programs recognise the manner in which the mind works and are based on the premise that knowledge in not transmitted but constructed by the individuals mind, learning is based on prior knowledge and that language influences culture and thoughts (Dewey, 1916; Piaget, 1964, 2003; Vygotsky, 1978; Bernstein, 1986). These designs also take context into consideration and highlight the social aspect of learning. This curriculum program is based on the philosophical notions of constructivism, progressivism, reconstructionism, existentialism, pragmatism and experimentalism. Therefore, the goals of the corresponding curriculum designs are to educate individuals according to their needs and interests as well as those of society. Curriculum as experiences of the students, views students in a very different way compared to models of product, program and intended learning. Here students are considered to be cultural beings and experiencing individuals whereas lecturers are regarded as research project directors, co-learners or facilitators and "travel agents" who guide and advise students (Gormally, 2016). The tools and methods used to learn and teach entail group work, group projects, experiments, problem-solving, individual exploration and critical problem analysis. Consequently, in student-centred

designs lecturers will see students as individuals and the content to be taught would need to fit the needs of individual students rather than the individual students fitting to the standards of the content.

Psychologically, the curriculum as intended learning, together with the student-centred and experience-centred curriculum programs, correlate well with humanistic theories of learning. This can be said because humanistic learning theories see learners as "autonomously thinking, socially responsible individual[s] who [are] capable of controlling [their] destiny" (Tanner & Tanner, 1995).

Thus, it is evident from the literature described above, that different conceptions of curriculum can and will influence the way a student is perceived, taught and assessed. Since most lecturers are ultimately responsible for the curriculum they choose, it can be said that lecturers play an important role in curriculum development. It is however, important to note that curricula are very often dictated by society's educational needs as expressed in curriculum documents, especially at a school level but also at a university level, in order to guarantee that undergraduate students obtain the quality of education required to be useful in our global society, colleges and schools of science must persistently develop their education and knowledge (Rice & Foster, 2016).

This point is particularly relevant in developing countries, such as SA, Brazil, Russia, India and China that have, in an effort to improve their economic development and consequently improve the value and worth of the lives of its people, spent large sums of money on education and more specifically, science education (Coll & Taylor, 2012). Koh *et al*. (2008) say that the political side and the significance it puts on education is tied to economic change of developing countries. On the social plane, education (particularly primary science education) is believed to instil in people the potential to improve their living situations by concentrating on basic local problems including the necessity of clean water, good nutrition and personal hygiene and health (Lewin, 1993). However, along with economic, political and sociological influences, the influence of certain ideologies has also been shown to impact on the development of science curricula in developing countries.

Up until the 1980s the science curricula of most developing countries were strictly traditional and content based. This type of teaching and learning is comparable to that

stipulated by curriculum as product and program that utilizes subject-centred curriculum programs and can be described by Freire's "banking concept". Here lecturers are viewed as "depositors" of information and students as "collectors" and in this way lecturers and students are de-humanized into objects that have no autonomy and hence no ability to rationalise and conceptualise knowledge at a personal level (Freire, 2008). However, in the 1980's and 1990's, world-wide curriculum reforms emerged in developed and developing countries in order to bring about the idea of world democracy (Coll & Taylor, 2012). Science curricula were changed to emphasise inquiry based views of science teaching and learning and this development was supported by notions that scientific knowledge is provisional, "man-made" and subject to question. These curriculum reforms had their origins in constructivism (Piaget, 1964, 2003, Vygotsky, 1978) and progressivism (Dewey, 1916) and resulted in curriculum as intended for students and experiences of students' models which resulted in teaching pedagogies that are student and experience-centred in design with continuous, performance based assessments (Rogan & Grayson, 2003). The curriculum reforms resulted in science curricula being deeply influenced by cognitive learning theories.

Psychologists have shown that children can only imitate actions that are within their developmental level. This is similar to the view of Piaget who said that learners can only learn if they have developed the operational or cognitive structures that enable them to do so (Piaget, 1964, 2003). He theorised that the key to cognitive development is self-regulation, a process whereby new knowledge or knowledge contrary to what is known (external stimulus) is accepted and combined with pre-existing knowledge, thus establishing a "new" equilibrium at a higher cognitive level (Piaget, 1964, 2003). Piaget defined development as a procedure that concerns all the structures of knowledge and proposed that learning is a limited process that occurs owing to situations or external stimuli. He viewed learning as a product of an individualist society, that is, students develop and learn on their own without the help or input from outsiders. The role of lecturers in light of this theory is that of a facilitator, meaning that the lecturer actively uses their knowledge in order to help the student to understand general ideas without taking a specific stand in the discussion themselves.

Vygotsky, on the other hand, theorised that the relationship between development and learning occurred in the zone of proximal development, which is defined as the distance

between the actual development level (problems solved by students independently) and the level of potential development (problems solved by students with guidance). He showed that students are able to imitate many different actions that exceed the constraints of their own abilities when given guidance, and so students learn by interacting and communicating with others who are more knowledgeable (Vygotsky, 1978). Consequently, Vygotsky's theory of learning views learning as a product of the community; the learning process is dependent on others and not just the child (student) as an individual (Vygotsky, 1978). The lecturer needs to be more actively involved in the learning process by using their knowledge to offer assistance and feedback as well as to provide the tools necessary for learning. Thus, the role of the lecturer is that of mediator of the learning process that is taking place in the learner.

The curriculum reforms not only emphasised cognitive learning theories that influenced the written, the supported and the taught science curricula but also the tested curricula or measures of student performance, that is, assessments or more traditionally, testing. Assessment is one of the most vital parts of instruction or teaching and differs significantly from testing (Dikli, 2003). It has long been believed that assessment drives learning (Wormald, 2009). Since assessments are often used to make conclusions about student competence and very often result in students putting more effort into obtaining high marks versus actually understanding concepts and learning (Pugh & Regehr, 2016). For this reason students tend to learn only what they know will be assessed. This can lead to undesirable student behaviours such as rote learning facts and cramming, and study techniques that do not promote deep learning. Furthermore, the format of an assessment can also manipulate student learning. Students have been shown to change their approaches to studying, based on assessment formats that utilise surface approaches for tests that they think may be assessing lower level knowledge and cognitive domains (Pugh & Regehr, 2016). So in order to prevent the adoption of surface level learning by students, lecturers need to change their understanding of assessment, from formative content-only assessments, to assessments of student learning that have more than one way for students to show their competency in content, practices and understanding (Sondergeld *et al*., 2016). Testing is considered to be formal and usually standardized; information about what students know and are capable of doing is collected at a single time point (Dikli, 2003; White, 1975). It is said that in testing,

students are provided with detailed procedures for controlling and achieving good results whereas in assessment, different manners and methods are used to collect information in different contexts at a number of points in time and is said to be formative (White, 1975; Law & Eckes, 1995; Dikli, 2003). Formative assessments are aligned with and are representative of constructivist or humanist paradigms and learning theories, expressed as student-centred pedagogies and problem-based learning (Altinyelken, 2010; Vavrus *et al*., 2011). More traditional paradigms and learning theories, such as positivism and behaviourism, use summative assessments such as testing.

The literature review above highlights how the philosophy, psychology and sociology of lecturers and/or curriculum developers influence the development of the goals of educational systems. These in turn dictate the curriculum design (product, program, intended for the student and experiences of students) and its underlining theory of learning that is selected, and this determines the curriculum program (subject-centred and student or experience-centred) that is to be implemented in the classroom. The influences of all these factors then impact upon the conceptualisations of the roles of lecturers (and students) and the way they teach and assess students.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 Overview and justification for the research design

The research paradigm of this study is that of interpretivism and in particular, constructivism. Interpretivists believe that reality is the interaction of an individual with their environment or experience. In order to investigate the nature of reality, interpretivists believe that knowing results from experiencing (Johnson & Onwuegbuzie, 2004). However, a possible drawback of interpretivism could be that "interpretivism does not allow for generalisations because it encourages the study of a small number of cases that do not apply to the whole population" (http://rubyvine.blogspot.com/2009/10/research-paradigms-positivism.html). In accordance with the interpretivist/constructivist paradigm I, the researcher, have constructed knowledge from the data collected and simultaneously interpreted what I observed in classrooms, interviews and text analyses. Since I co-constructed and interpreted data with participants, I have assessed and interpreted human

decisions and human behaviour and as such have made use of qualitative research methods (Johnson & Christensen, 2004), the tools for which are discussed in section 3.3.

3.2 Research population

The sample consisted of four Molecular Bioscience lecturers, lecturing across the Molecular Bioscience program within a tertiary learning institution. The molecular biosciences courses are lectured by multiple lecturers. The third year content domain is provided to lecturers, in other words, the main topics to be covered in the course are defined and mandatory. However, the course curricula are entirely decided upon by the lecturers themselves. At the second year level the curricula are laid out in terms of the content to teach in each lecture for the core courses. However, the way in which the content is taught is up to the individual lecturer. For the stand alone courses, the curricula are decided upon by the individual lecturers.

The participants were selected based on availability, willingness to participate, and different educational backgrounds as well as on anecdotal evidence of their differing teaching styles. Pseudonyms were used for the lecturer's names. Table 1 outlines the participating lecturers teaching experience, qualifications and level of course in which they were teaching.

The lecturers were observed during two separate 45 minute lectures, in an attempt to observe a range of classes for reliability purposes. However, only one lecture was selected for coding and analysis, that is, the second lecture. It was reasoned that the lecturer and students would be used to the presence of the researcher by the second observation and therefore, would be less likely to act differently when being taped. It was hoped that this would make the data more reliable. Unfortunately, no other researcher was enlisted to observe the classroom interactions but the observations were video recorded for validation by an external researcher.

Table 1: Participants' experience, qualifications and level of course

Lecturer	Qualifications	Teaching experience	Level of course being lectured
Doctor Alpha	PhD in Molecular and Cell Biology	8 years	Third year
Professor Beta	PhD in Biology (Professor)	18 years	Second year
Doctor Gamma	PhD in Molecular and Cell Biology	2 years	Second year
Professor Delta	PhD in Molecular and Cell Biology (Associate Professor)	14 years	Third year

All the participants agreed to be interviewed post observation. This was done in order to validate the observation data. The four lecturers also agreed to supply two past test papers they had set for the course material observed. Students were not selected per se, but participated by virtue of their registration for the course that the selected lecturer taught. However, the students were made aware that if they did not want to part take in the study they would be seated behind the camera when lectures were video recorded. In this way, the study could commence and the students would be able to attend classes without taking part in the study or having their reactions in the lecture recorded. Although they were given the option of not participating, it should be noted that no student objected to participating in the study.

3.3 Methodology

Owing to the nature of the research problem and research questions, three different tools were used to gather data, namely, classroom (teaching) observations (video recorded), interviews (audio recorded) and text analysis of summative assessments.

According to Bertram & Christainsen (2014) observations occur when a researcher observes, first hand, what actually transpires in learning environments. This enables the researcher to verify the context and location of the research. These observations were recorded, transcribed (where appropriate) and subsequently coded, see appendix 7.1. The observations were not guided by a pre-determined, pre-tested, standardised, structured observation schedule. The reason for not relying on a standardised observation schedule was to prevent excluding any aspects of the classroom environment. An example of the

drawbacks of structured observations was highlighted in a study by Mbano (2002) who used a structured observation tool and in this way opted not to include other aspects of the classroom environment and focussed on cognitive verbal interactions between the teacher and students and between the students themselves. However, despite attempts to record everything and to be non-selective, Bertram & Christiansen (2014) have pointed out that "any observation is selective".

The teaching and learning philosophies of lecturers were an important aspect of this study and so it was beneficial to engage with each lecturer face-to-face in order to ascertain their philosophies of scientific knowledge and curriculum. Therefore, all lecturers were interviewed post observation. This was done with the aid of audio recordings that were later transcribed verbatim for subsequent coding (appendix 7.3). The interviews enabled a first-hand account of the lecturers' philosophies (as they "see" themselves) and assisted in the validation of the observation data. Furthermore, using a semi-structured interview with open-ended questions (see appendix 7.2) permitted probed, clarified and detailed responses that supported the collection of relevant data (McMillan & Schumacher, 2006) in order to address the research questions.

A pilot interview was done to check that the questions were appropriate, after which some minor changes were made to the original interview questions. Opie (2004) stated that semi-structured interviews permit "depth of feeling to be ascertained by providing opportunities to probe and expand the interviewee's response" (p.118). This is not to overlook the dangers of interviews such as interviewees not being completely honest or perhaps holding back in their responses (Walford, 2001). However, aligning the interview data with observation data has enabled me to check if lecturers "practice what they preach". Furthermore, I was well acquainted with the participants and the learning institution at which they were working during the time of the study. I feel that this positively contributed to the interviewing process since our familiar relationships put the participants at ease and they appeared to be more open with respect to answering the questions and sharing their thoughts honestly. Although interviews are sometimes considered nothing more than a questionnaire with human interaction (McMillan & Schumacher, 2006), it was decided to rather interview the participants and not simply ask them to fill in a questionnaire post observation for a number of reasons, all of which relate back to the ability of the data to

better enable me to address my research problem and questions. Amongst some of the reasons are the following: Interview responses can be probed clarified and detailed. During a face-to-face interview verbal and non-verbal responses and behaviours can be observed and recorded and these can provide the interviewer opportunities to motivate the responses of the interviewee in order to gain a better data set (McMillan & Schumacher, 2006) although this is to be done with caution so that bias is not introduced into the data (Walford, 2001). However, Opie (2004) points out that audio(tape) recording the interviews may "provide a means to check against bias or misinterpretation" (p.123) and therefore, it was felt that by recording the interviews, an attempt was made to safeguard against bias.

It is known that assessment drives learning (Wormald *et al*., 2009). So in order to complete the triangulation of the data in this study, and in order to validate the findings, written evidence of assessments, that is, past test papers that had been set by the participating lecturers and that had been used in the various courses, were analysed using a taxonomic tool developed for analysis of life sciences assessments (Appendix 7.5).

3.4 Data collection and analysis

3.4.1 Observation data

The Constructivist Learning Environment Survey (CLES) that permits the monitoring of the development of constructivist approaches to teaching and deals with constrictions in the development of constructivist classroom environments was selected to code the classroom observations (Figure 2). This tool was originally designed by Taylor & Fraser (1991) and adapted by Taylor *et al*. (1994). This tool has been validated and was therefore considered to be a reliable tool. The logic behind using CLES was that lecturers ought to be adopting constructivist teaching practices (as per the need to shift towards a cognitive perspective) and this tool would enable one to gauge, to what extent, if any, the lecturers were or were not doing so.

The CLES tool was adapted for use in this study. Briefly, the observation recordings were played back and each time the indicators were witnessed these were transcribed verbatim (appendix 7.1) and the corresponding CLES scales recorded as a frequency count over the lecture period (see results section).

CLES SCALES	INDICATOR DESCRIPTION
Personal Relevance	The lecturer take into account the students prior learning of, amongst others, laws, rules and formula. The lecturer makes use of the students daily experiences as a meaningful context for the development of the students scientific knowledge. The lecturer connects university science to the students out-of-university life.
Student Negotiation	The lecturer encourages student-student negotiations and provides opportunities for the students to question, explain and justify their newly developing ideas to their fellow students and the lecturer too. The lecturer also provides opportunities for the students to critically assess the feasibility and validity of their own ideas.
Shared Control	The lecturer provides opportunities for the students to develop as autonomous learners . Students are encouraged to share control of the learning environment. This includes voicing their opinion on learning goals, designing and managing their learning activities and determining and applying assessment criteria.
Critical Voice	The lecturer provides a social environment where students feel comfortable questioning the lecturers teaching plans and methods, in a real and mutually beneficial way. Students are made to feel comfortable to express how they feel about their learning experiences and share what may enhance or impede their learning.
Uncertainty	The lecturer provides examples and experiences for students of the natural uncertainty and limitations of scientific knowledge. Students are provided with experiences that illustrate that scientific knowledge arises from exploring theories through human experiences and values that are constantly evolving as they are culturally and socially determined.

Figure 2: Constructivist Learning Environment Survey (CLES)

The CLES scales and indicator descriptions used to code the classroom observation recordings (Taylor & Fraser, 1991, Taylor *et al*., 1994, Taylor *et al*., 1997)

In some cases, all examples provided in appendix 7.1, more than one code was assigned to a single observation. The frequency of constructivist teaching in the learning environment was then used to interpret the teaching approaches of each lecturer by gauging to what extent, if any, teaching time was dedicated to constructivist, student-centred teaching. The transcriptions and coding were validated by an external researcher. It should be noted that student talk was often inaudible but it is not known to what extent this may have or have not affected or skewed the results. However, it can be stated that the study focussed on the lecturer's response to the student talk and not the student talk itself. Therefore, it was assumed that the influence on the data would negligible.

3.4.2 Interview data

After considering a number of interview coding tools designed to analyse teachers' epistemological beliefs published by an array of authors, the coding tool selected to analyse the interview data was taken from Luft & Roerig (2007). The reason this tool was selected is

two-fold. Firstly, this tool was reviewed and refined repeatedly to produce maps that could be used to describe and define numerous beliefs held by science teachers and was hence found to be valid and reliable. Secondly, while the semi-structured interview questions designed by Luft & Roerig (2007) were not exactly the same in this study, a considerable amount of overlap or similarity was observed between their interview questions and the questions in this study. On this point, Luft & Roerig (2007) designed seven interview questions as follows:

1. How do you maximise student learning in your classroom? (Marker 1)
2. How do you describe your role as a teacher? (Marker 2)
3. How do you know when your students understand? (Marker 3)
4. In the school setting, how do you decide what to teach and what not to teach? (Marker 4)
5. How do you decide when to move on to a new topic in your classroom?
6. How do your students learn science bests? (Marker 5)
7. How do you know when learning is occurring in your classroom? (Marker 6)

Questions numbered 1,2,3,4,6 and 7 overlapped with the interview questions in this study and where therefore used as markers for the lecturers beliefs.

The corresponding questions from this study, were as follows (using the question number from the interview):

15. What is it that you do that enables students to know what you want them to know? (Marker 1)
21. How would you describe the way in which you teach? i.e. describe your role in the lecture theatre (Marker 2)
36. How do you know that your students understand what is taught? (Marker 3)
28-30. How do you approach your curriculum design? Are there any external factors that affect the way in which you design your curriculum? e.g. is it imposed on you? How do you think assessment fits into your curriculum? (Marker 4)

16,22 &23. How do you think students learn best? How would you describe the way in which you think about teaching and the way in which teaching at a tertiary

level in general should happen? What would you consider the best approach to teaching and learning? (Marker 5)

Two important questions that formed part of this study's interview questions but were not covered by Luft & Roerig (2007) were:

a. How would you define knowledge? What about scientific knowledge? Is there a difference? (Question 12 of the interview, Marker 6)
b. What do you consider the primary aim of assessment? What do you consider important in an assessment? (Questions 31 and 32 of the interview, Marker 7)

These questions were added in as markers of lecturer beliefs. Two new maps based on those of Luft & Roerig were constructed, one for beliefs on scientific knowledge and one for beliefs on assessment. This process consisted of establishing definitions for each of the beliefs of traditional, instructive, transitional, responsive and reform-based codes. One set for beliefs about knowledge and one set for beliefs about assessment. This was followed by developing typical responses for each of the questions for each of the codes.

By way of example (see figures in chapter 3 and appendix 7.2.), the marker (interview question(s)) for assessment asked: "What do you consider the primary aim of assessment? What do you consider important in an assessment?" were used to categorise the lecturers' beliefs as, for instance, traditional. Traditional beliefs about assessment are that student learning is objectively measured through scored tests and results. Typical answers to this question could include things like "I use multiple choice questions". If these were the codes and responses of the lecturer for this question, the lecturer was then coded as traditional in their beliefs towards assessment. This was done in a similar fashion for the other belief categories and questions (markers).

Depending on the response of the lecturer to each marker (interview question(s)), their beliefs were coded as traditional, instructive, transitional, responsive or reform-based as per the maps designed by Luft & Roerig (1997) (Figures 3A-E) and Legg-E'Silva & Brenner (unpublished) (Figures 3F-G). It is important to note that the terminology teacher-centred

Figure 3A and 3B: Interview coding maps for markers 1 and 2

Maps for coding teacher's epistemological beliefs taken from Luft & Roerig (1997).

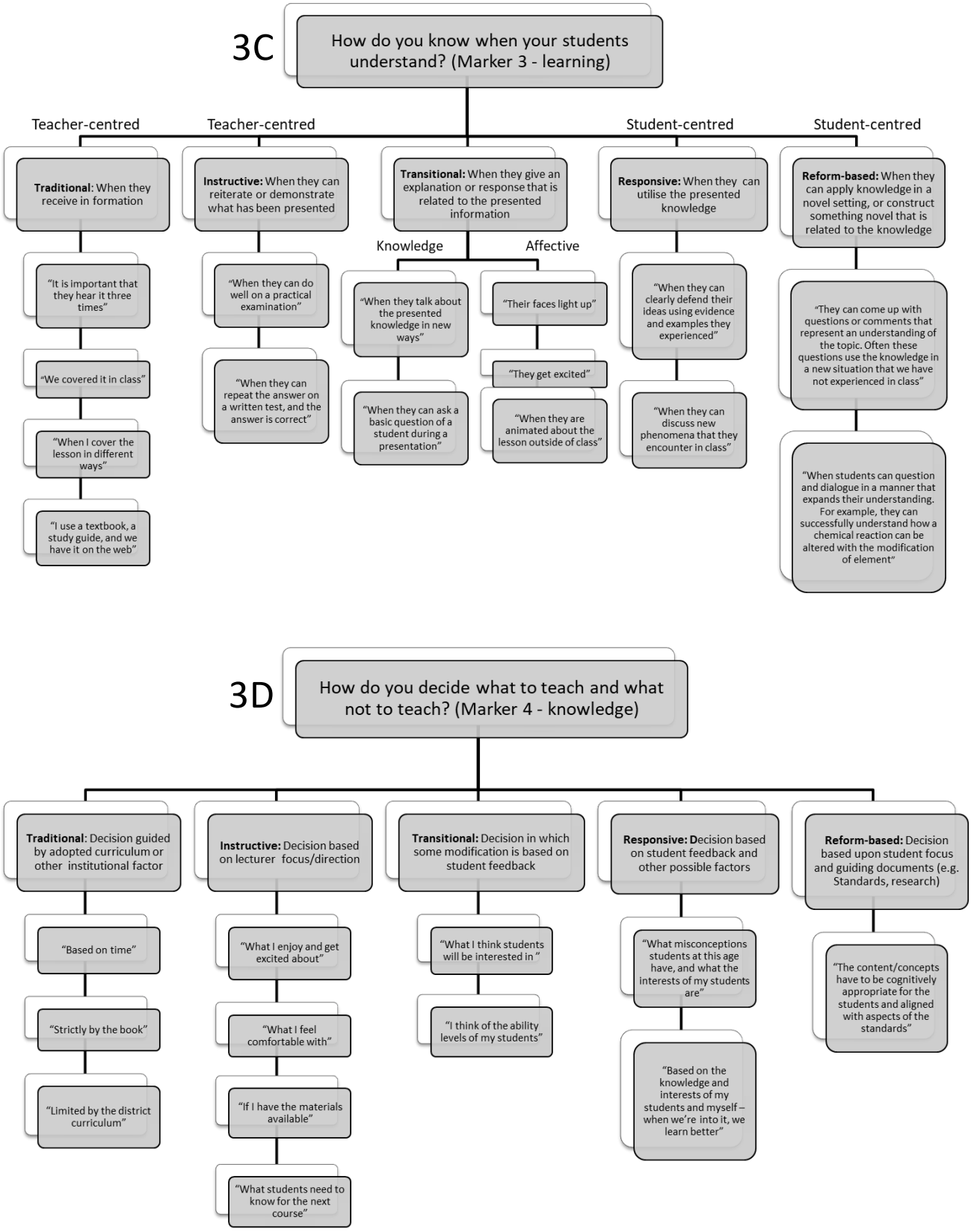
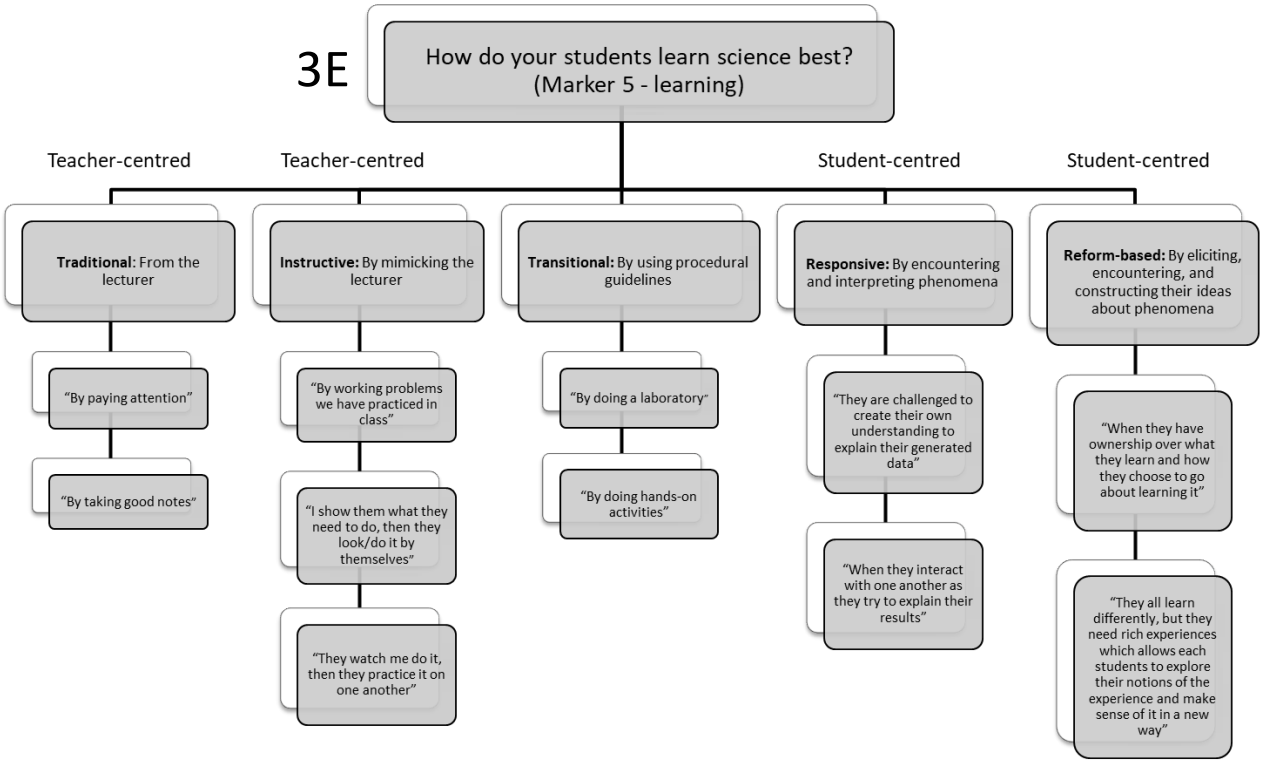


Figure 3C and 3D: Interview coding maps for markers 3 and 4

Maps for coding teacher's epistemological beliefs taken from Luft & Roerig (1997).



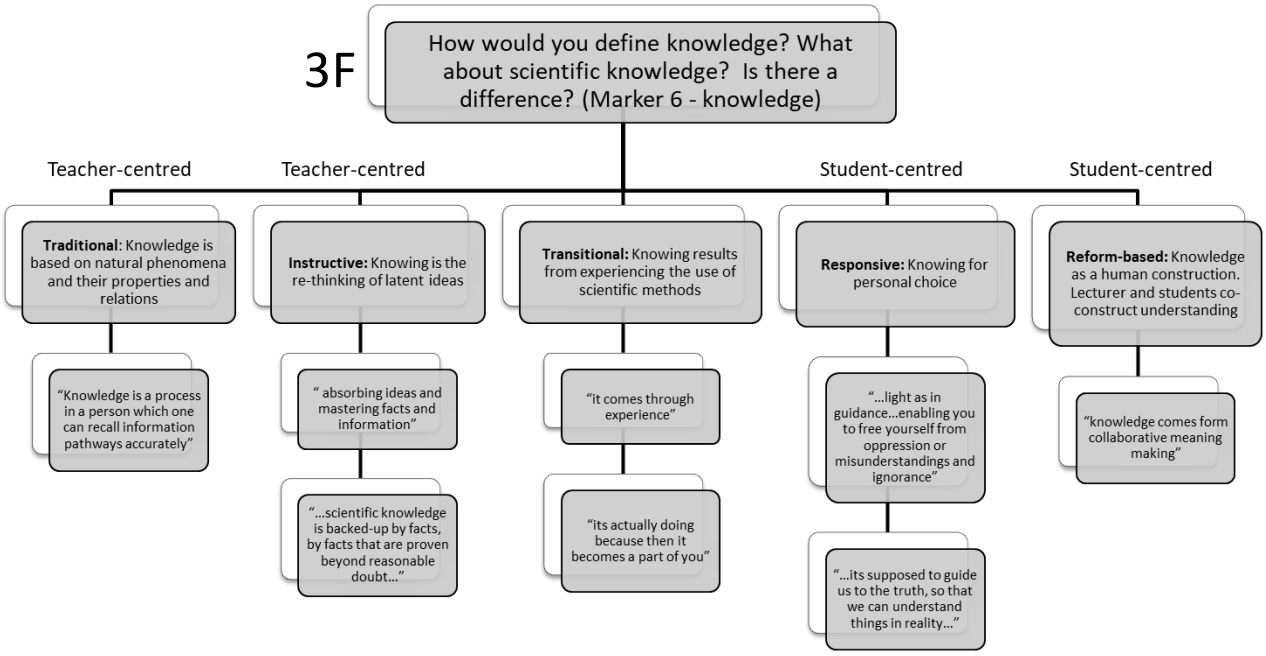


Figure 3E and 3F: Interview coding maps for markers 5 and 6

Maps for coding teacher's epistemological beliefs taken from Luft & Roerig (1997) and Legg-E'Silva & Brenner (unpublished).

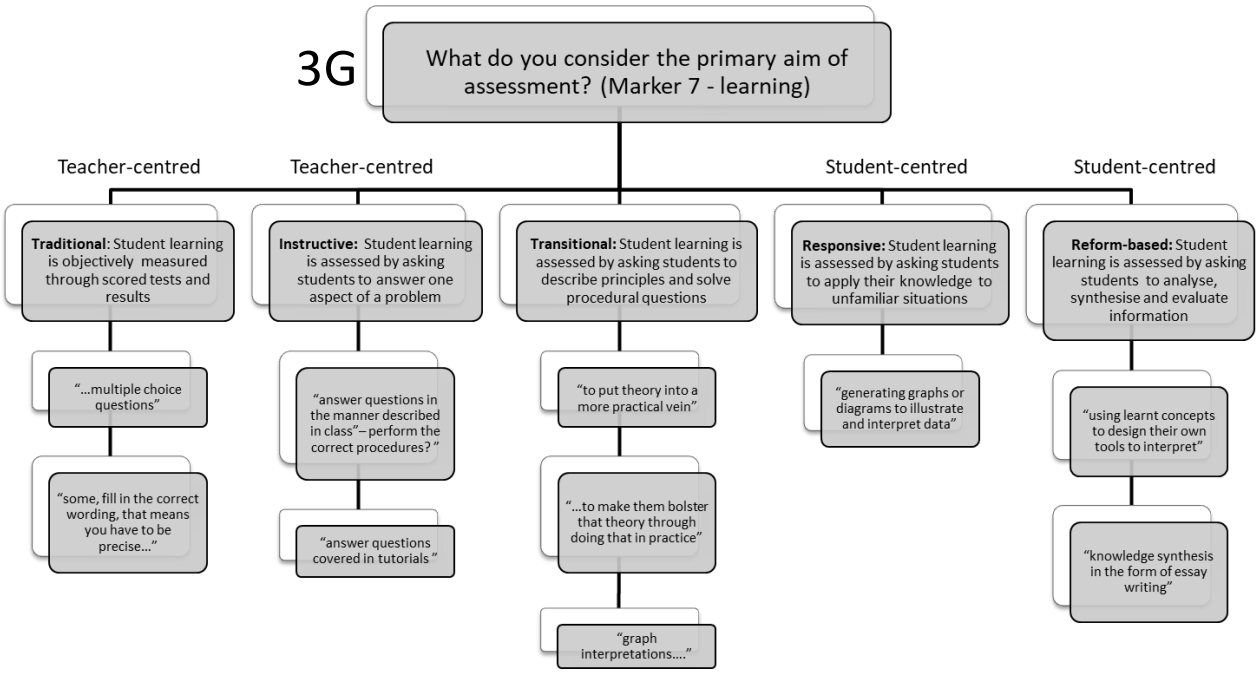


Figure 3G: Interview coding maps for marker 7

Maps for coding teacher's epistemological beliefs taken from Legg-E'Silva & Brenner (unpublished).

was used and replaced the more traditional terminology of subject-centred teaching since lecturers (teachers) were at the centre of this study. Once again, the data were expressed on frequency graphs for ease of interpretation and alignment (see results section). Also, the transcriptions and coding were again validated by an external researcher.

3.4.3 Text analysis data

The analysis tool or rather classification instrument, developed by Brenner *et al*. (2010) that was designed to make lecturers aware of their assessment practices was selected to analyse the test papers. This instrument makes use of a modified version of Bloom's Taxonomy and a framework modified from Anderson (2005) (Table 2). The rationalisation of the modification is well explained by Brenner *et al*. (2010) and will not be dealt with here.

Table 2: Framework used for analysis of class test questions

The Cognitive Process Dimension				
The Knowledge Dimension	Remember (Level 1)	Understand (Level 2)	Apply (Level 3)	Higher Abilities (Level 4)
Factual (F)				
Conceptual (C)				
Procedural (P)				

Taken from Brenner *et al*., 2010.

A brief explanation of the instrument is as follows: The cognitive process dimension distinguishes among questions that can be answered by the simple recollection of knowledge (level 1), questions that involve the understanding of concepts (level 2), questions that necessitate the application of knowledge to unknown situations (level 3) and questions that require investigation, synthesis and assessment (level 4) (Brenner *et al*., 2010). This instrument also classifies questions based on the knowledge dimension as factual (F), conceptual (C) and procedural (P) (Shavelson, 2002 in Brenner *et al*., 2010) as taken from Brenner *et al*. (2010. p.37):

"*Factual* questions refer to those where the knowledge can be learned, understood and applied without reference to the underpinning concepts". "*Conceptual* questions require a deeper knowledge of the underlying concepts" but since these questions can "be answered from recall alone, it is possible to classify a question as conceptual level 1 (C1)". "*Procedural* questions would include plotting of graphs, drawing of diagrams and calculations". "These operations might be completed by simple recall of previous examples (level 1), require understanding (level 2), require application (level 3) or might require synthesis and/or derivations that would put them at level 4".

Therefore, using this instrument, the questions in each test paper were categorised (see appendix 7.5) according to the framework in Table 2. As with the observation and interview

data, the text analyses data were expressed on frequency graphs for ease of interpretation and alignment (see results section). The coding was validated by four external researchers.

The data from the three different methodological tools were validated by alignment and triangulation and then used for correlations of the data.

3.5 Reliability and Validity

In order to ensure that the data gathered were reliable and valid, a number of steps were taken before, during and after data acquisition, as listed below:

1. Ethical clearance for the study was obtained from the Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate of the participating tertiary learning institution (Protocol number 2015ECE012). This entailed obtaining informed consent from all participating bodies, that is, the Head of the School of the participating Molecular Biosciences division as well as the lecturers and their students. Other ethical issues addressed were those of confidentiality and anonymity.
2. The sample used in the study was selected as described previously.
3. The researcher attempted to be as unobtrusive as possible during the observations by being seated at the back of the classroom, dressed in casual clothing (like the students) and entering the classroom alongside the students. A small video camera was used so that the recording of the observation is not overly obvious.
4. Transcription and coding of the observation, interview and test analysis data was inter-reliability checked by external researchers with scientific backgrounds.
5. Pilot interviews were conducted in order to check that the order of the questions was correct and logical, that the structure was correct and that there were no ambiguous questions or questions that may have offended or confused the interviewee.
6. Previously developed, used, tested and validated tools (described previously) were used to analyse the observation, interview and past test papers data.

3.6 Ethical considerations

In order to ensure that no one was harmed, treated unfairly or exploited during this study, ethical clearance was obtained by the Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate of the University of the Witwatersrand.

Letters were written to the Head of the School of Molecular and Cell Biology, the lecturers and the students informing them of the title of the study, the aim of the study as well as provided information about the researcher. The letters explained that participation was voluntary and that if they agreed to participate they could withdraw from the study at any point in time. The letters also stated that by participating, or declining to participate, they would not be advantaged or disadvantaged in any way. The letter to the Head of the School asked for permission to conduct the study in the school of Molecular and Cell Biology and also asked for permission for the lecturers and students within the school to be involved in the study.

Furthermore, the lecturers and students were assured that all the data that were gathered whether written, verbal or otherwise would be treated in a strictly confidential way and that their original names would not be used in the study or any publications that may result from the study. Lecturers and students were also informed that their information would only be used for the purpose of the study and for the improvement of learning and teaching science. A letter of consent accompanied the study information letter which lecturers and students were requested to sign should they agree to participate.

CHAPTER 4

RESULTS

The results of the triangulated data are summarised as shown in figures 4-7. Please note that the scales of the Y axes differ between lecturers. The graphs labelled A, B and C are representative of the observation, interview and text analysis data, respectively. The colour coding of the figures can be explained as follows:

- Green is representative of the constructivist philosophy of knowledge that is - associated with student-centred teaching programs (responsive or reform based),

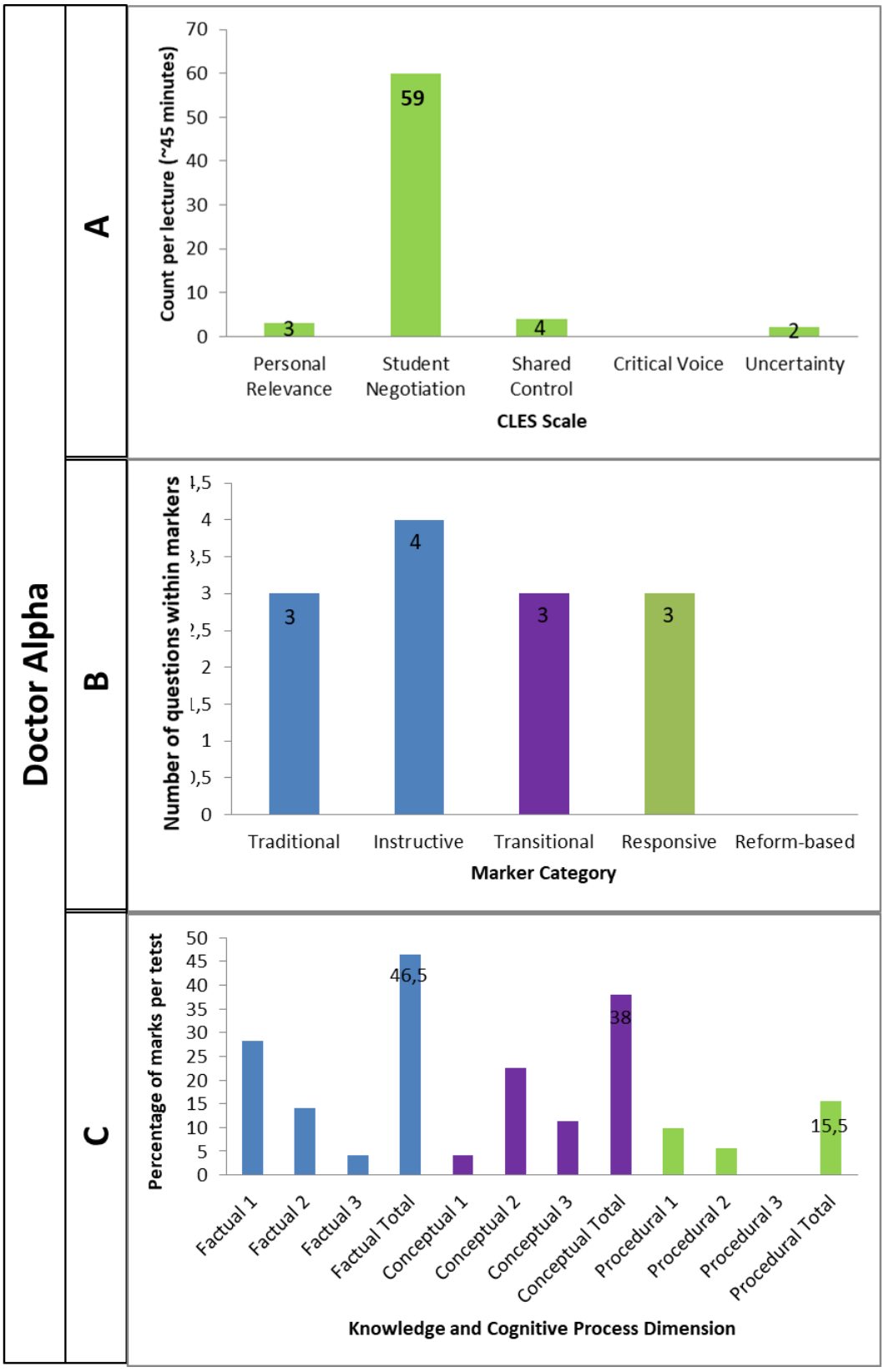


Figure 4: Triangulate data for Doctor Alpha

A, B and C represent summaries of the observation, interview and text analysis data, respectively.

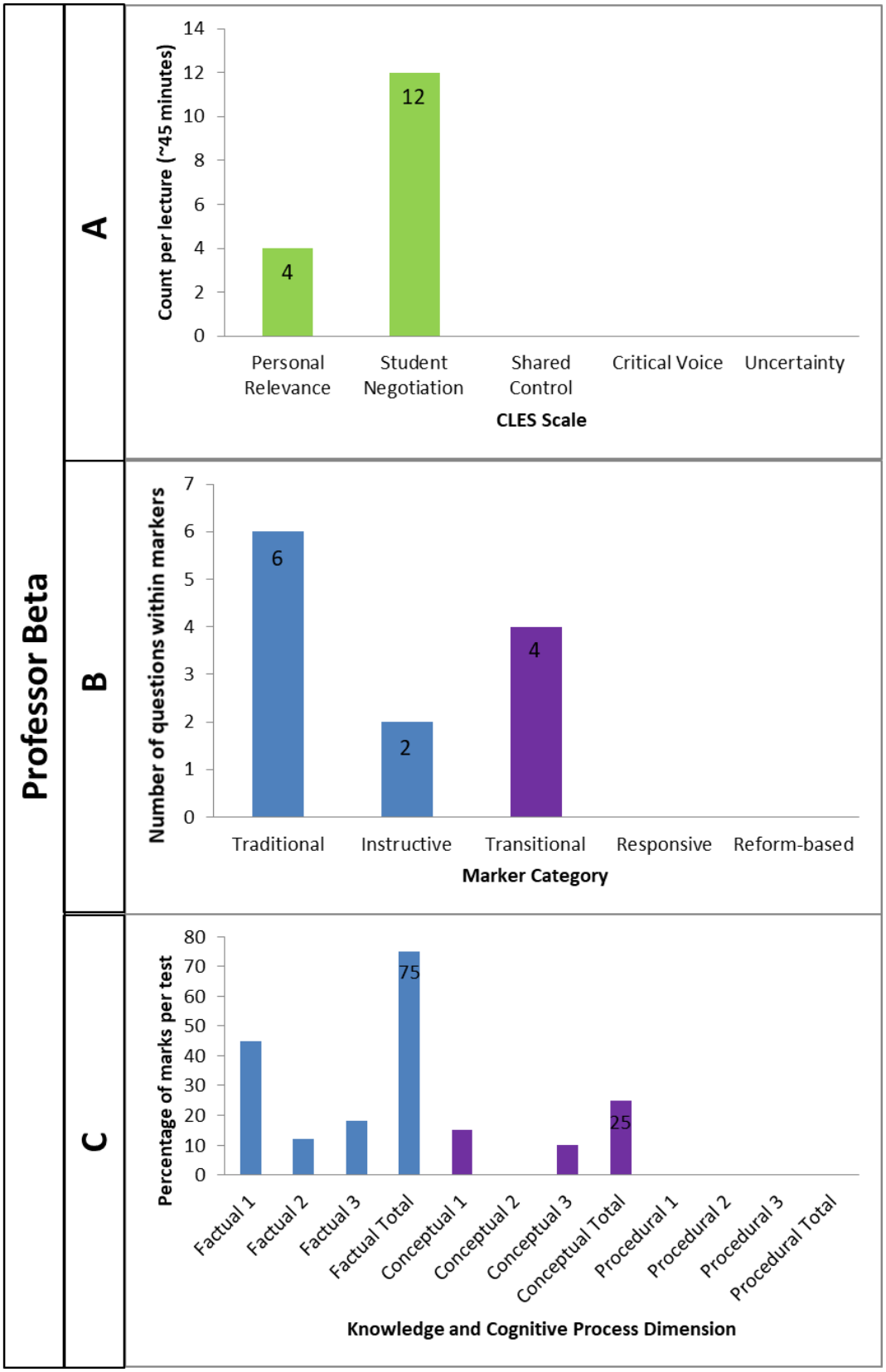


Figure 5: Triangulate data for Professor Beta

A, B and C represent summaries of the observation, interview and text analysis data, respectively.

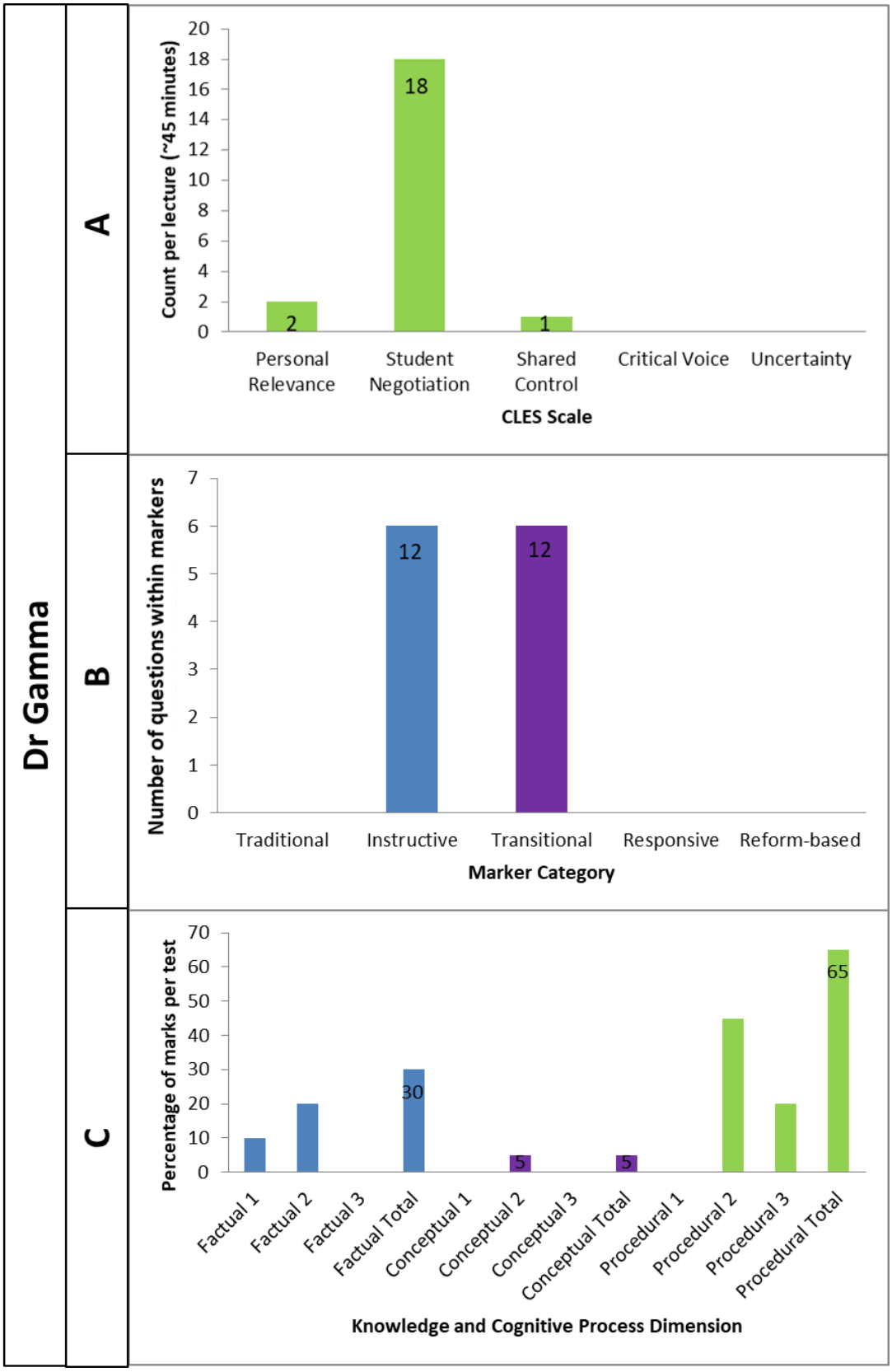


Figure 6: Triangulated data for Doctor Gamma

A, B and C represent summaries of the observation, interview and text analysis data, respectively.

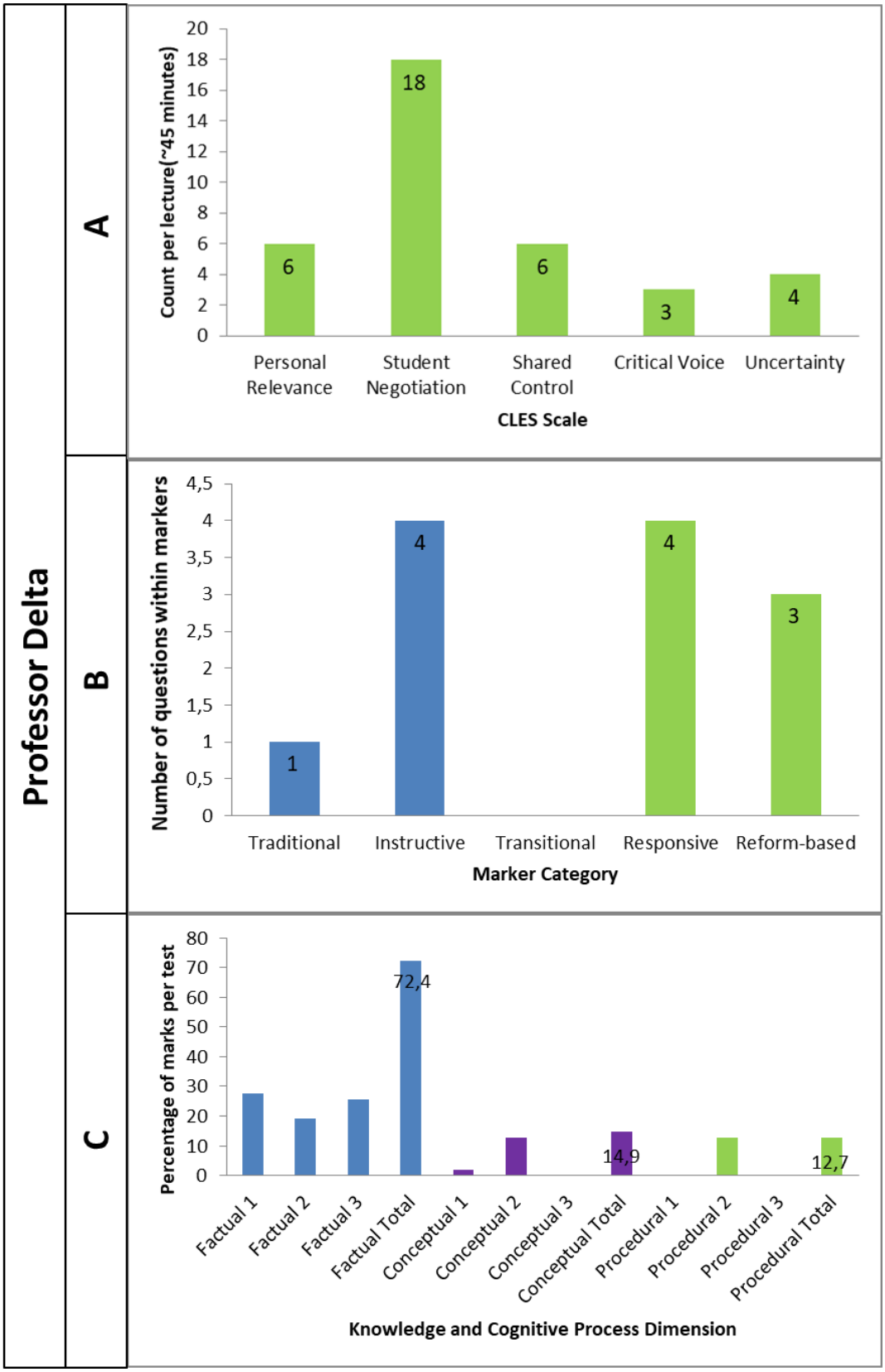


Figure 7: Triangulated data for Professor Delta

A, B and C represent summaries of the observation, interview and text analysis data, respectively.

associated with student-centred teaching programs (responsive or reform based), curricula as intended for student learning and experience and assessment questions that target higher level cognitive and knowledge domains concordant with deep teaching approaches

- Blue is representative of the positivist philosophy of knowledge that is associated with teacher-centred or subject-centred teaching programs (traditional or instructive), curricula as product or program and assessment questions that target lower level cognitive and knowledge domains concordant with surface teaching approaches.
- Purple is representative of a knowledge philosophy, learning perspective, curriculum design and program and assessment that are transitional and falls somewhere between those described above and represented by green and blue.

Furthermore, each figure is representative of the results for each one of the participating lecturers and will be described as such. It should be noted that for the observation data, lecturers were given the benefit of the doubt and each time they posed a question to the class or the students posed a question to the lecturer, it was coded as student negotiation. This was done since it was viewed as an opportunity, given by the lecturer, for students to voice their opinions and views of newly developing ideas or contradictions thereof. Lastly, while the coding instrument for the text analysis included a fourth level of cognitive process, none of the researchers coded any of the test questions as such, and so level four was excluded from the results.

4.1 Dr Alpha

4.1.1 Practices

Figure 4A shows that Dr Alpha predominantly used student negotiations (student voice) as her primary constructivist teaching tool (for examples see appendix 7.1.1). Lecturer talk time was recorded to be roughly 30 minutes out of a total class time of about 47 minutes, that is, 36% of the class time was dedicated to the student voice. On four occasions she permitted the students to take control of their learning environment, with one occasion lasting almost 10 minutes when students were allowed manage their learning activity and simply engage with their fellow students, question one another's views and their concerns. The lecturer also attempted to teach the material in such a way as to make it personally

relevant to the students. The following describes one such occasion (taken from appendix 7.1.1)

> After describing the conditions that are optimum for protein storage the lecturer puts the entire concept in easy to comprehend terms by stating that "we are trying to make the new home for our protein that was ripped out of its home and put in a new home, as comfortable as possible. So we keep pH, temperature and conditions as comfortable as possible for our protein so that it keeps stable and it doesn't deteriorate or aggregate it remains in solution and we can work with it"

Many university students have to leave home and stay in a new location in order to attend university. This example provided by the lecturer enables students to relate their own lives to that of the protein and in this way may comprehend the course material in an easier way.

Whilst descriptors for critical voice scales were not observed during Dr Alpha's teaching, uncertainty (examples provided by the lecturer of the limitations of science) occurred twice during the classroom interaction (see appendix 7.1.1). An example of this was when the lecturer provided an example of an unpredictable and undesirable experimental result i.e. insoluble protein, and proposed a scenario where the protein is insoluble and undesirable because it is bound to a membrane. This scale can be considered to be a very important indicator of constructivism, as the uncertainty and ever changing nature of scientific knowledge are at the forefront of constructivist epistemologies.

The observation data revealed that Dr Alpha made use of all but one scale of constructivism in her teaching, namely critical voice where students are provided opportunities to critically assess the practicality of their own ideas.

4.1.2 Beliefs

While the interview data (Figure 4B) reveal a tendency for Dr Alpha to have beliefs that are based on positivism, that is, teacher centred beliefs, there is also evidence that she is undergoing a shift towards student-centred beliefs that are concordant with constructivist philosophies of teaching and learning. This implies a dissonance between her beliefs and practices but is complicated by the apparent tendency to be undergoing a transition from teacher-centred to student-centred beliefs. This hypothesis is confirmed by the following words of Dr Alpha during her interview:

"…and now as I am shifting more towards trying to facilitate them…"

This response is indicative of a change she is consciously making to alter her approach towards the students.

Furthermore the data in Figure 4B reveal a mix of teacher-centred and student-centred responses. Seven responses indicated teacher-centred beliefs, three fell within transitional beliefs and three within the responsive category, which includes student-centred beliefs.

Consequently, it was concluded that Dr Alpha is transitional in her beliefs.

4.1.3 Assessment

The question types used by Dr Alpha to assess her students were split; 46.5% of the marks came from questions that were aimed at assessing students' factual knowledge and 53.5% from questions aimed at conceptual and procedural knowledge (figure 4C). There is a mix of questions ranging from factual level one to procedural level two. It is evident from the test paper and the percentage of questions aimed at conceptual (all levels, with level two dominating) and procedural (levels one and two) knowledge - which imply that the lecturer is trying to aim questioning at higher knowledge and cognitive domains as per her beliefs, as stated in her interview:

> "…I try to test them on application and on understanding somehow incorporating that knowledge that they have read through so that it's beyond just the memorising".

This fits in well with the observed practice and beliefs of the lecturer in that she is categorised as transitional. It is also interesting to note that the majority of the factual questions she set in her students assessments are level 1, whereas the conceptual questions are level 2 dominated, an example of this being:

> A protein has a molecular mass of 50 kDa when measured by gel filtration. When subjected to SDS-PAGE under non reducing conditions, two bands are seen with molecular masses of 30 kDa and 20 kDa. When subjected to SDS-PAGE in the presence of DTT, 2 bands are seen: one at 20 KDa, and 1 at 15 kDa. Determine the subunit composition of the protein

In this question students need to have conceptual knowledge of the different types of SDS-PAGE and how these alter proteins and influence how they would appear on a gel. So, a higher level of cognitive understanding is required.

Other interesting results are that the procedural questions make up the lowest percentage of questions and Level 4 (higher ability cognitive processes) questions were not used in the assessment.

Data triangulation for Dr Alpha provides assists one to conclude that she is undergoing a transition from a teacher-centred to a student-centred way of teaching and assessing her students.

4.2 Professor Beta

4.2.1 Practices

Figure 5A shows that as with Dr Alpha, but to a far lesser degree, Professor Beta predominantly used student negotiations (student voice) as his primary constructivist teaching tool (for examples see appendix 7.1.2). However, only 6% of the class time was dedicated to the student voice. This occurred 12 times during the lecture and can be described as examples of question, answer, rebuttal or question, answer, acceptance type interactions, as illustrated from the observation data:

> The lecturer asks the class "what is epidemiology?"
>
> A student answers that it's the study of causes and effect of diseases.
>
> The lecturer says this is not the case and provides a definition.

On four occasions Professor Beta incorporated personally relevant teaching approaches to the material covered in class. An interesting approach to this was taken during a lecture on HIV and AIDS in the form of newspaper articles from South African newspapers, see below example from appendix 7.1.2:

> The lecturer uses a newspaper article that reports that "HIV/AIDS claiming fewer lives report reveals" from 2010 and then shows one newspaper clip reporting that HIV was on the increase in 2012. The lecturer says it is because people are not using condoms and then chats about the students' night lives. He concludes by appealing to them to use condoms.

This provided students with an opportunity to see the relevance of what they learn in class, how this affects society and how it applies to their everyday lives.

It is noteworthy that the descriptors of the shared control, critical voice and uncertainty scales were not observed during Professor Beta's teaching.

The observation data revealed that Professor Beta made use of only two of the scales of constructivism in his teaching. It can be concluded that the teaching practices of Professor Beta appear are teacher-centred and do not seem to be influenced by constructivist learning theories but rather those of positivism and its associated curriculum design, program and teaching approach.

4.2.2 Beliefs

Eight responses from the interview data indicated teacher-centred beliefs (traditional and instructive), four fell within transitional beliefs and none of Professor Beta's responses and hence beliefs were found to be student-centred (responsive and reform-based) (figure 5B). Therefore, the interview data is concordant with the observation data (figure 5A). Professor Beta was discovered to have beliefs based on positivist philosophies with teacher-centred beliefs and practices. This can be highlighted by looking at some responses in the interview regarding knowledge and learning:

> "Knowledge is a process in a person which can recall information pathways accurately"
>
> "Scientific knowledge is to recall processes…"
>
> "well first of all it memory I think, they hear something and they can memorise it"
>
> and assessment:
>
> "multiple choice questions some questions which has only to fill in the right wording so that means you have no chance you have to be precise and just put this wording in…"

These responses all fell within teacher-centred beliefs codes, making the beliefs of Professor Beta very clear.

It can be said that Professor Betas' beliefs about knowledge, learning and assessment are rooted in positivism.

4.2.3 Assessment

Professor Beta remained traditional when it came to the manner in which he chose to assess his students. 75% of question marks were aimed at assessing students' factual knowledge and 23% were aimed at conceptual knowledge. No procedural knowledge questions were incorporated into his assessments and neither were level 4 cognitive process questions. It is surprising that at a second year course level, factual questions of level one dominated his assessment, one such example is provided below:

> Different influenza virus strains are described by antigenicity of HA and NA. Give the full names of HA and NA and explain their function in the life cycle of influenza.

Students do not need to understand what HA and NA are in order to simply recall their names; they just have to remember them. Furthermore, their functions can easily be remembered without necessarily understanding how, why and where they function and the application of this function.

So in conclusion, as with the lecturer's practices and beliefs, he is also traditional in his approach to assessment.

Data triangulation for Professor Beta allows one to conclude that he is traditional and instructive in his beliefs and practices as seen by his teacher-centred approach to teaching and assessment.

4.3 Dr Gamma

4.3.1 Practices

Figure 6A shows that Dr Gamma also predominantly used student negotiations (student voice) as his primary constructivist teaching tool (for examples see appendix 7.1.3). Lecturer talk time occurred 90.5% of the class time with very little to no student voice. The lecturer was observed to share control of the classroom on one occasion and also included ways to make the teaching material personally relevant to the students on two occasions, one such example being (appendix 7.1.3):

> The lecturer is discussing column chromatography and provides an example of how this technique is used in any Discovery labs and the labs that analyse mixtures or in labs where you monitor the acidity of water as used by the mines

This relates the course material to its applications in our everyday lives, where we use these techniques, such as chromatography and what they enable society to do.

It should however be noted that there were no descriptors of critical voice or uncertainty scales observed for Dr Gamma. The observation data showed that Dr Gamma made use of three scales of constructivism in his teaching, he did so twenty one times in a forty-two minute lecture. This may appear to have been done in a limited manner but is still recognised as the incorporation of constructivist approaches to his teaching.

For this reason it was deduced from the observation data that Dr Gamma may be experiencing a transition from positivist to constructivist teaching.

4.3.2 Beliefs

The interview data (Figure 3B) for Dr Gamma shows a split in his beliefs between instructional and transitional. This split leads one to believe that Dr Gamma is in a transitional beliefs state. Take for instance some of his responses to the interview questions:

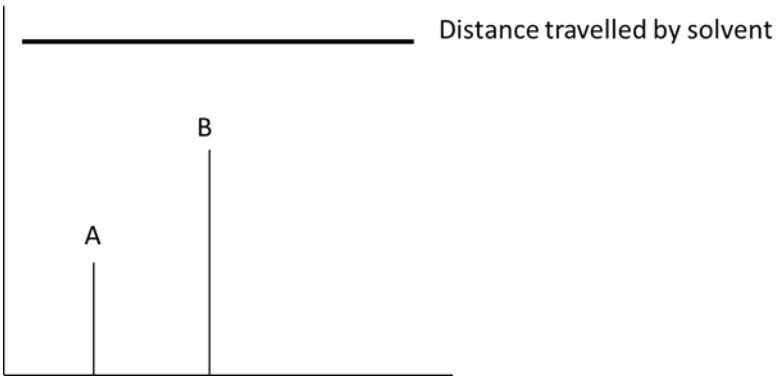
> "I try to make them think beyond what I teach" - transitional
>
> "the only way right now to know if the students understood is through the test and exam…" - instructional

Therefore, it was decided that there is consonance between the observed practices and beliefs of the lecturer as both appear to be transitional.

4.3.3 Assessment

Dr Gamma principally used questions that assessed procedural cognitive processes in his assessments. 65% of question marks were procedural with procedural level 2 dominating, 5% conceptual and 30% factual (figure 6B). An example of a level 2 procedural question is provided below:

> Use the thin layer chromatograph shown below to calculate the retention factors (Rf values) of A and B



Students are required to measure the length of line A and B and the distance travelled by the solvent from the x axis, this can be done with little to no understanding of how and why analytes travel through a TLC plate. However, it was coded as P2 as some understanding of how this graph works is required and the process of reading and interpreting graphs is considered procedural knowledge.

So to conclude, the data triangulation for Dr Gamma is the same as that for Dr Alpha, that is, he is undergoing a transition from a teacher-centred to a student-centred way of teaching and assessing his students.

4.4 Professor Delta

4.4.1 Practices

Just like Professor Delta's colleagues, student negotiations (student voice) were documented as his primary constructivist teaching tool (figure 7A), for examples see appendix 7.1.4). Although only 12.5% of the lecture time was dedicated to student voice, the constructivist teaching descriptors of all the constructivist scales were observed for Professor Beta (figure 7A). Furthermore, he was the only lecturer who was observed to include the critical voice CLES scale; one such interaction is highlighted below (taken from appendix 7.1.4) and includes an example of the uncertainty CLES scale:

> During a discussion on drugs the lecturer tells the students to go and read package inserts of drugs they are prescribed. They will learn about target sites and interferences but also the side effects.
>
> A students says she disagrees, she was reading medication package inserts, she can't recall which one though, it said the site of action is not known.

The lecturer says oh yes.

The student says you are taking medication and you don't know what it does.

The Lecturer says yes that is the other problem. So they obviously have this drug, they've tested in vitro (lab conditions) maybe even some cell culture and then it showed promise so what they did was put it into animal trials and it showed promise again and then into human trials. So they know this drug can treat this condition but the mechanism, how, what, why, when, who – all of those questions remain unknown.

Anecdotal evidence suggests that university students feel intimidated by their lecturers and are not comfortable posing questions to them, let alone disagreeing or arguing with them The fact that this has occurred three times in Professor Delta's lecture shows that he has provided a learning environment where his students clearly feel comfortable questioning what he teaches and an environment where they freely express their views. Additionally, the lecturer uses this opportunity to emphasise that there is uncertainty in science, scientists do not have all the answers, there are things we do not know but aspire to find out through questioning and exploration.

By utilising all the CLES scales on multiple occasions during his teaching, Professor Delta is considered to have teaching practices that are strongly influenced by constructivist philosophies and theories of teaching and learning and these are reflected by the associated teaching programs.

4.4.2 Beliefs

The interview data (figure 7B) for Professor Delta shows that his beliefs are dominated by student-centred beliefs even though he clearly maintains some teacher-centred beliefs. Nevertheless, he was the only lecturer to have responses that were considered reform based. Extracts of these responses are given below (see appendix 7.3.4):

When asked what he considered to be the primary aim of assessment and why assessment is important, he responded:

""to apply that knowledge to the understanding of a basic problem"

"apply it or answer a question outside what they have seen from just mere lecture examples…"

The observation and interview data (figures 7A and B) are well aligned and thus, Professor Delta was concluded to be student-centred in not only his practices but also his beliefs.

4.4.3 Assessment

The results for the assessment (figure 7C) set by Professor Delta are rather unexpected. It appears that traditional teacher-centred beliefs dictated his approach to assessment. His assessment mark allocation was 72.4% in favour of factual knowledge questions and only 27.6% conceptual and procedural. This would imply dissonance between his beliefs and practices versus his assessment approach. His classroom practices and beliefs infer that he is influenced by constructivist theories of teaching and learning, and that he is predominantly student centred in his beliefs and practices, yet level one factual knowledge questions led his assessments, examples below (appendix 7.4.4):

> The name “enzyme” was coined in 1878 by
>
> A.Emil Fischer
>
> B.Eduard Buchner
>
> C.James Sumner
>
> D.Moses Kunitz
>
> E.Fredrich Kühne
>
> _____ was the first enzyme to be crystallised demonstrating the protein nature of enzymes.
>
> A.Lysozyme
>
> B.Urease
>
> C.DNase
>
> D.RNase
>
> E.None of the above.

These questions can be answered by factual recall alone and there is no requirement for further or deeper comprehension. This type of questioning definitely contradicts his beliefs about assessment that were illustrated by way of example in section 4.4.2. and appendix 7.3.4.

Consequently the data triangulation for Professor Delta is not as straight forward as that for the other lecturers. Whiles the observation and interview data reveal a student-centred philosophy and approach, the text analysis data categorises the assessments of Professor Delta as traditional and teacher-centred.

CHAPTER 5

DISCUSSION

The aim of this study was to investigate whether individual lecturer's philosophies of scientific knowledge and the nature of science, are reflected in the way in which they teach, design curricula and set assessments in the Molecular Biosciences. Their philosophies of scientific knowledge and the nature of science are important because these lecturers are teaching and essentially training future scientists. Accordingly, these students need to learn to think, reason and approach problems as scientists do. This needs to be mirrored in the teaching and assessment approaches of lecturers since the views of students regarding the nature of science have been shown to be influenced by those of their lecturers. Lecturers consequently need to believe that science is ever changing and that scientific knowledge is not absolute; scientific knowledge is advanced through human enquiry and for this reason is subject to change. However, not only do lecturers need to acknowledge this view of scientific knowledge, they also need to put these beliefs into practice in their teaching, their curricula and the assessments they set. Only then will students be exposed to the true nature of science and learn to think and act as scientists.

University learning has its foundations in the concepts of adult learning and necessitates the support of learning through complex social situations that are rooted in sincerity and trust, learning from practice and affording opportunities for relationships and collaborations (Jogi *et al*., 2015). Also, the university setting is ever changing and ideas about where learning takes place have changed from being mainly classroom-based to comprise the co-curricular experience (Blakefield, 2013). With this change in ideas about learning comes an emphasis that students and their experiences can successfully contribute to the classroom dynamic and thus influence other's capacities to learn (Vygotsky, 1978; Flint, 2016). However, in order for these ideas of teaching and learning to become a reality at the university setting, lecturers will need to update, modify or change their pedagogical practices and this

necessitates a change in the beliefs of lecturers since beliefs play a vital role in classifying knowledge and information and they also have an important influence on behaviour (Ernest, 1991; Pajares, 1992). Tursucu *et al*. (2017) stated that a teacher's views (belief system about the nature of a subject) forms the building blocks of teachers' mental models of learning and teaching and the way in which teachers teach relates to their ideas of teaching, which in turn correlates to their ideas of learning (Trigwell & Prossner, 1996).

Since the Molecular Bioscience courses are taught by more than one lecturer, each with their own beliefs regarding the nature of science and scientific knowledge, it is not surprising that some students are receiving mixed messages about science and its practice in general. In order to investigate these mixed messages, the beliefs, practices and curricula designs and assessment approaches of four Molecular Biosciences lecturers were analysed. Interview data permitted the lecturers to share their inherent beliefs about the nature of science, scientific knowledge, curricula and assessment. This was followed by observations of their teaching that enabled one to gauge whether or not lecturers essentially practice what they believe. The data were triangulated by analysing assessments set by the individual lecturers.

The assessment analyses were a very important aspect of the study because, as mentioned previously, assessment drives learning (Wormald *et al*., 2009). There is no use believing in, and practising student-centred, constructivist science teaching and learning if you are not going to assess students in a corresponding way. This will ultimately contribute to mixed ideas about science and what is important in terms of how one becomes a scientist. If you are teaching students that science is not just a lot of facts to be learnt but then assessing them by asking them to recall facts, you are sending out the wrong message about science and scientists. Furthermore, if students are made to feel or come to know that surface level testing formats are utilised in assessments, this may inhibit or negatively impact their learning and allow them to resort to rote learning, memorisation and cramming. This is contradictory to what scientists need to do in their daily jobs, since they need to critically assess and analyse data, question and investigate and not merely recall facts.

The degree of data collection and triangulation of the methods was feasible as a result of the small sample population of 4 lecturers. As mentioned previously, the site for this

research was a tertiary academic institution with in excess of thousands of students and hundreds of staff members. Whilst it is recognised that this particular institutional context is appropriate to the data obtained, the results would not be generalizable to other tertiary academic institutions. However, the idea that lecturer's beliefs may impact learning can be generalised not only at a university level but at a school level too. Further limitations of the study included the small sample size, number of observations (and observers) and the use of only summative assessments. However, this approach supported the collection of detailed data and results that present a contextualised insight into the molecular biosciences department of this institution.

Additionally, my scientific and educational background stood me in good stead with regard to the comprehension of the content covered during the observations, the questions in the assessments and the preparation of the questions and interpretation of the responses during the interviews. Together with the relationships that I had established with the participants and my association with the tertiary learning institute, the observations, interviews and text analyses enabled the gathering of data that could be triangulated and that permitted the research questions to be appropriately addressed.

In this study, it was found that the lecturers had mixed views of the nature of science and scientific knowledge. These views were found to impact the curriculum, teaching and mode of assessment of each of the lecturers, except for Professor Delta when it came to assessment. His approach to assessment was completely different from his beliefs and practices. This highlights the disparity that students may experience in the Molecular Biosciences course since they may be taught one way, but they are assessed in another. So in the case of Professor Delta and more specifically with regard to his approach to assessment, there seems to be dissonance between his beliefs and practices. This aspect mirrors the findings of Yoon & Kim (2016) who found that there was no noteworthy relationship between beliefs about the nature of science and constructivist teaching. In contrast to Yoon & Kim (2016), but in agreement with the findings of this study for Professor Beta and Dr's Alpha and Gamma, Tsai (2002) and Kim & Yoon (2013) found that teachers' beliefs about the nature of science are closely associated to their beliefs about teaching science. In addition, they noted that this was more inclined to occur if teachers held naïve beliefs about both the nature of science and teaching science. A possible reason for the

disparity between the studies could be due to the research context, the study by Yoon & Kim (2016) was on pre-service teachers whereas the studies by Tsai (2002) and Kim & Yoon (2013) included in-service teachers who already had teaching experience.

The mixed views of the nature of science and scientific knowledge of the lecturers in this study and how these views affected the pedagogy, curriculum design and assessment approach (research sub-questions section 1.3) of the lecturers will be discussed in light of their educational backgrounds as it is felt that this could have played an important role in formulating their beliefs and practices.

5.1 Traditional view

Professor Beta was educated overseas and had 18 years of teaching experience (only a few of which had been in South Africa) and was therefore viewed as a senior lecturer. He was found to have deeply traditional or teacher-centred beliefs of the nature of science and scientific knowledge. Literature reveals that to alter senior teachers', such as Professor Beta's viewpoints, towards student-centred learning and away from traditional teacher-centred learning is a challenging and multifaceted process (Ertmer, 2005; Postareff *et al*., 2007). This can be explained by the findings of the study by Tillema (1997) that showed that teachers' beliefs are not easily changed especially when they are central to their thinking, reasoning and action. Professor Beta views scientists and scientific knowledge as being absolute, accurate and precise. He stated this repeatedly during his interview, and so it is apparent that this belief is deeply rooted within him. Maintaining traditional views of teaching and learning science, as well as, the nature of science, may also be due to a lecturer's own school science experience (Tsai, 2002; Shulman, 2005; Yoon & Kim, 2016). This was noted by Professor Beta during his interview, when asked about his lecturers, when he attended university:

> "Old fashioned. Sitting at their desk in class talking, little communication with class"
> "writing on the black board only and explaining, you just copy what they write on the board. I also did that in my first years on the lecturer level"

Professor Beta's views of the nature of science and knowledge can be described as naïve as they see scientific knowledge as the recollection of information pathways and facts

(interview data section 4.2.2). Teachers who have naïve beliefs about the nature of science are prone to having epistemologically consistent beliefs about teaching and learning and employ traditional teaching (Yoon & Kim, 2016), as is the case for Professor Beta.

This is reflected in his pedagogy or teaching program since he was also found to be traditional in his approach to teaching (observation data section 4.2.1). His apparent naïve beliefs consider scientific concepts as being transmittable; "to get knowledge transmitted to the students" (interview data appendix 7.3.2) and are associated with transmission or traditional teaching (Yoon & Kim, 2016). Professor Beta does nevertheless indicate confidence in his teaching ability. He has based this on student feedback (interview data, not shown) and for this reason he probably has not felt a need to alter his approach.

It is not surprising that student feedback on Professor Beta would be favourable given that he sees himself as an entertainer in the classroom (interview data), tells the students what to expect in class tests and exams (observation data) and incorporates lower level knowledge and cognitive domain questions into his assessments (assessment data). It is well established that students at university (adults) like to be aware of what they need to learn and why (Knowles, 1990). This makes the task of performing well in tests and exams easier and for this reason students prefer to rote learn. However, this does not promote deep learning that enables the cognition of concepts that can be applied to problems and used to critically assess problem situations. Ultimately, students are led to believe that science is a fixed set of facts, theories and rules that can be learnt and regurgitated. These are not characteristics one would encourage in scientific training since science graduates need to be able to solve real world problems by applying their knowledge.

The effect of Professor Beta's beliefs on his teacher-centred teaching is likewise manifested in his curriculum design. Professor Beta described a curriculum as

> "a set-up of a teaching unit….teaching objectives and teaching outcomes".

One would describe his curriculum design as that of product or program as he emphasises the teaching done by the teacher and not the learning and experiences of the students. Interestingly though, he also had the following to say about what he includes his "curriculum":

> "I incorporated more interested subjects or let's say more trendy subjects… also to include new subjects which are probably of interest for the students, first of all they would attend the course more frequently than they would if it would not be of interest, and second you get probably higher pass rates and average marks because you are teaching something what is really of interest of the students, you must take that into account"

It appears that the lecturer considered the students interests in his teaching material. However, this seems ill-placed and the emphasis, instead of being on student experiences and learning and training future scientists, ends up being on increased class attendance, higher pass rates and average marks which really reflect back on the teacher. These indicators of student performance, that is, their performance in tests and examinations are believed to be indicators of whether or not his students understand what he teaches them (interview data section 4.2.2) and these beliefs correspond well with his assessment approach.

Professor Beta believes that students learn by memorisation (section 4.2.2.) as aligned with his traditional beliefs and teaching practices. Teachers holding these beliefs usually have instructional goals that are focussed on rationally and evidently explaining why students' different conceptions are incorrect and why a scientific concept is correct (Yoon & Kim, 2016). This was reflected by the types of questions that he used most frequently in his assessments, that is, questions categorised as lower level cognitive, factual knowledge questions. Recall how Professor Beta described how he includes fill in the missing word type questions, he stated "this means you have no chance, you must be precise" and so students are expected to use the "correct" words. This gives students the impression that science can be learnt as a set of facts. This is concerning given the context in which he is teaching where the majority of his class does not have English as their mother tongue. Without being required to explain concepts in their own words and instead being required to fill in very precise words they are really being required to memorise words that might be unfamiliar and that they might not even fully understand in the context of which they are being used. Once again, this type of question supports the view that that scientific knowledge is absolute, rather than dialogic and open to question.

5.2 Transitional view

Doctors Alpha and Gamma were both educated in SA and obtained their PhDs from South African universities. Dr Alpha had 8 years of teaching experience and Dr Gamma 2 years, making Dr Gamma the least experienced lecturer. Both lecturers were found to have transitional views about the nature of science and scientific knowledge. That is, they are neither fully teacher-centred nor fully student-centred in their beliefs. This finding is congruent with that of Postareff *et al*. (2008) whose study showed that disagreement between beliefs and practices happened as lecturers changed from teacher-centred to student-centred beliefs. It is apparent that Dr Alpha's beliefs are still in the early transition phase and that she has changed her practices more so than her beliefs, whereas Dr Gamma incongruently appears to be further along in his belief's transition as compared to his practices. This is not surprising given his lecturing inexperience.

Dr Alpha's pedagogical practices are well aligned with student-centred teaching approaches. She has undergone some changes to the way in which she approaches her teaching, in her own words:

> "I have changed in my idea because initially I thought my role was to transmit knowledge and I was a transmitter. But now I try to see myself as more of a facilitator of um information so I'm trying to get them to understand the work, more than just trying to spew information at them"
>
> "in the past I kind of…now as I am shifting more towards trying to facilitate them…"

Dr Alpha later mentioned in her interview that:

> Mrs X (pseudonym) has "come to evaluate my lectures a couple of times, she's had some discussions with me, and you know you have to write up these teaching portfolios all the time for promotions and for this and that so I've written when you write them, you have to think about what's going on so it's sort of self-assessment"

In a study by Malkki & Lindblom-Ylanne (2012), in which they interviewed 76 university lecturers, they revealed that reflection leads to changes in beliefs and practices. It is clear that Dr Alpha has reflected on her teaching and has made an effort to change her teaching

ways. Malkki & Linblom-Ylanne also showed that time for reflection on experience enables change in beliefs (Malkki & Linblom-Ylanne, 2012). This appears to be the case for Dr Alpha and perhaps she needs more reflection time in order to affirm her student-centred beliefs.

It is apparent that Dr Gamma is battling with the enormity of pressures that come with being in an early teaching career phase trying to establish a teaching style, which is not uncommon (Gormally, 2016; Isiksal-Bostan, 2015). He had only been lecturing for two years and expressed his anxieties about lecturing to large classes (interview data, not shown):

> "…lecturing is just presentation in a large group, sometimes, or you just get there present and sometimes no interaction…I can say I enjoy more tutoring than lecturing….sometimes it creates that distance between me and the students and it can be chaotic at some point, if the student don't get what you did present"

Dr Gamma did however, express a desire to undergo further teacher training (interview data, not shown):

> "I guess I would probably prefer attending several courses, watch shows on teaching and learning in the process"

It seems as though he has undergone some self-reflection and in this way has made a decision to change his practices. His many years of tutoring small groups, and sitting in on lectures given by more experienced teachers might have played some part in his self-criticism. It has been found that reformed practice ought to be repeated for sufficiently lengthy periods of time so that the practices affects the "reformed" adequately to permit stability changes (Guskey, 2002; Sharma & Muzaffar, 2012) and so it can be hypothesised that Dr Gamma requires training and more time to reflect on and change his teaching practices in order to fully adopt a student-centred pedagogy.

The transitional beliefs and pedagogies of Dr's Alpha and Gamma are emulated in their curriculum designs. Both lecturers describe a curriculum as a list of content to be taught, this may be due to the prescriptive courses the lecturers teach, where the "curricula" are imposed on them (interview data not shown). Despite this, both lecturers expressed a need and a desire to incorporate and address new technologies, methods and techniques as they arise.

> Dr Alpha: "…I keep it topical so if there is new stuff that's come out, new techniques, new methods then I will include those…"
>
> Dr Gamma: "…I'll look at one or two companies and then look at innovations in terms of in my field of study and say ok, this is the new innovations and then I will probably take from there…"

These views correspond well with the ever changing nature of scientific knowledge and can be interpreted as a concerted effort by these lecturers to incorporate information that is relevant and meaningful to students today. This would imply that these lecturers views of what students need to know with respect to scientific knowledge will include the new discoveries and technologies of science. This is in contrast to Professor Beta who indicated that he included topical subjects as a means of getting students to attend his lectures.

Dr Alpha has expressed a need for her students, not so much to know things, but rather to experience them, as she feels that this is how students learn best (appendix 7.3.1). She believes students need to apply the knowledge they gain and instead of emphasising content she emphasises application. This can be seen in her approach to student assessments:

> "I try to test them on application and on understanding somehow incorporating that knowledge that they have read through so that its beyond just the memorising"
> "The primary aim of an assessment I would say is to um, again going back to the fact that they need to have hands on experience with the theory, it's to put the theory into a more practical vein and to make them, I suppose sort of bolster that theory through doing that in practice"

Dr Alpha mentions that she likes to assess her students in a number of ways and times during the course (interview data not shown). These include a laboratory report based on laboratory experiments, a "big write-up" where students are required to plot their results, describe their results and discuss using literature. Further assessments include short questions based on structural protein work and then probing questions with respect to protein models and finally the plotting and describing of protein folding data. So although Dr Alpha utilised factual questions that made-up a large percentage of the class test mark,

this taken together with her formative assessment approach, verify that she has transitional beliefs that impact her teaching and assessment.

The assessment approach by Dr Gamma is well described by the following (appendix 7.3.3).

> Dr Gamma: "I set the questions that actually then tend to see if they can use the information to arrive at a particular conclusion so, I will give them the information and the question will probe whether they can use that information to arrive at a conclusion or similar conclusion"

While Dr Gamma intends to set a procedural question, where students are required to use information to arrive at a conclusion, similar to what actual scientists do, it appears as though the conclusion is set and the information is not open to interpretation and this implies a traditional end game to the question. This does not promote the thinking and reasoning required by scientists and so, this type of approach to assessment is not desirable and will not make for effective training of future scientists. Looking at the split between the mark allocations for factual (30%) and procedural (65%) questions in the assessment set by Dr Gamma one can see how his transitional beliefs impact upon his assessment approach.

5.3 Student-centred view

Similarly to Dr's Alpha and Gamma, Professor Delta completed his PhD at a South African university. However, he had 14 years of teaching experience and he was therefore considered as a senior lecturer, much the same as Professor Beta. The views of the nature of science and scientific knowledge expressed by Professor Delta were concluded to be student-centred. This was in direct contract with his fellow senior lecturer Professor Beta who was found to have traditional beliefs. It was hypothesised that this may be due to difficulties experienced by senior teachers to undergo a transition from teacher-centred to student-centred beliefs and teaching practices (Ertmer, 2005; Postareff *et al*., 2007). However, Piggot-Irvine (2006) showed that neither age nor experience influences the adoption of new classroom practices but rather the individual make up of a teacher.

Professor Delta's student-centred beliefs were resonated by his pedagogical practices. He was observed to provide a teaching and learning environment where students were made to feel comfortable to pose questions, question the content being delivered, and share their knowledge and uncertainties about the subject. This was well reciprocated and welcomed

by the lecturer. A noteworthy example of one such classroom interaction played out as follows (appendix 7.1.4):

> Professor Delta asks if anyone has ever heard of people who have tried to commit suicide by drinking brake fluid?
>
> The class discusses this amongst themselves
>
> A student shares that antifreeze is also a potent hallucinogenic so you often have cases…
>
> Professor Delta interrupts: "antifreeze is also a potent hallucinogenic? Thank you for that, I did not know that"
>
> The class and the student laugh and then the student says: "it's a thing (inaudible)"

Professor Delta also had the following to say:

> "in other words the flow of information I feel must not only be lecturer to student, I feel they learn better when its actually student to lecturer because then they are framing the question, ok, they are telling you what they know and what they don't know"

These interactions illustrate how the lecturer allows the students to take control of the lecture, share their knowledge with their fellow class mates, and the lecturer, and in this way they are all learning and meaning making together. These interactions can be considered classical indicators of student-centred learning that have clearly been influenced by constructivist theories and philosophies of teaching and learning.

Professor Delta believes students need to know broad concepts, that is, the so called fundamentals of science. He expressed that scientific knowledge is "falsifiable – in other words its testable… it does not mean that everything in science has to be correct" (interview data not shown) and believes that by putting fundamental concepts into real life contexts, students' curiosities are "triggered" and this promotes their exploration of the basic concepts. This implies Professor Delta utilizes a curriculum that is intended for students.

Surprisingly, the non-traditional student-centred beliefs of Professor Delta, that so obviously influence his pedagogy, were not evident in his approach to assessment. Factual knowledge questions governed his summative assessment and reflected a teacher-centred, positivist

surface approach to student assessment. This is problematic because assessment motivates student learning. If students are assessed on a surface level, they will study and learn on a surface level. They will not learn to explore, engage with, question, reason and apply the knowledge they have gained to problems and this is ultimately what training scientists (science students) need to learn how to do. So despite teaching in a constructivist, student-centred way, if students are assessed traditionally they will continue to learn in a traditional manner and the teaching approach becomes somewhat insignificant.

Previous case studies have illustrated that there can be a disparity between a teacher's mental and performed models of teaching and learning (Cooney, 1985). Song and Looi (2012) showed that teachers have assortments of beliefs that form their practices. This was similar to the findings of Lameras *et al*. (2012) who found that teachers use alternate beliefs and practices in diverse contexts and Bartos & Lederman, in 2014, who found that teachers' beliefs are not always consistent with their practices, they hypothesised that this may be because they differ in their commitment to their adopted beliefs with their professed teaching contexts (Bartos & Lederman, 2014).

These scenarios seemed unlikely, as Professor Delta's teaching practices so intensely mirrored his beliefs. Fortunately, the interview data recorded the following that permitted one to deduce that Professor Delta may actually be student-centred in his approach to assessment:

> "there is an assessment on writing which is part of the curriculum, scientific writing, there is an assessment on performing and lab component and getting a result because those results are used to write up a lab report. There is assessment to a minor extent to each lecture, when I pose questions to students, so that's a form of an assessment and obviously the major assessment comes when students sit for an exam. Ok and that's obviously the major assessment however, I don't think that that's the best form of assessment uhm because some students find it very difficult to write down this information, some students can probably communicate this information a lot more effectively if they were given a chance to talk about it."

Perhaps by only including a summative assessment analysis in this research, the data was biased or skewed. However, this approach did reveal the disparity between beliefs and

practices of lecturers compared to their approaches to assessment. It is surprising that second and third year university science students were not required to answer level 4 cognitive process questions in their assessments. In fact, not one of the lecturers included questions in their assessments that could be considered to test level 4 cognitive processes. This level of questioning requires students to apply, synthesise and or derive knowledge (Brenner *et al*., 2010). One would imagine that this level of questioning would make-up a large percentage of the marks in university science test and exam question papers, since these are the types of questions that scientists need to address in their daily lives and so it is this level and type of questioning that should be used in order to better train future scientists in a university environment. This reverts back to the interpretivist and constructivist learning theories and philosophies that state that knowing results from experiencing (Johnson & Onwuegbuzie, 2004). Only if the lecturers allow their students to experience science and science problems as scientists do will they be sufficiently and correctly trained to become scientists. This needs to be reflected in the adoption of, and belief in student-centred teaching programs and curricula that are intended for student learning with the corresponding and associated assessment approaches.

5.4 Closing

In closing it can be said that this study has established that the views of the university lecturers have a direct relationship with their practices. This finding coincides with those of Bingimlas & Hanrahan (2010), Ernest (1991), Pajares (1992), Tursucu *et al*. (2017), Trigwell & Prosner (1996) and Caudle & Moran (2012) amongst others who have found that teacher's views form the foundations of teachers' mental models of learning and teaching. Bingimlas & Hanrahan (2010) furthermore found that teacher's beliefs are unchanging. In contradiction to this, this study provides evidence that teacher's beliefs can and will change but this necessitates self-reflection and continuous professional development. Perhaps a more interesting finding of this study is that changes in the beliefs and practices of lecturers to align with constructivist, student-centred approaches become inconsequential if their approaches to assessment remain traditional. Students will continue to receive mixed messages about the nature of science and scientific knowledge and will continue to think and approach problems on a surface level. This will negatively impact their training as scientists as they will not learn how to critically analyse, scrutinise and manipulate

information as well as apply their knowledge to problem situations. This may be useful to know when it comes to training new Molecular Bioscience lecturers as well as during the continuous professional development of more experienced lecturers as well as during the selection of lecturers to lecture across a single course.

The findings of this study are not only important to consider when setting up courses at a university level but can also form an important part of discussions in schools about teachers' views of the nature of science, teaching pedagogies and importantly assessment approaches.

CHAPTER 6

REFERENCES

Alhammad, A. (2015). A Conceptual Framework for Re-Shaping Science Education in Saudi Arabia. Science Education in the Arab Gulf States. Chapter 6. Part of the series Cultural and Historical Perspectives on Science Education. Pp. 121-136.

Altinyelken, H.K. (2010). Pedagogical Renewal in Sub-Saharan Africa: The Case of Uganda. *Comparative Education*, **43**, 273-294.

Ambross J, Meiring L & Blignaut S 2014. The implementation and development of science process skills in the natural sciences: A case study of teachers' perceptions. *African Education Review*, **11**, 459-474.

Anderson, W. L. (2005). Objectives, Evaluation and the Improvement of Education. *Studies in Educational Evaluation*, **31**, 102–13.

Anderson, D. (2014). The nature and influence of teacher beliefs and knowledge on the science teaching practice of three generalist New Zealand primary teachers. *Research in Science Education*, **45**, 395–423.

Asikainen, H. (2014). Successful learning and studying in the biosciences. Exploring how students' conceptions of learning, approaches to learning, motivation and their experiences of the teaching-learning environment are related to study success. Helsinki: Unigrafia.

Aydogdu, B (2015). The investigation of science process skills of science teachers in terms of some variables. *Educational Research and Reviews,* **10**, 582-594

Barnett, R. (2014). Thinking about higher education. In P. Gibbs & R. Barnett (Eds.),Thinking about Higher Education. (pp. 9–22). New York and London: Springer International Publishing Switzerland.

Barron, B. & Darling-Hammond, L. (2010). Prospects and Challenges for Inquiry-based Approaches to Learning. In *The Nature of Learning: Using Research to Inspire Practice*, edited by Hanna Dumont, David Istance and Fransisco Benavides, 199-225. Paris: OECD Publishing.

Bartos, S. A., & Lederman, N. G. (2014). Teachers' knowledge structures for nature of science and scientific inquiry: Conceptions and classroom practice, *Journal of Research in Science Teaching*, 51, 1150–1184.

Beane, J.A., Toepfer, C.F. Jr & Alessi, S.J. Jr (1986). Curriculum Planning and Development. Boston: Allyn and Bacon, Inc.

Belo, N.A.H., van Driel, J.H., van Veen, K. & Verloop, N. (2014). Beyond the dichotomy of teacher-versus student –focused education: A survey study on physics teachers' beliefs about the goals and pedagogy of physics education. *Teaching and Teachers Education*. **39**, 89-101.

Bernstein, B. (1986). On pedagogic discourse. In. J.G. Richardson (Ed.) Handbook of Theory and Research for the Sociology of Education (New York, Greenwood Press).

Bertram, C., & Christiansen, I. (2014). Understanding research: An introduction to reading research (1st ed.). (pp. 84-95). Van Schaik. Pretoria.

Biggs, J. & Tang, C. 2011 (4th ed) Chapter 1 The changing scene in university teaching and Chapter 2 Teaching according to how students learn. In J. Biggs and C. Tang. Teaching for Quality Learning in University. Maidenhead, Berks. Open University Press.

Bingimlas, K. & M. Hanrahan. 2010. The relationship between teachers' beliefs and their practice: How the literature can inform science education reformers and researchers. In: M.F. Tasar and G. Çakmakci (eds.). Contemporary Science Education Research: International Perspectives. Ankara: Pegem Akademi.

Blakefield, M. (2013, July). Assessing co-curricular learning. Presentation at the Assessment Workshop of the Higher Learning Commission, Chicago, IL.

Brenner, E., Moletsane, G. & Rollnick, M. (2010). A major effect of a minor intervention: The use of a classification instrument to create awareness of assessment practices amongst lecturers in a first year biology course. In Teaching and Learning beyond Formal Access: Assessment through the Looking Glass. HE Monitor No. 10. (pp 35-50). Council on Higher Education. South Africa.

Bruer, J. T. (1993). Schools for thought: A science of learning in the classroom. Cambridge, MA : MIT Press.

Burbules, N.C. & Linn, M.C. (1991). Science education and philosophy of science: congruence or contradiction? *International Journal of Science Education*. **13**, 227-241.

Caudle, L. A. & M. J. Moran. (2012). Changes in Understandings of Three Teachers' Beliefs and Practice Across Time: Moving from Teacher Preparation to In-service Teaching. *Journal of Early Childhood Teacher Education* **33**, 38–53.

CMS Collaboration. (2012). Observation of a new boson at a mass of 125 GeV with the CSM experiment at the LHC. *Physics Letters B*, **716**, 30-61.

Coil, D. Wenderoth, M.P., Cunningham, M. & Dirks, C. (2010). Teaching the process of science: Faculty perceptions and an effective methodology. *CBE-Life Sciences Education*. **9**, 524-535.

Coll, R. & Taylor, N. (2012). An international perspective on science curriculum development and implementation. In B. J. Fraser, K. G. Tobin & C. J. Mc Robbie (Eds.), Second international handbook of science education (24th ed., Vol. 2, pp 771-782). London: Springer.

Cooney, T. J. (1985). A beginning teacher's view of problem solving. *Journal for Research in Mathematics Education.* **16**, 324–336.

Davydov, V. V. (1990). Types of generalization in instruction. Reston, VA: National Council of Teachers of Mathematics.

Department of Basic Education (DBE), Republic of South Africa 2011. Curriculum and Assessment Policy Statement. Natural Sciences. Grades 7-9. Pretoria: Department of Basic Education.

Dewey, J. (1916). Democracy and education: an introduction to the philosophy of education. New York, NY: Macmillan.

Dikli, S. (2003). Assessment at a distance: Traditional vs. Alternative Assessments. *The Turkish Online Journal of Educational Technology*. **2**, article 2.

Dolmas, D.H.J.M., Loyen, S.M.M., Marcq, H. & Gijbels, D. (2016). Deep and surface learning in problem-based learning: a review of the literature. *Advances in Health Science Education*. **21**, 1087-1112.

Donnelly, J. (1999). Interpreting differences: the educational aims of teachers of science and history, and their implication. *Journal of Curriculum Studies*. **31**, 17–41.

Driver, R. & Odham, V. (1986). A Constructivist Approach to Curriculum Development in Science. *Studies in Science Education*. **13**, 105-122.

Duschl, R.A. & Osborne, J. (2002). Supporting and Promoting Argumentation Discourse in Science Education. *Studies in Science Education*. **38**, 39-72.

Ernest, P. (1991). The philosophy of mathematics education. London: Falmer.

Ertmer, P. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technology integration? *Educational Technology Research and Development*. **53**, 25–39.

Flint, E.S. (2016). Engaging Social Constructivist Teaching in the Diverse Learning Environments; Perspectives from a First Year Faculty Member. *Higher Education for the Future*. **3**, 38-45.

Freire, P. (2008). The Banking Concept of Education. Ways of Reading. 8th Ed. David Bartholomae & Anthony Petrosky. Boston: Bedford-St. Martin's. 242-254.

Fry, H., Kettridge, S. & Marshall, S. (eds) (2009). Chapter 2: Understanding student learning. In H. Fry, S. Kettridge and S. Marshall (eds) A Handbook for Teaching and Learning in Higher Education. New York and London: Routledge, 8-11.

Gallagher, J. J. (Ed.). (1991). Interpretive research in science education (NARST Monograph, Number 4). Kansas City: Kansas State University & National Association for Research in Science Teaching.

Gallas, K. (1995). Talking their way into science: Hearing children's questions and theories, responding with curricula. New York: Teachers College Press.

Gormally, C. (2016). Developing a teacher identity: TAs' perspectives about learning to teach inquiry based biology labs. *International Journal of Teaching and Learning in Higher Education*. **28**, 176–192.

Giest, H. & Lompscher, J. (2003). Formation of Learning Activity and Theoretical Thinking in Science Teaching. In. A. Kozulin, B.Gindis, V.S. Ageyev. & S.M. Miller (Eds.), Vygotsky's Educational Theory in Cultural Context (pp. 267-288). Cambridge: Cambridge University Press.

Grayson, D.J.(ed.) (2010). Critical issues in school Mathematics and Science: Pathways to progress. Pretoria, South Africa: Academy of Science of South Africa (ASSAf).

Greeno, J. G., Collins, A. & Resnick, L. B. (1996). Cognition and learning. In D. C. Berliner & R. C. Calfee (Eds.), Handbook of Educational Psychology. New York: Macmillan, 15-46.

Guskey, T. (2002). Professional development and teacher change. *Teachers and Teaching*. **8**, 381–391.

Hamilton, M. (2017). Pedagogical transitions among science teachers: how does context intersect with teachers beliefs? *Teachers and Teaching*. **10**, 1-15.

Hang, N.V.T., Meijer, M. R., Bulte, A.M.W. & Pilot, A. (2015). The implementation of a social constructivist approach in primary science education in Confucian heritage culture: the case of Vietnam. *Cultural Studies of Science Education*. **10**, 665–693

Hatch, J. A. (2002). Doing qualitative research. In Educational settings. Pp 11-20. New York: Suny.

Hirst, P. H. (1969). The logic of the curriculum. *Journal of Curriculum Studies*. **1**, 142-158.

Hirsch, E. D. (1987). Cultural literacy: What Every American Needs to Know. New York: Vintage Books.

Hirsch, E. D. (1988). A postscript by E. D. Hirsch. *Change*. **20**, 22–26.

Houghton, W. (2004) Engineering Subject Centre Guide: Learning and teaching theory for engineering academics. Loughborough: HEA Engineering Subject Centre

Isiksal-Bostan, M., Sahin, E., & Ertepinar, H. (2015). Teacher beliefs toward using alternative teaching approaches in science and mathematics classes related to experience in teaching. *International Journal of Environmental & Science Education*. **10**, 603–621.

Johnson, B., & Christensen, L. (2004). Quantitative, Qualitative and Mixed Research. In Educational Research: Quantitative, Qualitative and Mixed Approaches Second Edition. pp. 29-56, Allyn & Bacon, USA.

Johnson, R. B., & Onwuegbuzie, A.J. (2004). Mixed methods research: a research paradigm whose time has come. *Educational Researcher*. **33**, 14-26.

Jogi, L., Karu, K. & Krabi, K. (2015). Rethinking teaching and teaching practice at university in a life long learning context. International. *Review of Education*. **61**, 61-77.

Jones, M. G., & Carter, G. (2007). Science teacher attitudes and beliefs. In S. K. Abell & N. G. Lederman (Eds.), Handbook of research on science education. pp. 1067–1104 New York: Routledge.

Karpov, Y.V. (2003). Vygotsky's Doctrine of Scientific Concepts: Its Role for Contemporary Education. In. A. Kozulin, B.Gindis, V.S. Ageyev. & S.M. Miller (Eds.), Vygotsky's Educational Theory in Cultural Context (pp. 65-82). Cambridge: Cambridge University Press.

Kattington, L.E. (2010). Handbook of Curriculum Development: Education in Competitive and Globalizing World Series. Nova Science Publishers, Inc. NY.

Kelly, A.V. (2004). The Curriculum: Theory and Practice. SAGE Publications Ltd, London.

Keser, O.M. & Akdeniz, A.R. (2010). Assessment of the constructivist physics learning environments. Asia-Pacific Forum on Science Learning and Teaching, Volume 11.

Kim, J-I. & Yoon, H.G. (2013). Elementary school teachers' beliefs about science teaching, science learning and the nature of science. *Journal of Science Education*. **37**, 389-404.

Kincheloe, J. L., & Tobin, K. (2009). The much exaggerated death of positivism. *Cultural Studies of Science Education*. **4** , 513–528.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*. **41**, 75-86.

Koh, T. S., Tan, K. C. D., & Cheah, H. M. (2008). Science education in Singapore: Meeting the challenges ahead. In R. K. Coll & N. Taylor (Eds.), Science education in context: An international examination of the influence of context on science curricula development and implementation. pp. 283–290. Rotterdam: Sense Publishers.

Knowles, M.S. (1990). The Adult Learner: A Neglected Species. 4th Ed. Houston, TX:Gulf Publishing Co. 292 p.

Kruse, J. (2009). Learning Theories: Pillars of Teaching Decision-Making. *Iowa Science Teachers Journal*. **36**, 2-7.

Lameras, P., P. Levy, I. Paraskakis, & S. Webber. 2012. Blended University Teaching Using Virtual Learning Environments: Conceptions and Approaches. *Instructional Science*. **40**, 141–57.

Law, B. & Eckes, M. (1995). Assessment and ESI. Peguis publishers: Maintoba, Canada.

Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), Handbook of research on science education (pp. 831–880). Mahwah, NJ: Lawrence Erlbaum Associates.

Lemke, J. L. (1990). Talking science: Language, learning, and values. Norwood, N.J.: Ablex.

Lewin. K. (1993). Planning policy on science education in developing countries. *International Journal of Science Education*. **15** , 1–15.

Lovat, T. and Smith, D. (1995). Curriculum Action on the Reflection Revisited. 3rd Ed. Wentworth Falls, NSW. Social Science Press.

Lucas, K.B. & Roth, W.M. (1996). The nature of scientific knowledge and student learning: Two longitudinal case studies. *Research in Science Education*. **26**, 103-127.

Luft, J., & Roehrig, G. (2007). Capturing science teachers' epistemological beliefs: The development of the teacher beliefs interview. *Electronic Journal of Science Education*. **11**, 38–63.

Mälkki, K. & S. Lindblom-Ylänne.(2012). From Reflection to Action? Barriers and Bridges Between Higher Education Teachers' Thoughts and Actions. *Studies in Higher Education*. **37**, 33–50.

Maor, D. and Taylor, P. C. (1995). Teacher epistemology and scientific inquiry in computerized classroom environments. *Journal of Research in Science Teaching*. **32**, 839–854.

Markic, S. & Eilks, I. (2012). A comparison of student teachers' beliefs from four different science teaching domains using a mixed methods design. *International Journal of Science Education*. **34**, 589-608.

Mayer, R. E. (2000). What is the place of science in educational research? *Educational Researcher*. **29**, 38-39.

Mbano, N. (2002). Verbal interactions in CASE lessons in Malawi. *African Journal of Research in Mathematics, Science and Technology Education.* **6**, 83-94.

Mbeki T. Address of the President of South Africa, Thabo Mbeki, at the second joint sitting of the third democratic parliament, Cape Town. Speech delivered in Cape Town. 2005 February 11.

McMillan, J.H. & Schumacher, S. (2006). Quantitative Research Designs and Methods. In. Research in Education: Evidence-Based Inquiry Sixth Edition. pp. 203-210, 350-357. Allyn & Bacon, USA.

Merrill, M. D. (2012). First principles of instruction. Hoboken: Wiley.

Meyer, D. Z., Meyer, A. A., Nabb, K. A., Connell, M. G., & Avery, L. M. (2013). Theoretical and empirical exploration of intrinsic problems in designing inquiry activities. *Research in Science Education*, **43**, 57–76.

Miyazacki, T. (2016). Is changing teaching practice the mission impossible? A case study of continuing professional development for primary school teachers in Senegal. *Compare*. **46**, 701-722.

Molefe, M.L. (2011). A study of life sciences projects in science talent competitions in the Western Cape, South Africa, with special reference to scientific skills and knowledge. PhD thesis. Cape Town, South Africa: University of Cape Town.

Molefe, L., Stears, M. and Hobden, S. (2016). Exploring student teachers' views of science process skills in their initial teacher education programmes. *South African Journal of Education*. **36**, 1-12.

Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies*. **19**, 317–328.

Opie, C. (2004). Research procedures. In Doing Educational Research. (Ed) Pp. 111-129. Sage. London.

Pajares, M. F. (1992). Teachers' beliefs and educational research: cleaning up a messy construct. *Review of Educational Research*. **62**, 307–332.

Parsons, J. & Beauchamp, L. (2012). From Knowledge to Action. Shaping the Future of Curriculum Development in Alberta. Alberta Education, Alberta, Canada.

Piaget, J. (1964, 2003). Development and learning. *Journal of Research in Science Teaching*, **40**, supplement, S8-18.

Piggot-Irvine, E. (2006). Establishing criteria for effective professional development and use in evaluating an action research based programme. *Journal of In-Service Education*. **32**, 477–496.

Postareff, L., Lindblom-Ylänne, S., & Nevgi, A. (2007). The effect of pedagogical training on teaching in higher education. *Teaching and Teacher Education*. **23**, 557–571.

Postareff, L., Katajavuori, N., Lindblom-Ylänne, S. & K. Trigwell, K. (2008). Consonance and Dissonance in Descriptions of Teaching of University Teachers. *Studies in Higher Education*. **33**, 49–61.

Prosser, M & Trigwell, K. (1999). Understanding Learning and Teaching. The Experience in Higher Education, Buckingham: The Society for Research into Higher Education and Open University Press.

Pugh, D. & Regehr, G. (2016). Taking the sting out of assessment: is there a role for progress testing? *Medical Education*. **50**, 721-729.

Rambuda, A.M. & Fraser, W.J. (2004). Perceptions of teachers of the application of science process skills in the teaching of Geography in secondary schools in the Free State province. *South African Journal of Education*. **24**, 10-17.

Rice, L.L. & Foster, D.D. (2016). An International and Domestic Examination of Faculty Epistemological and Pedagogical Teaching Beliefs. *North American Colleges and Teachers of Agriculture Journal*. **60**, 334-342.

Rogan, J.M., & Grayson, D.J. (2003). Towards a theory of curriculum implementation with particular reference to science education in developing countries. *International Journal of Education*. **25**, 1171-1204.

Ryder, J. & Leach, J. (1999). University science students' experiences of investigative project work and their images of science. *International Journal of Science Education*. **21**, 945-956.

Ryder, J., Leach, J. & Driver, R. (1999). Undergraduate Science Students' Images of Science. *Journal of Research in Science Teaching*. **36**, 201-219.

Schwab, J. J. (1962) The teaching of science as enquiry [The Inglis Lecture]. In J.J.Schwab and P.F. Brandwein (eds), The Teaching of Science (Cambridge, MA: Harvard University Press), 3–103.

Scott, K.M. (2016). Change in university teachers' elearning beliefs and practices: a longitudinal study. *Studies in Higher Education*. **41**, 582-598.

Sharma, A., & Muzaffar, I. (2012). The (non) making/becoming of inquiry practicing science teachers. *Cultural Studies of Science Education*. **7**, 175–191.

Shavelson, R., Li, M., Ruiz-Primo, M.A. &Ayala, C.C. (2002). Evaluating New Approaches to Assessing learning. Keynote Address. Joint Northumbria/EARLI Assessment Conference, University of Northumbria, Newcastle.

Shulman, L. S. (2005). Signature pedagogies in the professions.*Daedalus*. **134,** 52–59.

Sickel, A.J. (2015). Beliefs, Knowledge, and Context: A Longitudinal Study of a Beginning Biology Teacher's 5E Unit. *School Science and Mathematics*. **115**, 75-87.

Slavin, R.E. (2003). Educational Psychology: Theory and Practice. 7th Ed. A and B Publisher, New York.

Sondergeld, T.A., Peters-Burton, E.E. & Johnson, C.C. (2016). Integrating the Three Dimensions of Next Generation Science Standards: Issues and Solution for Authentic Assessment of Student Learning. *School Science and Mathematics Journal*. **116**, 67-70.

Song, Y., & C. K. Looi. (2012). Linking Teacher Beliefs, Practices and Student Inquiry-Based Learning in a CSCL Environment: A Tale of Two Teachers. *International Journal of Computer-Supported Collaborative Learning*. **7**, 129–59.

Stenhouse, L. (1975). An Introduction to Research and Development. Heinemann Educational Books: London.

Tanner, D. & Tanner, L. (1995). Curriculum Development. Theory into Practice. 3rd ed. Englewood Cliffs: Merill.

Talyzina, N. F. (1981). The psychology of learning. Moscow: Progress.

Taylor, P.C. & Fraser, B.J. (1991). Development of an instrument for assessing constructivist learning environments. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, L.A.

Taylor, P.C., Fraser, B.J. & White, L.R. (1994). The revised CLES: A questionnaire for educators interested in the constructivist reform of school science and mathematics. Paper presented at the annual meeting of the American Educational Research Association, Atlanta, GA.

Taylor,P.C., Fraser, B.J. & Fisher, D.L. (1997). Monitoring constructivist classroom learning environments. *International Journal of Educational Research*. **27**, 293-302.

Taylor, P.C., Taylor, E. & Luitel, B.C. (2012). Multi-paradigmatic Transformative Research as/for Teacher Education: An Integral Perspective. In. B. J. Fraser, K. Tobin, C. J. McRobbie. Second International Handbook of Science Education, (ed, 373-387. Netherlands: Springer.

Tillema, H. H.(1997). Stability and Change in Student Teachers' Beliefs. *European Journal of Teacher Education*.**20**, 209–12.

Trigwell, K., & Prosser, M. (1996). Changing approaches to teaching: A relational perspective. *Studies in Higher Education*.**21**, 275–284.

Trumbull, D. & Slack,M. J. (1991). Learning to ask, listen, and analyze: using structured interviewing assignments to develop reflection in preservice science teachers. *International Journal of Science Education*.**13**, 129–142.

Tsai, C. C. (2002). Nested epistemologies: science teachers' beliefs of teaching, learning and science. *International Journal of Science Education*. **24**, 771-783.

Tsai, C. C. (2007). Teachers' scientific epistemological views: the coherence with instruction and students' views. *Science Education*. **91**, 222-243.

Tursucu, S., Spandaw, J., Flipse, S. & de Vries, M.J. (2017). Teachers' beliefs about improving transfer of algebraic skills from mathematics into physics in senior pre-university education. *International Journal of Science Education*. **39**, 587-604.

Umugiraneza, O. & Bansilal, S. (2017). Exploring teachers' practices in teaching Mathematics and Statistics in KwaZulu-Natal schools. *South African Journal of South Africa*. **37**, 1-13.

Van Merrienboer, J. J. G., & Kirschner, P. A. (2013). Ten steps to complex learning (2 nd (2nd Rev ed.). New York: Routledge.

Vavrus, F., Thimas, M. & Bartlet, L. (2011). Ensuring Quality by Attending to Inquiry: Learner-Centred Pedagogy in Sub-Saharan Africa. Paris: UNESCO.

Vhurumuku, E. & Mokeleche, M. (2009). The nature of science and indigenous knowledge systems in South Africa, 2000-2007: A critical review of the research in science education. *African Journal of Research in Mathematics, Sceince and Technology Education*. **1**, 96-114.

Von Glasersfeld, E. (1991). A constructivist's view of learning and teaching. In R.Duit Goldberg , F., Niedderer, H. (Ed.), Research in physics learning: Theoretical issues and empirical studies (pp. 29-39). Kiel:IPN

Vygotsky, L.S. (1978). Mind in Society: The development of higher psychological processes. Cambridge, MA: Harvard University Press. Chapter 6 (pp. 79-91).

Walford, G. (2001). Interviews. In Doing Qualitative Educational Research: A Personal Guide to the Research Process. pp. 80-94, Continuum, London.

Weston, D. (2014). A Positive Constructivist: An Internal Debate on Opposing Educational Philosophies. *Teaching and Learning*. **8**, 1-19.

White, J.P. The Concept of Curriculum Evaluation. In Golby, M. et al. (1975). Curriculum Design. London. OUP.

Wormald, B.W., Schoeman, S., Somasunderam, S. & Penn, M. (2009). Assessment Drives Learning: An Unavoidable Truth? *Anatomical Sciences Education*. **2**, 199-201.

Yoon, H.G. & Kim, B.S. (2016). Preservice Elementary Teachers' Beliefs about Nature of Science and Constructivist Teaching in the Content-specific Context. *Eurasia Journal of Mathematics, Science & Technology Education.* **12**, 457-475.

Zais, R.S. (1976). Curriculum. Principles and Foundations. New York: Harper and Row Publishers.

CHAPTER 7

APPENDICES

7.1 Classroom observation coding

7.1.1 Observation of Dr Alpha

Start 0.00.10 End 47.20.00 (Lecturer talk time 29.51.88)

6 min 52 sec

Shared Control

1. Lecturer asks students what they think about proteins being in solution, if cells are lysed? (opens floor to all students)

Student Negotiation

One student says yes

1. The lecturer does not say yes or no but asks why the student thinks so, giving the student time to reflect on and explain their answer

The student mentions proteins are now a "moosh" and are aggregating

2. The lecturer uses this opportunity to question this thought of aggregated proteins in solution and allows the student to explain this concept

10 min 52 sec

Student Negotiation

1. The lecturer asks how you know if protein is in the supernatant or pellet after centrifugation? If you know if its soluble no not?

A student proposes using the biuret test

2. The lecturer asks if this would help answer the question - allowing students to voice their opinion

The student says that it tells you if it is a protein

3. The lecturer agrees but further probes students by asking how they know if it's the specific protein they are looking for, as there are many proteins present and the biure t test does not decipher between them

Another student proposes spectrometry

4. The lecturer agrees but ask how this method deciphers between the protein of interest and others? - in an attempt to further the students exploration

A student replies that you use the protein's specific absorption spectrum

5. The lecturer points out all proteins absorb at the same specific wavelength so now what?

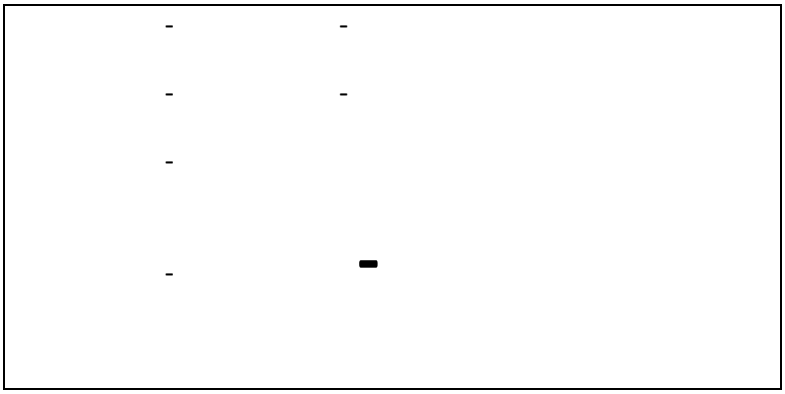
Another student proposes a 2D separation and excision of the protein

6. The lecturer reminds the students of SDS PAGE by asking what separation technique this uses that they know well

12 min 30sec

Student Negotiation

The lecturer draws a SDS PAGE gel on the board as follows



1. And asks where the protein of interest is

One student replies in the pellet

2. The lecturer asks her to explain her answer

The students says because they over expressed the protein, representative of the thick band in pellet

3. The lecturer uses this opportunity to ask whether the students now know if the protein is soluble

The class replies insoluble as it is in the pellet

14 min 00 sec

Uncertainty

1. Lecturer provides example of unpredicted and undesirable experimental results i.e. insoluble protein and proposes a scenario where the protein is insoluble and undesirable because it is bound to a membrane

The lecturer suggests that they could go about rectifying the problem and getting it off the membrane by using salts or detergents.

14 min 31 sec

Student Negotiation

1. The lecture asks why one should use salts and detergents to get protein off a membrane?

   A student says detergents are amphipathic molecules and as such disrupt the membrane

15 min 01 sec

Student Negotiation

1. The lecturer asks what are the properties of membrane proteins in terms of hydrophilic and hydrophobic residues?

   A student answers: proteins have both groups, hydrophilic on the outside of membranes in the cytosol and hydrophobic on the inside

2. The lecturer says good and then reiterates that it has a very hydrophobic region on the inside and then asks what would happen if you took the membrane away? What happens to the hydrophobic groups?

   No Response

3. She prompts the class again asking if it will be happy inside the aqueous solvent?

   A student responds: hydrophobic regions will interact with hydrophobic regions of other proteins and aggregate

The lecturer, yes and then it will be insoluble again and goes on to say that detergents shield hydrophobic residues preventing aggregation as explained previously by the student

17 min 51 sec

Student negotiation

1. Lecturer asks students to propose whether warmer or cooler temperatures are better for keeping proteins stable

   Some students quietly answer: cooler

2. The class is quiet so the lecturer prompts the students to express their ideas by asking whether they think 37^{o}C, or 20^{o}C would be better for stable proteins?

   One student proposes that it depends on the protein

   The lecturer states the students can assume proteins in general

   Some student softly says body temperature

The lecturer repeats this out aloud and the class says yes

Another student says 25^{o}C

And another student says it depends on the source of protein

The lecturer reminds the class that the protein is being taken out of it "home" and is now in conditions it is not used to

A student says that temperature should be kept constant

The lecturer repeats this in agreeance

3. Again the lecturer prompts the students to engage by asking if the students if warm or cool temperatures in general are better?

Students mumble softly

No reply

4 The lecture asks one student what they think

The student says cooler

The lecturer says yes, cooler

20 min 04 sec

Student Negotiation

During a description of buffering conditions and buffer characteristics the word proteases is mentioned by the lecturer

1. The lecturer asks the class: "what are proteases? What do they do?"

A student replies they cleave peptide bonds

In agreeance with the student, the lecturer repeats this statement

20 min 23 sec

Student Negotiation

1. The lecturer asks if it is good or bad news if proteases are present in buffers?

Some student replies it is not good news

2. The lecturer asks why it is not good news?

A student replies: you are going to destroy the protein

The lecturer agrees and repeats the statement

20 min 40 sec

"Personal Relevance"

1. The lecturer states that if this protein is a protease it has just got its mouth opening and closing and it just wants to munch up all the protein. So we have to be careful we do not want proteases in the solution

20 min 59 sec

Student Negotiation

1. While discussing reducing conditions the lecturer asks the class if they know what amino acid will be affected by reducing conditions?

   A student replies: cysteine

   The lecturer says, yes good cysteine. Cysteines can form disulphide bonds in oxidising conditions and we don't want that so we try to maintain reducing conditions

21 min 32 sec

Personal Relevance

1. After describing the conditions that are optimum for protein storage the lecturer puts the entire concept in easy to comprehend terms by stating that "we are trying to make the new home for our protein that was ripped out of its home and put in a new home, as comfortable as possible. So we keep pH, temperature and conditions as comfortable as possible for our protein so that it keeps stable and it doesn't deteriorate or aggregate it remains in solution and we can work with it"

21 min 58 sec

Student Negotiation and Shared Control

1. During revision of what has just been discussed i.e. protein, expression and storage conditions, the lecturer invites the students to chat to their class mates and write down the steps they would follow to express and solubilise a membrane protein

   The class discuss openly with their surrounding class mates in small groups (some work on their own and the lecturer goes around from group to group and aids student negotiations and keep students discussing etc)

   The lecturer repeats that the students must write it down

26 min 57 sec

Shared control

1. Students are seen asking the lecturer a number of questions

   Open discussion lasts 22 min 05 – 29 min 08

29 min 09 sec

Student Negotiation

1. The lecturer asks who would like to share their method?

29 min 32 sec

   The lecturer identifies a student and asks him to share his method

   The student says first you lyse the cell

2. The lecturer asks the class if that would be the very first step?

The class says no

3. The lecturer also says no and asks what you would have to do first?

The class all shout out answers but you can clearly hear some student say: "express"

The lecturer says yes, you first have to express the protein and goes onto explain that you need protein in the cell.

30 min 03 sec

Shared Control and Uncertainty

A student asks if it is necessary to express the protein even if you know what it is

1. The lecturer repeats the question so the class can hear it and then says well the question is you want to purify and solubilise, right? So if you want to purify you have to express, you will not have enough protein if you don't do that right? OK so you express it they you lyse it then what?

Back to student who was sharing his method

The Lecturer asks: " how do you lyse it and where do you express it?"

30 min 33 sec

Student Negotiation

Another student replies express in bacterial cells

1. The lecturer says yes and then asks the original student who was sharing their method how to lyse it?

The student proposes osmosis

30 min 43 sec

Student Negotiation

1. The lecturer questions osmosis in a bacterial cell?

The class shouts no.

The class shouts answers and the lecturer asks use?

The lecturer confirms that you should use some kind of mechanical (inaudible), perhaps sonication, we've used sonication, it is very cool. You put a little probe inside of the solution and it goes bzt bzt bzt like that and boom the bacterial cells open up

31 min 10 sec

Student Negotiation

1. The lecturer says ok cells are lysed what is next?

A student replies centrifuge

The lecturer says and then what do we see?

The class chatters

2. The lecturer asks: “what if it’s a membrane protein where should it be?

   The class replies in the pellet

3. The lecturer says ok, what next?

   Some students reply re-suspend in detergents

4. The lecturer says good and then? Centrifuge again and then? Hold thumbs and cross fingers that it *will be in the supernatant (class is heard saying this simultaneously with the lecturer)*

The lecturer discusses other steps that can be taken in order to solubilise proteins

32 min 52 sec

Student Negotiation

1. The lecturer asks what the pI of a protein is

   Class responds (inaudible)

   Lecturer says what?

   The class is heard saying isoelectric point

2. The lecturer asks what this means?

   A student replies

   The lecturer says brilliant and repeats the answer: “the pH at which a protein has no net charge”

34 min 16 sec

Student Negotiation

1. The lecturer asks the class how they think one goes about purifying their specific pm, how one would separate that protein from the others within the solution?

   The class mumbles but offers no definite explanation

   The lecturer prompts the class by asking if all proteins in the solution are the same?

   The Class say no

   The lecturer says yes that’s the cool thing they are not the same

2. The lecturer asks what is different about them?

   A student says one of those things (refers to list of protein properties on the white board)

   The lecturer says yes, one of those things, but for example, give me an example of how you would separate the proteins

   A student proposes using a putative ligand **34 min 57 sec**

   The lecturer says yes, good so we can see what it binds to, its will bind to a ligand and the other poteins will not, good.

3. What else?

   A student proposes an idea (inaudible) **35min 08 sec**

The lecturer says you have to be careful with gels, they are preparative (inaudible) remember how much protein you load on a gel. Imagine you have a tube of about 20ml of protein that you want to separate, how are you going to do that on a gel? You have to be careful of gels but the idea behind it is right.

35 min 42 sec

Student Negotiation

1. The lecturer asks what else could be used to separate proteins?

   A student says we mentioned PI some proteins are cations at some pHs (inaudible)

2. The lecturer says yes so we are separating according to?

   The student says charge.

   The lecturer says good, separating according to charge

36 min 11 sec

Student Negotiation

A Student asks if it is possible to use a specific antibody?

1. The lecturer says yes antibodies, we can, and again its specific binding, yes certainly we do that
2. The lecturer asks if there is anything else the students can think of, something that is in the board perhaps **36 min 19 sec**

   Student says (inaudible)

3. The lecturer says yes nice so we can separate according to?

   The student replies (inaudible)

   The lecturer says yes, nice, there are different things. Proteins differ in size, they differ in charge, they differ in their functional capacities, what they bind to, they differ in hydrophobicity…..

39 min 44 sec

Student Negotiation and Personal Relevance

1. The lecture asks why salting in, adding a little bit of salt to water, will make the protein in that water more soluble?

   A student replies, won't adding salt to water make the solution more polar and then the (inaudible)

Student negotiation

2. The lecturer says yes you are kind of on the right track. It has got to do with, what does salt have?

   The students reply ions

3. The lecturer says ions, what do proteins have?

   The student says (inaudible)

4. The lecturer says yes and if you put the two together and what happens? **40 min 21 sec**

   The student says (inaudible)

5. The lecturer says so if you have ions in the salt and ions in the protein because protein have all those charged amino acids and salts have got charges, put them together

   The class replies yes

   A Student says that the proteins will tend to (inaudible) of the proteins will tend to bind to the ions and then hence through (inaudible) will bind to each other **40 min 38 sec**

6. The lecturer says yes exactly. Remember proteins have charges, positive and negative and they are going to want to stick to each other, you put the ions in and the ions will bind to the charges and the charges will stick to each other. When proteins stick to each other they become less soluble. When proteins are prevented from sticking to itself it becomes more soluble……

7. The lecturer asks why do proteins precipitate out when you add too much salt? **41min 50sec**

   A student says salt particles have a higher (inaudible) then what proteins are

   The lecturer says yes that is exactly what happens

43 min 42 sec

<u>Student Negotiation</u>

1. The lecturer puts up a solubility plot and asks if you wanted to purify Serum albumin, how one would do so using solubility? Based on solubility and ionic strength specifically. How would you purify out serum albumin in a mixture of fibrinogen, haemoglobin, pseudogobulin serum albumin and Myoglobin?

   The student says (inaudible)

   The student says (inaudible)

   The Lecturer says so in this particular instance?

   The student says (inaudible)

2. The lecturer says so you reduce ionic strength to 7? So what is going to happen at ionic strength 7 (student replies (inaudible)), to your whole solution? What is going to happen to all these proteins if you put them at ionic strength 7? What will happen to fibrinogen at this high ionic strength? Is it going to be soluble or insoluble ?

   The class replies insoluble

3. The lecturer says completely insoluble and precipitated. And Hemoglobin and Pseudoglobulin?

The class mumbles

The lecturer says at pH 7?

The class mumbles

The lecturer says you can even say ionic strength 6. What about serum albumin at 6? Where is the point at 6, is it soluble or insoluble?

The class says soluble and lecturer agrees

4. The lecturer says so we can separate out, good. We are going to put an ionic strength of 6 in the solution, these 3 (points to board) are going to precipitate out, those 2 are going to remain in solution.
5. The lecturer asks how do we separate soluble and insoluble mixtures? **46 min 00 sec**

A student replies: centrifuge

6. The lecturer asks what will happen when we centrifuge? These (points to board) are going to go into the pellet or supernatant?

The class replies pellet **46 min 26 sec**

The lecturer repeats in agreeance

7. The lecturer asks how they can separate serum albumin and myoglobin from e ach other

A student replies saying, increase the ionic strength.

8. The lecturer says yes and asks which one is going to precipitate out

The class replies serum albumin

9. The lecturer says and that's the one you want, so then we centrifuge and do we want the pellet or the supernatant?

The class replies pellet

The lecturer says yes we want the pellet because its precipitated out of solution and then we can reduce the ionic strength to get it back into solution and whaalaa we have se rum albumin all on its own

7.1.2 Observation of Professor Beta

Start 00.00.01.20 End 51.32.03 (Lecturer talk time 49.08.11)

00 min 57 sec

Student negotiation

1. During a re-cap of the previous lecture the lecturer asks: "what is angiogenesis?"
   A student answers: "the development of blood vessels"

   The lecturer repeats the question and the answer given by the student to the class as if in agreement

2. The lecturer then asks: “for what (inaudible) need angiogenesis?”

   Another student answers: (inaudible)

   The lecturer then says (as if repeating what the student had said) transportation of nutrients, and also oxygen to organs which is essential for the body.

3. The lecturer asks which molecule can block angiogenesis? The class does not respond. He then repeats the question in a different way and asks the class what would be a therapeutic for treatment of tumour angiogenesis in your opinion? Again no one offers an answer so the lecturer states HER2/neu, Herceptin, (inaudible). The lecturer asks if (inaudible) would block tumour angiogenesis? Again no one answers and the lecturer gestures to the class to offer an explanation. The lecturer then asks how you block tumour angiogenesis, what is the (inaudible) used to block (inaudible)? Again no response so the lecturer asks a group of students what they would use to block tumour angiogenesis. The group does not offer an explanation.

   Another student puts their hands up and offers an explanation (inaudible).

   The lecture repeats the answer out aloud: “with LRP/LR specific antibodies, exactly that would it be”

4. The lecturer asks what the strategy would be to induce apoptosis in tumorigenic tissue? No one in the class offers and explanation so the lecturer repeats the question.

   A student replies: “(inaudible)

   Lecturer responds by saying that the tumour suppressor is very general , it does apoptosis and it does cell cycle control, that’s right.

5. The lecturer then asks which one they were using the previous day to induce apoptosis?

   A student replies (inaudible)
   The lecturer repeats the answer the one with the p21

   Another student says (inaudible)

   The lecturer repeats this saying you would use microRNA’s ok.

05 min 01 sec

6. The lecturer goes on to ask: “and direct it against what?

   Student replies (inaudible)

The lecturer says that's good that RNA interference (inaudible) it could be microRNA's or siRNA's and then asks what molecule the RNA would be directed against.

Student replies (inaudible)

05 min 19 sec

7. The lecturer asks what would be down regulated to induce apoptosis

   Another student replies: (inaudible)

   The lecturer repeats this saying LRP/LR

05 min 44 sec

8. The lecturer asks what the central enzymes are in apoptosis?
   Another student replies: (inaudible)

   The lecturer says no, topoisomerases play no role in apoptosis (inaudible). The lecturer repeats the question and then says cas…?, cas…..?, cas…?, cas…..?, you guys are slow today, what's wrong ? It's a Tuesday and the temperature is alright, you are not frozen, hey? It's too hot outside. The lecturer repeats the question. No one offers an explanation so the lecturer answers saying caspases.

09 min 27 sec

9. The lecturer states that a proto oncogene is supporting cancer. The lecturer asks the class is this statement correct?

   The class all respond saying no.

09 min 51 sec

10. A student puts their hand up asks a question (inaudible)

    The lecturer says: "no, you have a mutation in your gene for Ras, producing a Ras protein, which has a lysine in it and its oncogene is the inducing especially in your pancreatic tissues, cancer. But it can also be, as you can see (refers to slide presentation) capable (inudicble) present in other cancer types like colonic cancer or lung cancer so within a less frequent mutation.

15min 27 sec

11. A student asks a question: (inaudible)

    The lecturer says MDM2 the proto oncogene with an oncogene. The oncogene is very strong and MDM2 is very strong binding to (inaudible) okay, (inaudible) got it? Good.

32 min 34 sec

<u>Personal Relevance</u>

1. The lecturer uses a newspaper article that reports that "HIV/AIDS claiming fewer lives report reveals" from 2010 and then shows one newspaper clip reporting that HIV was on the increase in 2012. The lecturer says it is because people are not using condoms and then chats about the students night lives. He concludes by appealing to them to use condoms.

36 min 52 sec

Personal Relevance

1. The lecturer relates the sex life's of students or "life style" to rates of HIV and cervical cancer

37 min 38 sec

Personal Relevance

1. The lecturer, during a discussion on the top causes of death in SA in 2010, mentions that the 3rd one, diarrhoea, is not nice and that he had diarrhoea a few weeks when he was lecturing them during the concepts course. Diarrhoea is not nice at all and affects your life.

41 min 23 sec

Student Negotiation

1. The lecturer asks the class "what is epidemiology?"

A student answers that it's the study of causes and effect of diseases.

The lecturer says this is not the case and provides a definition.

45 min 44 sec

Personal Relevance

1. While discussing HIV/AIDS related statistics the lecturer reports on HIV stats in SA provinces, how many people out of a specified population analysed are HIV+. He states the highest rate of infection occurs in KZN and calls them the Durbanites. He also points out the prevalence in the Western Cape is lowest and suggests "not much goes on there"

7.1.3 Observation of Dr Gamma

Start 40.06.00 End 1.22.0.16 (Lecturer talk time 38.06.20)

42 min 56 sec

Student Negotiation

Student asks, with respect to paper chromatography techniques just explained what affects the size (inaudible) the speed of the sample?

1. The lecturer says no, not the speed of the sample, the distance that the sample travels will be dependent of the polarity if its less polar (inaudible) ok. If it is less polar, like in this case, if its less polar, in most cases it will travel the furthest and the more polar it will remain somewhere around here (draws on board) ok.

43 min 30 sec

Student Negotiation

Another student asks does the size affect the polarity?

1. The lecturer asks student to repeat question

Again the student asks if the size affects the polarity

The lecturer says the size has the effect on polarity? Not exactly its does not really affect it, it is not about the size.

The student says but if I have a larger molecule and a small molecule will the smaller one still travel faster?

2. The lecturer says yes if you have 2 molecules a larger one and a smaller one, if your larger one is more polar it means it won't travel far, it won't travel the furthest **43 min 42 sec**

The student asks but if I have a smaller one that is more polar will the larger one travel the fastest furthest?

3. The lecturer says no it does not depend on size **44 min 10 sec**

The student says yes but you just referred to if there's a smaller molecule it will travel the fastest so I'm just reversing it saying if the larger one is more polar, will it travel faster than the smaller one?

4. The lecturer says no, if the larger one is more polar, remember the lesser polar it is, it will travel further and the more polar it is then it will not travel further **44 min 20 sec**

The student says: turning it around if the larger one is less polar will that travel faster (inaudible) **44 min 47 sec**

5. The lecturer replied saying it depends on the (inaudible)

46 min 21 sec

Student Negotiation

A student asks if TLC is polar?

1. The lecturer repeats the question and says it not about the TLC being polar or non polar, sorry

The student comments (inaudible)

The lecturer says no I am saying to you that the TLC, we'll come to the TLC later on, you will see that if the TLC. You will see if the more polar the sample, I can say, yes it is more polar depending on the stationery phase. The stationery phase it will be more polar, ok and therefore the mobile phase will be non-polar, ok?

47 min 02 sec

Student Negotiation

Another student asks, with chromatography is it like let's say polar in a polar solvent would your polar molecule move further or (inaudible)

1. The lecturer asks if this is in a TLC

The student asks if its like opposite more further or is it the same kind of (inaudible)

The lecturer says in TLC remember the if (inaudible) the reason why I am saying the stationary phase is more polar is because the polar molecule will interact with each other as they move along whereas the non-polar will just move ok

48 min 12 sec

Personal Relevance

1. While discussing separation of components of a mixture based on differences in physical characteristics the lecturer mentions molecular size and uses the example of work the students had already covered previously. Lecturer reminds them this was based on separation based on size, molecular weight.

55 min 49 sec

Student Negotiation

A student asks a question about GC (inaudible)

1. The lecturer replies ok it means that (inaudible) the type of stationary phase that we have

A student asks (inaudible)

2. The lecturer says look its like here (points to drawing on board) we have a supportive phase behind me (inaudible) silica behind here that (inaudible) providing the support ok

1hr 07 min 55 sec

Student Negotiation

A student asks to refer to the previous graph about chromatographic retention time and would like to know what its stands for

1. The lecturer says that it just refers to the time from the first sample to the next sample to the peak of another sample.

The student asks if we use it in any of the equations

2. The lecturer replies no.

1hr 08 min 30 sec

Student Negotiation

Another student asks a question (inaudible) she refers to the equation:

k' = moles A stationary phase / moles A mobile phase

1. The lecturer says yes if k' is less than 1.0 separation is poor

1hr 10 min 48 sec

Student Negotiation

Student asks with respect to TLC if the sample should be at the same level as the solvent, should the solvent not be underneath.

1. The lecturer replies that it should be equated with your plate

The student asks if the solvent should touch

The lecturer continues, the plate and also the sample. OK?

1hr 14 min 27 sec

Student Negotiation

Referring to the example on the board regarding TLC Rf a student asks if B will be more non polar

1. The lecturer replies yes B will be more non polar on A

1hr 14 min 46 sec

Student Negotiation

Student asks a question (inaudible)

1. Lecturer says ok, in most cases you have your in your TLC normally you will have your silica being more polar, this plate here would be more polar and then because its polar most of the times the (in audible) will be interacting to the polar molecules on the plate and because your solvent is non polar (inaudible) student (inaudible) interaction

1hr 15 min 48 min

Student Negotiation

Student says they have a question about (inaudible) distance travelled by solvent (inaudible) separate the samples, then we put the samples on that line but were told that the solvent should go (inaudible). When you are measuring the distance do you start at the line where you (inaudible) or at the very bottom of the paper?

1. Lecturer says no, you start at the line that you drew the lecturer illustrates this on the board

1hr 16 min 45 sec

Shared Control

A student asks if the lecture can redo the illustration on the board but with the lecture theatre light on

1. The lecturer apologises turns the light on and again provides the explanation

1hr 17 min 58 sec

Student Negotiation

Another student comments that on the whatsapp response when we draw these lines, on the examples provided sometimes we put the line at the very bottom and sometimes (inaudible)

1. The lecturer says its up to you actually (inaudible) because, depending on whether you want to be conservative, most of the time when you want to be conservative you just use a small silica plate and you just draw a line at the bottom, close to the bottom, cause you don't want to use too much of the plate (inaudible)

1hr 20 min 32 sec

Personal Relevance

1. The lecturer is discussing column chromatography and provides an example of how this technique is used in any Discovery labs and the labs that analyse mixtures or in labs where you monitor the acidity of water as used by the mines.

7.1.4 Observation of Professor Delta

Start 00.00.00 End 00.30.13 (Lecturer talk time 26.49.04 + (3.02-2.53)

1 min 37 sec

Personal Relevance

1. The lecturer reminds the student of previous mathematical knowledge
   Y=mx + c and uses this to show the students the formula + graph manipulation to calculate enzymatic parameters.

8 min 33 sec

Student Negotiation

1. The lecturer asks what CNS depressant means? What does it do to you?
   A student replies that it stops conduction of the nerves.

2. The lecturer repeats this to class
   The student continues to explain (inaudible)

   The lecturer says gee I was just looking for a simple answer, student x is way too complicated (laughs).

3. The lecturer asks if anyone else has other explanation?
   Another student says it makes you fall into a coma and die. (Everyone laughs)

   The lecturer then describes what a CNS depressant is and adds each student explanation in along with his own.

10 min 35 sec

Personal Relevance

1. The lecturer during a discussion on competitive inhibitors provides cytochrome c oxidase as an example target of such an enzyme and then goes on to say cytochrome c oxidase provides an example of how blood pH levels are reduced to critically low levels resulting in acidosis.

2. The lecturer reminds the class that they learnt about cytochrome c oxidase in the previous year's course.

11 min 45 sec

Student Negotiation

A student asks if methanol is an inhibitor why would you treat methanol poisoning with more alcohol?

Shared Control

Another student proposes that the methanol itself is not the inhibitor but the metabolic products are, and so you have to out compete with ethanol so its excreted as methanol

1. The lecturer says yes, so it is about the metabolic products, they are the problem, okay?

12 min 50 sec

Student Negotiation

A student says so they are not competitive inhibitors of cytochrome c oxidase, they competitive inhibitors of the alcohol dehydrogenase

1. The lecture says they competitive inhibitors of ?

The Student reiterates alcohol dehydrogenase

The lecturer says yes of alcohol dehydrogenase, yes!

14 min 16 sec

Student Negotiation and Personal Relevance

A student asks (inaudible)

1. The lecturer (inaudible) I am not sure what actual percentages would be but I know generally, ok so I'm not a drinker (everyone laughs) but I do know your hard spirits they would generally contain up to what percentage of alcohol?

Shared Control

1. Class discussion

The lecturer says 40% of alcohol and finally answers students by saying I assume that would be the percentage administered.

15 min 21 sec

Student Negotiation

1. The lecturer poses the question of how one would administer 40% alcohol to an alcohol poisoned patient?

One student proposes that oral administration is best as it passes from the gut to the liver and that is where you want to be

2. The lecturer says how about via a drip, straight into the blood stream?

Class discussion

Some student proposes a suppository (everyone laughs)

16 min 35 sec

Student Negotiation

1. The lecturer asks if anyone has ever heard of people who have tried to commit suicide by drinking brake fluid?

Class discussion

16 min 41 sec

Shared Control

A student shares that antifreeze is also a potent hallucinogenic so you often have cases…….

1. Lecturer interrupts and restates that antifreeze is also a potent hallucinogenic? Thank you for that lecturer says jokingly, I did not know that (class laughs)

The student continues and says that it's a thing (inaudible)

17 min 25 sec

Student negotiation

1. The lecturer asks if the student is ok?

The student replies that they were just saying (with respect to brake fluid) you could get drunk, hallucinate and melt down cause it all just works so well together (everyone laughs)

The lecturer jokingly says he has to advise against that.

18 min 26 sec

Personal Relevance

1. During a discussion on drugs the lecturer tells the students to go and read package inserts of drugs they are prescribed. They will learn about target sites and interferences but also the side effects.

18 min 31 sec

Shared Control, Uncertainty, Critical Voice

A students says she disagrees, she was reading medication package inserts, she can't recall which one though, it said the site of action is not known.

1. The lecturer says oh yes.

The student says you are taking medication and you don't know what it does.

The Lecturer says yes that is the other problem. So they obviously have this drug, they've tested in vitro (lab conditions) maybe even some cell culture and then it showed promise so

what they did was put it into animal trials and it showed promise again and then into human trials. So they know this drug can treat this condition but the mechanism, how, what, why, when, who – all of those questions remain unknown.

23 min 00 sec

Student Negotiation, Shared Control, Critical Voice, Uncertainty

1. During a discussion by the lecturer on homeopathy it is suggested that ancient knowledge about herbs and plants etc should not be disregarded, itis where we come from. Modern science does not have all the answers.

A student says with all respect to this ancient knowledge, they used to leach blood out to cure this and crack skulls open and they used to break jaws, bones, just because they got one thing right and just because its ancient knowledge does not make it anymore (inaudible) reputable?

The Lecturer says we are not including all those really grim and horrific things that you have mentioned. We are talking of (inaudible) with herbal medicine (inaudible)

23 min 55 sec

Uncertainty

1. The lecturer says: what I am saying is, if you have a lot of researchers that are actually going back and looking at these plants and isolating the active ingredients in order to try and assess their properties. Yes, in the past they never had the tools we have and in 100 years people are going to look at us and say did what they do really mean anything? You must understand it's a process of evolution and that is how we go through things. So don't bash things, it is where we come from.

24 min 36 sec

Student Negotiation, Shared Control, Critical Voice

A student says she's not bashing the use of herbal medicines; she is bashing the not testing of it. You don't just take something; a lot of our medicines come from herbal medicines but were tested before you use them.

1. The lecturer agrees and states that this is where the medicines control council comes in…….

26min 23 sec

Uncertainty

1. The lecturer explains ARV drugs that are not given at right time and doses are very dangerous. There are many side effects and people do not like to mention these as they only look at, yes these are good for HIV infection and that is what we have and that is what we take. So nobody looks at the other effect…. And yes as scientists we design these drugs

but we can't predict all of the effects all of the targets that these drugs would actually bind to.

28 min 11 sec

Student Negotiation

1. The lecturer asks: "what is methotrexate? There is no response so again the lecturer asks: "anyone? Any idea? Methotrexate yes?"

A student replies: "something with a methyl group?

The student, class and lecturer laugh.

2. The lecturer asks: "have you guys not heard of methotrexate?"

The class replies no

The lecturer says that it is an anticancer drug

29 min 08 sec

Personal Relevance

1. The lecturer tells the students that the next time they go to the pharmacy they should read the information on some of the boxes of medicines and they will see how many have targets that are enzymes and many are competitive inhibitors

30 min 12 sec

Student Negotiation

1. After putting up a question similar to those they will get in tests and exams, the lecturer asks: "how do we calculate the value for alpha?
   He answers by explaining how this is done

32 min

2. The lecturer asks if the units need to be converted
   He answers by saying, no as all the units are the same

33 min

3. A student asks a question (inaudible)

The lecturer replies that micro molar is considered large

4. The student now asks: "then what is considered small?"

The lecturer replies: "nano molar, pico molar and femto molar are considered small"

7.2 Interview questions

1. Where did you attend High school and University?
2. What were your teachers like and how would you describe your teachers teaching styles?

3. Who was your favourite teacher and why?
4. What did you study at university?
5. Where did you complete your postgraduate studies and in what field?
6. What were your lecturers like and how would you describe their lecturing styles?
7. Who was your favourite lecturer and why?
8. How long have you been a lecturer?
9. How did it come about that you became a lecturer?
10. Do you enjoy lecturing? What do you enjoy most? What don't you enjoy?
11. What content are you currently teaching?
12. How would you define knowledge? What about scientific knowledge? Is there a difference?
13. What knowledge do you think students doing your course need?
14. In your opinion, how do students know?
15. What is it that you do that enables students to know what you want them to know?
16. How do you think students learn best?
17. What do students need to be able to do at university, in general?
18. What do you consider important in your field as a scientist?
19. How do you as a scientist think? Do you think that you are typical of most scientists?
20. Do you take this into account when designing your curriculum?
21. How would you describe the way in which you teach? – i.e. describe your role in the lecture theatre.
22. How would you describe the way in which you think about teaching and the way in which teaching at tertiary level in general should happen?
23. What would you consider the best approach to teaching and learning?
24. How do you find the students that you have taught?
25. What do you understand by the term curriculum?
26. Describe the curriculum that you are teaching currently?
27. What factors have impacted on the way in which you've designed your curriculum?
28. How do you approach your curriculum design?
29. Are there any superfluous factors that affect the way in which you design your curriculum? –e.g. is it imposed on you?
30. How do you think assessment fits into your curriculum?
31. What do you consider to be the primary aim of assessment?
32. What do you consider important in an assessment?
33. What types of questions do you set?
34. Do students know what to expect from your questions or are they a total surprise?
35. Is this important with respect to your ideas of teaching?
36. How do you know that your students understand what is taught?
37. Is there anything you would like to add or discuss about teaching and learning in general?

7.3 Interview coding – lecturer beliefs

7.3.1 Doctor Alpha Beliefs

Marker 1 (Interview Question 15: What is it that you do that enables students to know what you want them to know?)

Responsive (Student-centred)

"suppose it is doing, it is reading and doing would enable them to know…"

"its actually doing because then it becomes a part of you"

Marker 2 (Interview Question 21: How would you describe the way in which you teach? – i.e. describe your role in the lecture theatre)

Transitional (Content)

" … I try to see myself as more of a facilitator of um information so I am trying to get them to understand the work more than just trying to spew information at them…"

Marker 3 (Interview Question 36: How do you know that your students understand what is taught?)

Instructive (Teacher-centred)

"…suppose ultimately it would come via their marks and their assessment"

Marker 4 (Interview Question's 28-30: How do you approach your curriculum design?, Are there any superfluous factors that affect the way in which you design your curriculum? –e.g. is it imposed on you?, How do you think assessment fits into your curriculum?)

Instructive (Teacher-centred)

"I also try keep it topical so if there is new stuff that's come out, new techniques, new methods, then I will include those and take out the more out-dated stuff"

"it helps to have a textbook and to follow the headings of the textbook"

Marker 5 (Interview Question's 16, 22 and 23: How do you think students learn best?, How would you describe the way in which you think about teaching and the way in which teaching at tertiary level in general should happen?, What would you consider the best approach to teaching and learning?)

Traditional

"…you have to give them notes…"

"…sometimes they need more help getting to the right way of thinking"

Marker 6 (Interview Question 12: How would you define knowledge? What about scientific knowledge? Is there a difference?)

Transitional

"something that becomes inherent inside you, something that becomes a part of you would be your knowledge as opposed to just information that comes and goes"

"it comes through experience"

Marker 7 (Interview Question's 31 and 32: What do you consider to be the primary aim of assessment?, What do you consider important in an assessment?)

Transitional

"to put theory into a more practical vein"

"…to make them…bolster that theory through doing that in practice"

7.3.2 Professor Beta Beliefs

Marker 1 (Interview Question 15: What is it that you do that enables students to know what you want them to know?)

Instructive (Teacher-centred)

"they must have cognitive capabilities of course, then when they have this cognitive abilities they will pick-up what I am teaching"

Marker 2 (Interview Question 21: How would you describe the way in which you teach? – i.e. describe your role in the lecture theatre)

Transitional (Student-centred)

"first of all I am an entertainer"

"the more enthusiastic the lecturer on a topic the higher will be the rate that students taking up the information"

"the lecturer usually picks it up also when he is in class an sees is the student responding…"

Marker 3 (Interview Question 36: How do you know that your students understand what is taught?)

Instructive (Teacher-centred)

"…from the clicker questions, the answers in percentages…"

"…I explain it again to them…"

"…first clicker questions results…second it is the tutorial and third it is the lack of clarity cards…"

Marker 4 (Interview Question's 28-30: How do you approach your curriculum design?, Are there any superfluous factors that affect the way in which you design your curriculum? –e.g. is it imposed on you?, How do you think assessment fits into your curriculum?)

Transitional

"…to include new subjects which are probably of interest for the students"

"because you are teaching something what is really of interest of the students"

Marker 5 (Interview Question's 16, 22 and 23: How do you think students learn best?, How would you describe the way in which you think about teaching and the way in which teaching at tertiary level in general should happen?, What would you consider the best approach to teaching and learning?)

Traditional (Teacher-focused)

"…be fit mentally and physically and the person who is more fit mentally and physically will take up information better, quicker and recall information better and transfer information better"

Marker 6 (Interview Question 12: How would you define knowledge? What about scientific knowledge? Is there a difference?)

Traditional

"Knowledge is a process in a person which can recall information pathways accurately"
"Scientific knowledge is to recall processes as I said before, or information on a scientific level, correctly"

Marker 7 (Interview Question's 31 and 32: What do you consider to be the primary aim of assessment?, What do you consider important in an assessment?)

Traditional

"…multiple choice questions, some questions which has only to fill in the right wording so that means you have no chance, you have to be precise…"
"…and then I follow-up the hierarchy in Blooms Taxonomy of cognitive domain which is comprehension and analysis"

7.3.3 Doctor Gamma Beliefs

Marker 1 (Interview Question 15: What is it that you do that enables students to know what you want them to know?)

Transitional (Cognitive)

"I try to make them think beyond what I teach"

Marker 2 (Interview Question 21: How would you describe the way in which you teach? – i.e. describe your role in the lecture theatre)

Instructive (Teacher-centred)

"the student then get to engage with the material and then I play the role of correcting them or informing them…"

"my roles is just to make sure I clarify the misconception…"

Marker 3 (Interview Question 36: How do you know that your students understand what is taught?)

Instructive (Teacher-focused)

"the only way right now to know if the students understood is through the test and exam…"

Marker 4 (Interview Question's 28-30: How do you approach your curriculum design?, Are there any superfluous factors that affect the way in which you design your curriculum? –e.g. is it imposed on you?, How do you think assessment fits into your curriculum?)

Instructive (Teacher-centred)

"…look at the innovations in terms of in my field of study and say ok, this is the new and then I will probably take from there and mix it with the theory…"

Marker 5 (Interview Question's 16, 22 and 23: How do you think students learn best?, How would you describe the way in which you think about teaching and the way in which teaching at tertiary level in general should happen?, What would you consider the best approach to teaching and learning?)

Transitional (Teacher focused)

"if an individual explain better, for one…"

"whether it is (topic subject) interesting to the students or not…"

Marker 6 (Interview Question 12: How would you define knowledge? What about scientific knowledge? Is there a difference?)

Instructive (Teacher-centred)

"…scientific knowledge is backed-up by facts, by facts that are proven beyond reasonable doubt…"

Marker 7 (Interview Question's 31 and 32: What do you consider to be the primary aim of assessment?, What do you consider important in an assessment?)

Transitional

"check the level of knowledge acquired"

"I will continuously check if the group that I was teaching grasped some of the concepts that I wanted them to …"

7.3.4 Professor Delta Beliefs

Marker 1 (Interview Question 15: What is it that you do that enables students to know what you want them to know?)

Reform-based

"…in fact I am actually quite happy if they are wrong because then we can actually unpack the concept to see why they have misunderstood it, why they thought it was whatever they thought…"

Marker 2 (Interview Question 21: How would you describe the way in which you teach? – i.e. describe your role in the lecture theatre)

Traditional

"a conduit, at certain times information only comes through me…"

"…I try to ensure…that the student tries and understand it the way that I understand it"

"…how I pass on information"

Marker 3 (Interview Question 36: How do you know that your students understand what is taught?)

Instructive

"when I question them…"

"…I would ask a question and based on the feedback and the answers that I get I would know whether they understood or not"

Marker 4 (Interview Question's 28-30: How do you approach your curriculum design?, Are there any superfluous factors that affect the way in which you design your curriculum? –e.g. is it imposed on you?, How do you think assessment fits into your curriculum?)

Instructive

"…and so there are the students that will then become our postgrad students and we require them to understand this kind of material"

"…we would try and expose students to material or to work which is relevant to our own research interests"

"we focus on basic concepts that would be required in molecular and cell biology"

Marker 5 (Interview Question's 16, 22 and 23: How do you think students learn best?, How would you describe the way in which you think about teaching and the way in which teaching at tertiary level in general should happen?, What would you consider the best approach to teaching and learning?)

Responsive

"…when they are passionate about a subject"

"…where there is curiosity…"

"…when they engage with each other…"

"…when they engage with the lecturer"

"…I feel they learn better when its actually students to lecturer because then they framing the question, they are telling you what they know and what they don't know…"

Marker 6 (Interview Question 12: How would you define knowledge? What about scientific knowledge? Is there a difference?)

Responsive

"…knowledge is light"

"…light as in guidance…enabling you to free yourself from oppression or misunderstandings and ignorance"

"…its supposed to guide us to the truth, so that we can understand things in reality…"

Marker 7 (Interview Question's 31 and 32: What do you consider to be the primary aim of assessment?, What do you consider important in an assessment?)

Reform-based

"to apply that knowledge to the understanding of a basic problem"

"apply it or answer a question outside what they have seen from just mere lecture examples…"

7.4 Texts for analysis

7.4.1 Class test questions - Doctor Alpha

Total marks: 70

QUESTION 1 (14 marks)

You wish to purify a protein that consists of three domains: a zinc finger domain, a leucine zipper and a forkhead DNA binding domain. The protein sequence is cloned into a plasmid with ampicillin resistance. The N-terminus is fused to a hexahistadine tag and a thrombin cleavage site.

i) How would you express and purify this protein? Justify your answer fully (6)

ii) Do you expect the zinc finger domain to interfere with your purification method discussed in part i)? How could you account for this? (3)

iii) What is the difference between a domain and a subunit? (3)

iv) Leucine zippers have a coiled coil motif. Describe this form of supersecondary structure (2)

QUESTION 2 (10 marks)

i) Draw L-cysteine and assign its chiral centre either the R or S configuration (3)

ii) What is the unique role of cysteine residues in proteins? (1)

iii) Which is the amino acid that contributes the most to protein fluorescence and why? (2)

iv) Describe what you would do to monitor the fluorescence of a protein in the native and denatured state. (2)

v) Draw a hypothetical fluorescence spectrum to illustrate your answer to iv) above. (2)

QUESTION 3 (5 marks)

A protein has a molecular mass of 50 kDa when measured by gel filtration. When subjected to SDS-PAGE under non reducing conditions, two bands are seen with molecular masses of 30 kDa and 20 kDa. When subjected to SDS-PAGE in the presence of DTT, 2 bands are seen: one at 20 KDa, and 1 at 15 kDa.

i) Why were both gel filtration and SDS-PAGE used in this experiment? (3)

ii) Determine the subunit composition of the protein (2)

QUESTION 4 (6 marks)

i) Explain how dansyl chloride can be used for N-terminal identification of peptides (3)

ii) What can be used for C-terminal identification? (1)

iii) If trypsin cleaves at too few points in a specific protein that you would like to sequence, what could you do and why? (2)

QUESTION 5 (6 marks)

i) Define secondary structure (1)

ii) What spectroscopic technique could you use to study secondary structure? (1)

iii) Draw a typical spectrum from the above mentioned technique for a β-sheet protein (2)

iv) Why are secondary structures mainly found buried within the protein interior? (2)

QUESTION 6 (5 marks)

Briefly discuss the general features of globular proteins

QUESTION 7 (16 marks)

i) What does "resonance" refer to in the term nuclear magnetic resonance? (2)

ii) Draw and label the crystallisation phase diagram (4)

iii) Describe the organisation of a crystal of space group P2 (4)

iv) What are the three properties of waves and how are they accounted for in an X-ray crystallography experiment? (3)

v) What is the Ramachandran plot and how can it be used in validation of protein structures? (3)

QUESTION 8 (9 marks)

i) Discuss the following statement: Proteins fold in response to a balance between opposing forces (5)

ii) Name 2 thermodynamic parameters that can be obtained from a protein unfolding curve and state what these parameters represent (4)

7.4.2 Class test questions - Professor Beta

Total marks: 100

Question 1 (5 marks)

Circle the number of the following correct statement/s. 0.5 marks will be subtracted for any wrong answer; no negative marking will apply

1.) Ebola virus infections, AIDS, Diabetes mellitus, atherosclerosis and Creutzfeldt-Jakob Disease all belong to the group of non-communicable diseases.

2.) Physical exercise decreases the number of mitochondria in muscle cells, resulting in less energy, which weakens strength and endurance.

3.) When glucose levels drop, the prefrontal cortex in the brain sends out signals to stop eating.

4.) Betanin in beetroot slows down the growth rate of prostate and breast cancer cells.

5.) The laminin receptor LRP/LR induces apoptosis and blocks metastasis.

6.) Statins reduce Arachidonic Acid (AA) levels, which is concentrated in bone marrow and promotes spread of prostate cancer.

7.) Approx. 6% of all deaths in South Africa are due to diabetes and related disorders.

8.) Females with mutations in the tumor suppressor BRCA1 have an approx. 80% higher risk to develop breast cancer compared to females expressing wild-type BRCA1.

9.) Women who increase the amount of vitamin C in their diet to 100mg a day have a 22% reduced risk of developing breast cancer.

Question 2 (4 marks)

Circle the following correct answer/s. 0.5 marks will be subtracted for any wrong answer; no negative marking will apply

An African female suffering from AIDS…

1.) has HIV particles using Tyr3 RTK as the main and CXCR4 and CCR5 as co-receptors.

2.) should be treated with a cocktail consisting of inhibitors of reverse transcriptase, protease, integrase and the cell entry process.

3.) might have a heterozygous mutation in her CCR-5 gene which results in a more rapid progression of AIDS.

4.) is suffering from a zoonotic disease.

5.) is suffering from a disease which has been originally transmitted from chimpanzees or sooty mongabeys to humans.

6.) might be treated with a histone acetylase inhibitor which drives out HIV from her DNA, resulting in neutralization of viruses on the cell surface by her natural immune system

7.) must have a mutation in her gene encoding CD4.

Question 3 (5 marks)

A) Describe the role of DC-SIGN in communicable diseases. (3 marks)

B) Name a medical procedure for removing DC-SIGN co-receptors and explain the consequences. (2 marks)

Question 4 (3 marks)

A) What does the acronym "ROS" stand for? (1 mark)

B) Assess the role of ROS in diseases you have heard of. (2 marks)

Question 5 (3 marks)

Circle the following correct statement/s. 0.5 marks will be subtracted for any wrong answer; no negative marking will apply

A person suffering from Parkinson's Disease…

1.) has a mutation in her/his gene for APP, presenilin-1 or has an increased number of alleles for APOE-e4.

2.) has dopaminergic cells.

3.) might have an impaired UPS.

4.) must be heterozygous for methionine at position 129 of the prion gene.

5.) might have mutations in the gene PARK2.

6.) might show an improvement of disease progression when treated with anti-LRP/LR specific antibodies.

Question 6 (3 marks)

Circle the following correct statement/s. 0.5 marks will be subtracted for any wrong answer; no negative marking will apply.

A person 1.90 m tall weighing 109 kg…

1.) has a BMI of 28.55.

2.) is obese.

3.) might suffer from insulin resistance, resulting in an decreased insulin stimulated glucose transport from the blood into erythrocytes and increased lipolysis, respectively.

4.) might suffer from diabetes type 2 and might be treated with substances (i) resulting in lower insulin secretion of pancreatic cells, (ii) decreasing glucose levels in the blood and (iii) decreasing the responsiveness of cells to insulin.

5.) might have a increased risk of developing atherosclerosis.

Question 7 (4 marks)

Circle the following incorrect statements. 0.5 marks will be subtracted for any wrong answer; no negative marking will apply

Atherosclerosis involves/presents as

1.) Foam cell formation, in case LDL is high and HDL is low.

2.) Foam cell formation, in case LDL is low and HDL is high.

3.) atherosclerotic formation with necrotic core of carbohydrates and fibrous cap of rough muscle cells.

4.) atherosclerotic formation with necrotic core of lipids and fibrous cap of smooth muscle cells.

5.) Rupture of the endothelium and occlusive blood clot formation.

6.) Rupture of the foam cells and inclusive blood clot formation.

7.) as stroke, myocardial infarction and angina pectoris.

8.) as stroke, diabetes and obesity.

(1 mark for any correct answer)

Question 8 (4 marks)

Circle the following incorrect statement/s. 0.5 marks will be subtracted for any wrong answer; no negative marking will apply.

Marcrophage foam cell formation involves/is determined by

1.) Adhesion of monocytes to and migration of monocytes through activated endothelial cell layers into the intima.

2.) differentiation into microphages.

3.) low plasma LDL and reduction of LDL to oxLDL.

4.) high plasma LDL and oxidation of LDL to oxLDL.

5.) expression of scavenger receptors by macrophages binding to and Internalizing axLDL, which becomes degraded.

6.) cholesterol accumulation as cholesteryl ester in cytosolic droplets, leading to foam cell formation.

7.) the relative release of LDL-derived cholesterol and the influx of HDL determining the amount of cholesterol accumulation.

Question 9 (3 marks)

Describe the main commonalities between Prion Disorders, Alzheimer's Disease, Huntington's Disease and Parkinson's Disease.

Question 10 (6 marks)

a) Circumcised males have an approximately 63% reduced risk of getting infected with HIV.

Give a detailed explanation for this finding. (2 marks)

b) Explain the fact that sexually transmitted infections (STIs) increase the susceptibility to HIV infection. (4 marks)

Question 11 (2 marks)

Circle the following incorrect statement/s. 0.5 marks will be subtracted for any wrong answer; no negative marking will apply.

NITRIC OXIDE…

a) …is also termed nitrogen monoxide, which is a free radical important for pleiotropic physiological and pathological processes.

b) …causes ischaemic (restriction in blood supply) damage to organs such as the liver.

c) …may result in carcinomas, inflammation, diabetes Type-1, multiple sclerosis and arthritis in case it is chronically expressed.

d) …helps people in high altitudes (e.g. Johannesburg) to avoid hypoxia by aiding pulmonary vasculature vasodilation.

e) …contributes to vessel homeostasis by inhibiting muscle contraction, platelet aggregation, and leukocyte adhesion to the epithelium.

f) …stimulates guanylyl cyclase, producing cGMP from GTP. cGMP then activates protein kinase A, which phosphorylates myosin light-chain phosphatase. This activates myosin light chain-kinase and dephosphorylation of myosin light chain which results in smooth muscle contraction.

Question 12 (6 marks)

Different influenza virus strains are described by antigenicity of HA and NA. Give the full names of HA and NA and explain their function in the life cycle of influenza.

Question 13 (6 marks)

Compare Dengue Virus infections and Ebola Virus infections with respect to:

a) the genome of the infectious agents (2 marks)

b) the clinical symptoms caused (2 marks)

c) the main receptor/s used for virus entry (2 marks)

Question 14 (6 marks)

In this course on the Molecular Basis of Disease, you learnt about a number of diseases. Propose which of them are avoidable and formulate prophylactic actions to avoid them.

7.4.3 Class test questions - Doctor Gamma

Total marks: 20

Question 1

A 0.010mol.dm^{-3} solution of X has an absorbance of 0.5 at 420 nm when in a cuvette with a 1 cm path length. Assuming that the same optical cell has been used, determine the concentration of X if A_{420} is 0.25 (3 marks)

Question 2

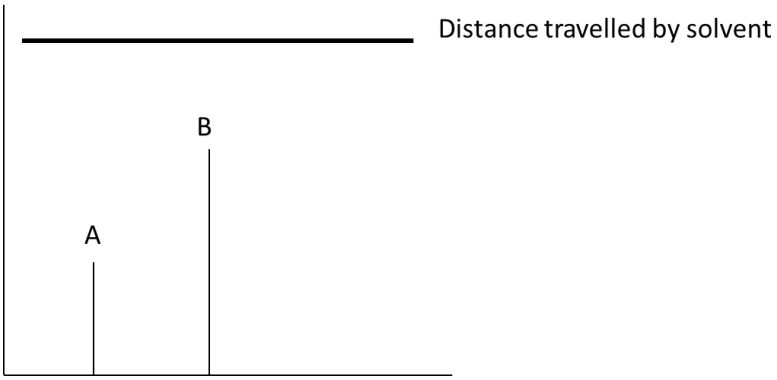
A chromatogram shows two similar sized peaks, one with a retention time of 22.5 min and a peak width of 0.82cm and the second with a retention time of 24.0 min and a peak width of 0.96 cm. The void time is 0.32 min. Calculate the resolution of the peak and the retention factor of the second peak. The chart speed is 0.5cm/min (4 marks)

Question 3

With the aid of a diagram describe flame ionisation chromatography (5 marks)

Question 4

(i) Use the thin layer chromatograph shown below to calculate the retention factors (Rf values) of A and B



(ii) Explain what is suggests about the polarity of A and B (2 marks)

Question 5

a) What is Plank's constant? (2 marks)
b) Describe the equation used to calculate energy using Plank's constant (2 marks)

Question 6

In column chromatography what is meant by the capacity factor (k)? What value of k would you indicate when a system is optimal? (2 marks)

7.4.4 Class test questions - Professor Delta

Total marks: 50

Circle the correct answer. All questions are 1 mark each unless indicated otherwise.

1. _____ is the target enzyme for poisons which interfere with the regular sequence of nerve impulses.

A. Superoxide dismutase

B. Acetylcholine esterase

C. Glutathione transferase

D. Hydrogen peroxidase

E. Catalase

2. The _____ addition of a hydride ion to C4 of _____ results in a _____ hydrogen.

A. re-face; NADH; pro-R

B. re-face; NAD+; pro-S

C. si-face; NAD+; pro-S

D. si-face; NADH; pro-S

E. Both A and C are correct

3. For the reaction E + S ↔ ES, the law of mass action states that

A. Keq = e – ΔG/RT

B. ΔG = ΔH - TΔS

C. Ka = [ES]/[E][S]

D. Kd = [E][S]/[ES]

E. all the above are correct.

4. Which of the reactions below are catalysed by EC4 enzymes?

A. tryptophan → serotonin + CO2

B. fumarate + H2O → L-malate

C. fructose-6-phosphate + ATP → fructose-1,6-bisphosphate + ADP

D. 2-phosphoglycerate ↔ phosphoenolpyruvate + H2O

E. Both A and D are correct

5. The chirality of the α-carbon of cysteine is defined as _____.

A. 2S

B. pro-S

C. 2R

D. pro-R

E. None of the above.

6. _____ is the major non-protein thiol in humans and plays important protective roles in oxidative stress and drug detoxification.

A. γ-Glutamylcysteinylglycine

B. Vita-thion

C. Cysteine

D. Glutathione

E. Both A and D are correct

7. Enzymes have evolved to enhance the _____ between active sites and _____ to better realise _____ in order to lower activation energies and to enhance reaction rates.

A. complemetarity; substrates; binding energies

B. complementarity; transition states; binding energies

C. interactions; products; enthalpy

D. interactions; transition states; binding energies

E. both B and D are correct

8. A hydrogen bond can be formed between

A. a weakly basic donor group and a weakly acidic acceptor group.

B. the lone pair orbitals of two electronegative atoms.

C. two electronegative atoms 4 Å apart.

D. a weakly acidic donor group and a weakly basic acceptor group.

E. none of the above.

9. When an L-□-amino acid is formed from an □-keto acid, the amino group is added to the _____ face of the keto acid.

A. Re

B. Si

C. Pro-re

D. Pro-si

E. Both A and C are correct.

10. _____ specificity refers to the fact that enzymes are quite selective about the identities of the _____ in their substrates.

A. Substrate; opposite charges

B. Geometric; chemical groups

C. Co-enzyme; prosthetic groups

D. Catalytic; pro-chiral carbons

E. All of the above are correct.

11. When investigating the kinetic properties of an enzyme in vitro, it is important to use assay conditions that yield linear reaction progress curves. This will ensure that

A. the relationship between vo and [enzyme] is linear

B. the concentration of product is negligible

C. there are no effects due to a back reaction

D. substrate is still in excess with respect to enzyme

E. all of the above options

12. Given the spectroscopic data shown in the plot below, what is the extinction coefficient in M-1cm-1 for the chromophore? [4 marks]

A. 2.5

B. 1.0

C. 0.25

D. 0.17

E. 0.07

13. For a spontaneous reversible reaction, ΔH = 50.4 kcal/mol; this means that

A. it is favoured enthalpically and entropically.

B. the entropy is negative at all temperatures.

C. The entropy is positive at temperatures below ΔH/ΔS.

D. it is unfavoured enthalpically and favoured entropically.

E. Choices C and D are both correct.

14. Glucose-6-phosphate dehydrogenase catalyses the oxidation of glucose during the pentose phosphate pathway and requires NADP as a coenzyme. This reaction can be monitored continuously with time at 340 nm because of the spectroscopic properties of the _____ form of the _____ ring of NADP.

A. oxidised; ribose

B. reduced; adenine

C. oxidised; adenine

D. reduced; nicotinamide

E. oxidised; nicotinamide

15. Obtaining reaction rate data from non-linear progress curves involves fitting a/an _____ to the _____ section of the curve. This method can be highly _____.

A. straight line; initial; unreliable

B. tangent; initial; inaccurate

C. hyperbole; intermediate; reliable

D. exponential; final; accurate

E. Both A and B are correct.

16. To which class does the enzyme belong that catalyses the following reaction?

A. EC2

B. EC3

C. EC4

D. EC5

E. EC6

17. To which class does the enzyme belong that catalyses the following reaction?

A. EC1

B. EC2

C. EC3

D. EC4

E. EC5

18. The name "enzyme" was coined in 1878 by

A. Emil Fischer

B. Eduard Buchner

C. James Sumner

D. Moses Kunitz

E. Fredrich Kühne

19. _____ was the first enzyme to be crystallised demonstrating the protein nature of enzymes.

A. Lysozyme

B. Urease

C. DNase

D. RNase

E. None of the above.

20. Enzyme-catalysed reactions are highly stereospecific because of the inherent _____ of enzyme structures and, thus, the _____ nature of their active sites.

A. symmetry; chiral

B. shape; polarity

C. asymmetry; symmetric

D. flexibility; dynamic

E. chirality; asymmetric

Question 21.

What are the two main features identified in X-ray studies of enzymes (2 marks)

Question 22.

Distinguish between the following terms: (2 x 2 marks = 4 marks)

1. Cofactors and Coenzymes.

2. Holoenzyme and Apoenzyme.

Question 23.

Briefly discuss the reasons for non-linear progress curves the during acquisition of enzyme kinetics data. (4 marks)

Question 24.

Write short notes describing the use of the following techniques in monitoring the progress of an enzyme-catalysed reaction. (3 x 4 marks each = 12 marks)

Fluorescence:

Radioisotopes:

Immunochemical:

Question 25.

The following enzyme kinetics assay details are given:

Non-enzymatic reaction rate (AU/sec): 1.4565x10-4

Rates of the enzyme-catalysed reaction.

Readings (AU/sec): 1. 3.3262x10-3

2. 3.3343x10-3

3. 3.3398x10-5

4. 3.3094x10-3

ε (substrate) = 9600 M-1.cm-1

Volume of enzyme used: 20 µL

Total reaction volume (including enzyme): 2 mL

Concentration of stock enzyme: 1 µM

Enzyme molecular weight: 54 kDa

Answer the following questions:

1. Calculate the velocity of the enzyme in µM.min-1. (2 marks)

2. Calculate the velocity in µmol.min-1. (1 mark)

3. Calculate the specific activity of the enzyme. (2 marks)

7.5 Text analysis

The following colour coded summary can be used for ease of reference for the text analysis data:

Coding	Colour
Factual level1 (F1)	
Factual level 2 (F2)	

Factual level 3 (F3)	
Conceptual level 1 (C1)	
Conceptual level 2 (C2)	
Conceptual level 3 (C3)	
Procedural level 1 (P1)	
Procedural level 2 (P2)	
Procedural level 3 (P3)	

7.5.1 Class Test Coding – Doctor Alpha

Total 71 Marks

8 (26 including sub questions) Questions

Question number	Knowledge and Cognitive Process Dimension	Mark Count
1I	C3	6
1II	C2	3
1III	F1	3
1IV	F1	2
2I	P1	3
2II	F1	1
2III	F2	2
2IV	C2	2
2V	P2	2
3I	C1	3
3II	C3	2
4I	F3	3
4II	F1	1
4III	C2	2
5I	F1	1
5II	F1	1
5III	P2	2
5IV	F2	2
6	F1	5
7I	F1	2
7II	P1	4
7III	C2	4
7IV	F2	3
7V	F2	3
8I	C2	5
8II	F1	4

Percentage of Questions (percentage of marks)

% F1 = 34.6 (28.2% of marks) % C1 = 3.8 (4.2% of marks) % P1 = 7.7 (9.9% of marks)

% F2 = 15.4 (14.1% of marks) % C2 = 19.2 (22.5% of marks) % P2 = 7.7 (5.6% of marks)

% F3 = 3.8 (4.2% of marks) % C3 = 7.7 (11.3% of marks)

MARKS: 46.5% Factual 38% Conceptual 15.5% Procedural

7.5.2 Class Test Coding – Professor Beta

Total 60 Marks

14 (19 including sub questions) Questions

Question number	Knowledge and Cognitive Process Dimension	Mark Count
1	F1	5
2	F1	4
3a	F2	3
3b	F2	2
4a	F1	1
4b	F3	2
5	F1	3
6	C1/C2	3
7	F1	4
8	F1	4
9	F3	3
10a	C1	2
10b	C1	4
11	F2	2
12	F1	6
13a	F3	2
13b	F3	2
13c	F3	2
14	C3	6

Number of Questions (percentage of marks)

% F1 = 36.8 (45% of marks) % C1 = 15.8 (15% of marks)

% F2 = 15.8 (12% of marks)

% F3 = 26.3 (18% of marks) % C3 = 5.3 (10% of marks)

MARKS: 75% Factual 25% Conceptual 0% Procedural

7.5.3 Class Test Coding – Doctor Gamma

Total 20 Marks

6 (8 including sub questions) Questions

Question number	Knowledge and Cognitive Process Dimension	Mark Count
1	P2	3
2	P3	4
3	P2	5
4I	P2	1
4II	C2	1
5A	F1	2
5B	F2	2
6	F2	2

Percentage of questions (Percentage of marks)

% F1 = 12.5 (10% of marks)

% F2 = 25 (20% of marks) % C2 = 12.5 (5% of marks) % P2 = 37.5 (45% of marks)

% P3 = 12.5 (20% of marks)

MARKS: 30% Factual 5% Conceptual 65% Procedural

7.5.4 Class Test Coding – Professor Delta

Total 47 Marks

25 (30 including sub questions) Questions

Question number	Knowledge and Cognitive Process Dimension	Mark Count
1	F1	1
2	F1	1
3	F1	1
4	F2	1
5	F1	1
6	F1	1
7	F2	1
8	F1	1
9	F1	1
10	F1	1
11	C1	1
12	P2	1
13	C2	1
14	F1	1
15	C2	1
16	F2	1
17	F2	1
18	F1	1
19	F1	1
20	F2	1
21	F1	2
22.1	F2	2
22.2	F2	2
23	C2	4
24A	F3	4
24B	F3	4
244C	F3	4
25.1	P2	2
25.2	P2	1
25.3	P2	2

Percentage questions (percentage marks)

% F1 = 40 (27.7% of marks)	% C1 = 3.3 (2.1% of marks)	
% F2 = 23.3 (19.2% of marks)	% C2 = 10 (12.8% of marks)	% P2 = 13.3 (12.7% of marks)
% F3 = 10 (25.5% of marks)		

MARKS:	72.4% Factual	14.9% Conceptual	12.7% Procedural