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AN EXPLORATION OF SCIENCE LECTURERS' VIEWS ON QUALITY TEACHING IN SCIENCE AT UNIVERSITY

A thesis presented in partial fulfilment of the requirements

for the degree of

Doctor of Philosophy

in Education

at Massey University, Palmerston North,

New Zealand

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ABSTRACT

Undergraduate university students learn science in ways that are different to those used in professional science laboratories and do not prepare them for their work as practising scientists. This study aimed to explore lecturers' views on quality teaching and learning in science and what influenced their views and practice.

I developed a theoretical framework of sensitising lenses based on quality as a complex system and wicked problem, to explore science lecturers' views on quality teaching and learning in undergraduate science. This framework, together with key ideas from complexity thinking, guided all aspects of the research. The research design was a multistage mixed methods approach consisting of a dissensus Delphi study followed by a large-scale survey and semi-structured interviews.

The problem definition, openness and social complexity lenses identified characteristics that science lecturers associated with quality teaching and learning in undergraduate science. Quantitative data revealed views with varying extents of consensus on these characteristics. Based on these views I proposed a transformative framework for understanding quality teaching and learning in undergraduate science in which generic principles of good teaching are embedded in ways of thinking and practising in science, social relationships are promoted, and variable cultural and sub-discipline factors are included according to the specific context. From this, quality could be viewed as a complex system (rather than a wicked problem) and conditions for its emergence proposed.

The non-linearity and multiple-causality lenses identified influences affecting lecturers' quality teaching. These showed the main driver of lecturers' changing their teaching was reflective practice, with student feedback the main contributor to this. However, findings from quantitative data showed many characteristics associated with quality teaching were implemented less often than expected, suggesting reflective practice was underutilised. I suggest the potential gap between reflective practice and action is teacher agency. With the aid of the problem resolution lens, I propose a conceptual framework for quality teaching in undergraduate science that has the potential for the

emergence of quality from a complex system, and recommend actions for lecturers, educational development and institutions to help achieve this potential.

ACKNOWLEDGEMENTS

I would like to thank my supervisors Nick Zepke, Linda Leach and Peter Rawlins for the opportunity to pursue the research. Your support and encouragement made this intellectual journey possible.

I thank my family for tolerating 'Mrs Grumpy', especially during the protracted writing-up phase.

I am extremely grateful for financial support for the research from the following: Institute of Education, Massey University; Institute of Fundamental Sciences, Massey University; and Ako Aotearoa.

Most of all, I thank the science lecturers who gave their time in contributing their views, without you this research would not have been possible. I am especially grateful to members of the Delphi panel including: Gary Bold, Juliet Gerrard, Kevin Gould, Judy Magee, Derek Moot and Michael Walker.

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CHAPTER 1: INTRODUCTION

1.1 My background and interest in this topic

I'm a scientist, lecturer, immigrant, mother, educator and advocate, not necessarily in that order. I am a senior lecturer in microbiology and have been a university lecturer since 2002, soon after arriving in New Zealand from the United Kingdom. However, I became a university lecturer by accident rather than design. I was always interested in science and initially trained as a medical laboratory scientific officer in microbiology after leaving school, studying on-the-job and through day release and evening classes at technical college. As the profession changed to graduate entry, along with nursing and other health-related professions, I thought it prudent to upgrade my qualifications and left work for university. A BSc (Hons) in microbiology led to a PhD scholarship followed by a post-doctoral research fellowship and finally a permanent position as a research scientist with a Crown Research Institute. I was a full-time research scientist, supervised postgraduate research projects in collaboration with local universities and organised short in-house courses for technical and junior medical staff. I enjoyed the limited supervision and teaching for which I was responsible but my focus was unequivocally scientific research.

I became a lecturer as the result of serendipity. My family and I moved to New Zealand in 2001 when my husband secured a job at a city hospital. Our daughter was four years old, had not yet started school, and I was happy to spend time with her and helping the family settle into life in New Zealand. Three months later, our daughter settled at school and a house bought, the novelty of staying at home had worn off and I missed science so I sent my curriculum vitae to the local university. Serendipity struck and they needed a lecturer in microbiology, having been unable to find a suitable replacement for one who had recently moved abroad. The university viewed my research experience favourably and offered me a position as lecturer.

However, being a scientist and teaching undergraduate science were very different things. The lecturer position involved lecturing and supervising laboratory classes for

200-level science students studying introductory microbiology. Initially, I used the material from the previous lecturer and quickly came to the conclusion that there had to be a better way of teaching science than delivering lectures from the front of the class and supervising laboratory classes based on following a recipe-like format. As a practising scientist, I had experienced much more social, discussion-based teaching and learning. My experiences as a practising scientist, prior to becoming a university science lecturer, suggested that there was a disconnection between the practice of science and the teaching of science at university undergraduate level.

My concerns about undergraduate science teaching led me to study education. Discussing my view that there should be better ways of teaching than lecturing with colleagues in the staffroom, in particular, a tutor with a background in teaching in the secondary schools sector and studying for a Master of Education, led to the suggestion that I should pursue 700-level papers in education. Subsequently, I enrolled in the Postgraduate Certificate in Tertiary Teaching followed by the Postgraduate Diploma in Education (Adult Education). These courses transformed my thinking on teaching and learning and, combined with my experience as a practising scientist, led to significant changes in my teaching practice. These were both major contributions to the teaching that led to my Ako Aotearoa tertiary teaching excellence award (TTEA) in 2012.

1.2 Undergraduate science teaching and quality

The way that undergraduate students have traditionally learnt science at university is not the same as how it is learnt in professional science laboratories and does not prepare students for the way that practising scientists use science (Fischer, 2011; National Research Council (U.S.) Committee on Undergraduate Biology Education to Prepare Research Scientists for the 21st Century, 2003). Teachers have a significant influence on student learning (Entwistle, 2003; Hattie, 2012). However, the predominant teaching and learning activities in science at universities remain traditional lectures and prescriptive laboratory sessions despite overwhelming evidence in the educational literature that other activities can increase student engagement and enhance learning (Biggs, 2011; Handelsman et al., 2004; Waldrop,

2015; Wieman, 2014). To enhance the education of undergraduate science students, it is necessary to understand why university science lecturers teach the way they do.

Principles of good teaching advocated for higher education are generic in nature and do not take account of discipline (Biggs, 2011; Chickering & Gamson, 1987). However, there is considerable support for the notion that disciplines such as those in the sciences have their own approaches to learning and hence quality teaching (Coppola & Krajcik, 2013). This is shaped by the specific knowledge underpinning disciplines and has been characterised as 'ways of thinking and practising' in a discipline (Entwistle, 2005; McCune & Hounsell, 2005). To work effectively in science, graduates need good problem-solving and communication skills in addition to specialist scientific skills (Anonymous, 2015; Chan, 2011), hence it is important that opportunities to learn both are provided in science teaching.

The appointment of academic staff, the main staff responsible for teaching students in higher education institutions, is based on research achievements for university staff, or industry experience for polytechnic staff. In contrast to the primary and the secondary school sectors, no formal teaching qualifications are required for staff to teach in the New Zealand higher education sector. This results in academic staff with little or no formal experience of teaching or teaching qualifications being responsible for the education of large numbers of students.

A Bachelor of Science degree is required to work in most scientific professions, for example, as a laboratory technician in the agricultural, chemical, food, health or pharmaceutical industries. Since 2002, government funding of institutions offering degree-level programs has been partly dependent on the quality of their research outputs, determined through the Performance Based Research Funding (PBRF) model. As the institutions traditionally most involved in research, universities are the most affected by the implementation of PBRF. Although PBRF was intended to enable governments to target and invest in the research most likely to yield returns, it has led to universities encouraging individual academics to prioritise activities that will improve their PBRF ranking (Roa, Beggs, Williams, & Moller, 2009). In addition to disadvantaging long-term research, practical and applied research, Māori knowledge

and culture, women, collaborative research and local research, the inevitable effect of prioritising research outputs in universities is that teaching has become a lesser priority. This is of particular concern in undergraduate science where teacher-led learning remains the default pedagogy (Waldrop, 2015).

Research indicates that the whole learning environment influences student learning (Bryson & Hand, 2007; Entwistle, 2003). The teacher has a vital role in enabling student learning through his/her teaching approaches and these are influenced by his/her perceptions about teaching and learning (Entwistle, 2003; Trigwell & Prosser, 1996). Therefore, science lecturers' teaching approaches, and beliefs about teaching, contribute to quality teaching and learning in undergraduate science. However, there is a lack of research on understanding why traditional lecturing and prescriptive laboratory formats continue to dominate undergraduate science teaching.

Quality *per se* is a contested notion in education with multiple meanings and diverse purposes. Quality is perceived as a 'wicked' problem and a complex problem. Wicked problems are ill-defined, have stakeholder-dependent views, change with time and context and today's apparent solution may fail tomorrow (Krause, 2012). For example, the stakeholder groups involved in quality in higher education in New Zealand include students, lecturers, departmental managers, university (or polytechnic) management, educational developers, funding agencies, government, graduate-employing industries and cultural groups that vary with location and topic. Students may view quality in terms of how closely classes relate to assessments within a course whereas university managers may view quality in terms of course pass rates or even programme completion rates, for example, in BSc (Microbiology). Complexity thinking also may be applicable to quality (Davis, 2008; Davis & Sumara, 2010). This considers whole systems with their multiple interacting components and conditions that promote change. I suggest both concepts may contribute to the understanding of quality teaching and learning in undergraduate science.

Because of the differences between how science is learnt and practised in professional laboratories, and undergraduate science teaching, I was interested in exploring lecturers' views of quality teaching and learning. My views on quality, learning,

teaching, and the purpose of education will influence how I interpret the results of this study so I state them here. I consider quality to be transformation, a significant change in thinking that emerges from a complex system, and its purpose to be transformative in enhancing the cognitive, emotional and physical skills of students, and empowering by enabling students to influence their own learning process (Harvey & Knight, 1996). This concept of quality as transformation accords with education being a participatory process and contrasts with views of quality as a consumer product.

I believe learning occurs by doing, and either thinking about a new experience or thinking about an old experience in a new way, and connecting this to existing knowledge in the cognitive, physical or emotional domains. I believe social interaction may aid this but is not essential, and that context is extremely important for learning. I also believe that individuals may have different learning preferences and that these may vary at different times and in different environments. I believe learning should be transformative in the sense of significant intellectual and personal development (Hoggan, 2016). I believe the role of teaching is to enable learning. Also, I believe that education should enable students to fulfil their individual academic potential and to be socially responsible contributing citizens and that these are both important in undergraduate science education; these are being increasingly recognised as important in all higher education (Blum & Bourn, 2013).

In summary, my experiences as a practising scientist and university lecturer, and the educational research showing the benefits of active learning in undergraduate science (Handelsman et al., 2004), suggest there is a disconnection between the way students learn science in professional laboratories and at university. Teachers have a significant influence on student learning (Entwistle, 2003; Hattie, 2012) and therefore have a professional and moral responsibility to make this a constructive and positive influence. The current funding system for universities in New Zealand has produced a climate that prioritises research over teaching and therefore adversely affects undergraduate students' education, especially as this sector does not require formal teaching qualifications. Also, there appears to be a resistance to change from traditional lecture-based teaching to more active approaches in the sciences (Waldrop, 2015). Exploring university science lecturers' views on quality teaching and learning

may lead to an understanding of quality in teaching and learning as a concept within the discipline of science at the university level. I expect that this, together with an exploration of the specific influences on science lecturers' teaching, will contribute to an understanding of the ways in which science lecturers' teach. An increased understanding of this will aid the design of educational development approaches for use by, and with, this group to influence teaching practice and enhance student learning in science, or affect other changes to do this.

My study is specifically interested in the views of science lecturers in universities because: (1) traditionally they have little or no formal teacher training yet are responsible for the teaching and learning of students; (2) very few studies have been published on lecturers' views and this thesis intends to contribute to the research on science lecturers' understanding of quality teaching as well as to the general research literature and (3) I am a science lecturer, tertiary teaching excellence award-winner and a student of tertiary science education who wants to make a difference.

1.3 Aims of the Research

This research aimed to explore the meanings university lecturers ascribe to quality teaching and learning in undergraduate science, the influences on their teaching, and to use the findings to create proposals for action. To do this, I planned to use a mixed methods research design as this combines the advantages of depth from approaches giving qualitative data and breadth from approaches yielding quantitative data.

1.3.1 Research Questions

The main research question was:

What do university science lecturers in New Zealand consider to be quality teaching and learning in undergraduate science?

To inform this question, I developed five sub-questions:

1. What do national award-winning tertiary teachers consider to be quality teaching and learning in undergraduate science?

2. What do a larger sample of university science lecturers consider to be quality teaching and learning in undergraduate science?
3. What are the main influences on lecturers' views on teaching and learning?¹
4. What implications do these findings have for university science lecturer educational development programmes?
5. What other proposals for action arise from this?

1.4 Overview of the thesis

I present this thesis in nine chapters. In this first chapter, I provide the background and context for the study including my background as a practising scientist and lecturer that led to my interest in this topic. The chapter highlights the funding issues facing New Zealand universities and issues in undergraduate science teaching in general.

In chapter two, I review the current literature most relevant to the research. I outline quality as a contested notion in higher education and justify the focus on complexity thinking and quality as an emergent property. The relationship between quality teaching and learning in undergraduate science is highlighted.

I explain the methodology and methods employed in this research in chapter three. I justify the sensitising lenses framework based on complexity thinking and wickedity, and the multistage mixed-methods design consisting of a Delphi study followed by a lecturer survey and interviews. I relate each stage of the design to the research questions. I also outline the data collection and analysis methods.

In chapter four, I present the analysis and interpretation of the data from the dissensus Delphi study in Phase 1 of the research. The findings from this provide example

¹ The focus of this sub-question changed during the study. In Phase 1, the focus was on development as a teacher. In response to survey findings in Phase 2, this was expanded to explore broader influences on teaching and became: 'What are the main influences on lecturers' quality teaching'.

statements for a range of characteristics associated with quality teaching and learning in science that form the basis of the lecturer survey in Phase 2 of the research.

Chapter five presents the findings from the lecturer survey in Phase 2 of the research. Exploratory factor analysis of quantitative data reveals underlying factors and statistical analysis determines any significant differences between universities or disciplines within the sciences. Quality related characteristics and influences on teaching are identified by viewing qualitative data through the sensitising lenses.

In chapter six, I present the findings from the lecturer interviews, completing Phase 2 of the research. Quality related characteristics and influences on teaching are identified by viewing the interview data through the sensitising lenses.

Chapter seven integrates the findings from chapters four, five and six. This provides categories of characteristics of quality teaching in science with varying extents of consensus.

Chapter eight discusses the main findings. This focuses on the concepts arising from the research and relates these to the literature. I propose a transformative framework for understanding quality teaching and learning in undergraduate science. Based on this, and quality as a complex system, I propose a conceptual framework for the emergence of quality.

In Chapter nine, I summarise the research findings and offer some practical recommendations for providing conditions with the potential to lead to the emergence of quality. Finally, I suggest some areas for future research and then conclude this thesis.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This review focuses on quality teaching and learning in science at the undergraduate level in universities. I start with a review of the literature on quality in higher education including the contested nature of quality, lecturers' views of quality and quality as a complex problem. Then I review quality teaching and learning, with a brief sketch of learning theories, and the relationship between learning, teaching and the lecturer. I then focus on teaching and learning in science, and science lecturers' views of quality teaching and learning. I conclude with a brief review of the main influences on university lecturers' teaching and justify the need for this study. The intention is to provide an overview of key features of relevance to this study rather than a comprehensive or critical review of quality teaching and learning in general.

2.2 Quality in higher education

Higher education has undergone enormous changes in the last 30 years including wider student participation, the need for institutions' contributions to society to be more visible, especially meeting employers' needs, and ready access to information through the internet. Barnett (2000) described the change in higher education in the 21st century as a shift from universities' traditional primary role as knowledge producers to one of performativity—or 'doers'—and encouraging a climate of performing 'to the test' (or to achieve specific outcomes) that is unlikely to produce the human qualities necessary in the current age of supercomplexity (Barnett, 2000; Bengtson, 2018). Along with performativity, business practices including accountability for government funding and requirements for evidence of quality have been increasingly applied to higher education (Biesta, 2004).

2.2.1 Quality is a contested notion

During the last 30 years, the idea of quality has increasingly dominated the higher education landscape. However, the meaning of quality in an educational context often varies with the group using the term and can refer to processes or outcomes. Five meanings are commonly ascribed to quality in higher education: quality as exceptional

(or excellence), perfection (or consistency, conforming to standards), fitness for purpose (meeting minimum requirements), value for money, and transformative (changing the student participant, enhancing and empowering them) (Harvey & Green, 1993; Harvey & Knight, 1996; Harvey & Williams, 2010a). Quality as perfection and quality as transformation focus on the process whereas the other definitions focus on outcomes. In addition, two main forms of quality are identified: Type 1 (or quality assurance) is associated with a performativity and accountability focus and Type 2 (or quality enhancement) is focused on enhancement of student learning (Knight & Trowler, 2000b).

There are a range of perspectives on the relationship between quality assurance and quality enhancement including at least: separate, in opposition, assurance linearly leading to enhancement, and integral (Williams, 2016). Accountability and enhancement are perceived as separate due to the disparate interests of the stakeholders involved—governments, academics, students and the public—with some groups viewing these as in opposition to each other. Occasionally, for example in Scotland, quality assurance is considered to lead to quality enhancement. Finally, quality assurance and quality enhancement are viewed as parts of the same cycle, including students and staff in the process. A review of 15 years of publication in *Quality in Higher Education* found that quality assurance systems from north-west Europe and USA have been applied globally irrespective of the context (Harvey & Williams, 2010a). Also, external quality evaluations did not necessarily lead to improvement and are associated with loss of academics' trust. Quality assurance is associated with clearer documentation and transparency but academics have resisted the consumerist approach to higher education quality (Harvey & Williams, 2010b).

It has been suggested that lecturers have been alienated in the quality assurance process and should be more closely involved as they are often responsible for implementing changes recommended to enhance student learning. Biesta (2004) refers to the rise of accountability in education as part of a wider societal culture of accountability that has dramatically changed relationships and the self-perceptions of those involved. He argues that the accountability culture makes a shared concern for the common good impossible and that it is a professional task for academics to reclaim

this (political) responsibility. A rethink of quality assurance systems to clarify their foundations, including the purpose of education, also has been urged (Biesta, 2009; Blackmur, 2010). Using a critical systems approach, an exploration of the relationships between knowledge, power and meanings given to quality assurance systems by the various communities involved showed the systems served the accountability purposes of agencies outside universities rather than academics (Houston & Paewai, 2013). These authors suggest the power and knowledge distance between designers of quality assurance and academics leads to systems that are incapable of enhancing university teaching and research. Interestingly, an analysis of the contribution of quality enhancement to the power play in the politics of quality assurance in the UK found quality assurance personnel acknowledged that quality came from people providing the programmes, i.e. lecturers (Filippakou, 2017). She also suggested New Zealand higher education is in a similar position to England, Wales and Australia in terms of state control and quality assurance with strong state control of quality assurance systems but little associated quality enhancement (Figure 1).

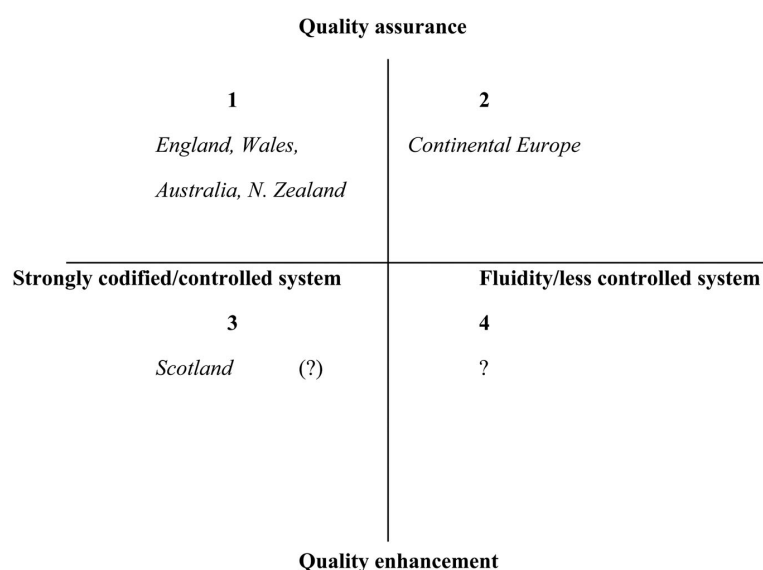


Figure 1. A diagrammatic representation of national quality systems. ? indicates that the space below the horizontal line is sparsely populated. Reprinted from 'The Evolution of the Quality Agenda in Higher Education: The Politics of Legitimation', by O. Filippakou, 2017, *Journal of Educational Admin & History*, Volume 49(1), p. 49. Copyright 2017 by Taylor & Francis. Reprinted with permission.

It is likely that the USA would fit mostly in quadrant 1 on this model, with some variation between states, whereas Taiwan may fit in quadrant 3 (Cheng, 2015). A move

towards greater governmental regulation and less self-regulation by institutions was noted in the USA whereas the opposite situation in Taiwan provided a climate conducive to institutional self-improvement (Cheng, 2015). The importance of networking with international quality assurance agencies rather than governments to enhance quality assurance in developing countries in Asia, especially with the massification of education in this region, was noted by Hou et al. (2015).

Quality is political and reflects power and prevailing discourses, for example, marketisation of higher education. This has led to distrust by, and alienation of, those who enact quality, for example, lecturers and course designers. According to Biesta (2004) this leaves quality enhancement to individuals, uncoordinated and in danger of being no one's responsibility unless reclaimed by lecturers.

Impact of quality assurance on quality enhancement

Despite the rise in quality assurance practices, there is very limited evidence of a positive effect of these on enhancing teaching and learning with Houston (2010) suggesting there has been little meaningful involvement from academic staff. Although quality improvement may have been a secondary goal of quality assurance, it is the aspect that encourages lecturers to actively participate (Westerheijden, Hulpiau, & Waeytens, 2007). However, follow-up depends on the institution. A study of audit processes in 30 Australian universities showed that external audit, and the external and internal operating environment, positively influenced quality assurance processes within universities (Shah, 2013). There were improvements in the collection of student surveys and feedback but there was limited improvement in enhancing the student experience. The study also suggested a systemic failure to determine educational outcomes for students. A written survey of Portuguese academics on the effects of the implementation of an internal quality assurance system on teaching and learning indicated increased bureaucracy, more interest in teaching but no improvement in teaching and learning (Tavares, Sin, Videira, & Amaral, 2017). The authors suggest these findings may be due to a lack of improvement in pedagogic training. Their survey findings also indicated that lecturers considered being involved in development of

quality assurance, and using the information, would potentially improve teaching and learning.

Attempts to standardise quality assurance systems in Europe, intended to encompass both accountability and enhancement, have resulted in a prevailing discourse of accountability. Brady and Bates (2015) reported a case study of a business faculty in the UK that showed how quality assurance subverted teaching and learning. One effect revealed in their study was a 'culture of dissociation' where lecturers lost their community of practice and the authors suggest that uniform standards and excessive control may therefore lead to a reduction in quality teaching and learning. In an alternative approach in Norway, lecturers viewed a learning outcomes approach as more useful than a traditional quality assurance approach for quality enhancement (Aamodt, Frølich, & Stensaker, 2018).

The meanings of quality in higher education vary with the group applying the term. There is a range of perspectives on the relationships between quality assurance and quality enhancement with a suggestion that assurance has become political, and lecturers have been alienated from the assurance process, making enhancement impossible (Filippakou, 2017; Houston & Paewai, 2013). There is a need for lecturers to reclaim responsibility for quality and for enhancement and assurance to work closely together for the benefit of student learning (Biesta, 2004).

2.2.2 University lecturers' views of quality

There have been relatively few studies of science lecturers' conceptions of quality (Jordens & Zepke, 2017; Lomas, 2007). The literature shows variations between lecturers from different cultures and their views on quality, its purpose and their willingness to enact systems imposed from external authorities. Lomas interviewed 20 lecturers from a range of disciplines in the UK and the majority of these associated quality with fitness for purpose and accountability (Lomas, 2007). A literature and interview-based study of academics' conceptions of quality and quality assurance in Finnish and English higher education systems indicated an association with a management Type 1 quality assurance model in England whereas in Finland lecturers associated aspects of Type 1 and Type 2 quality with quality assurance (Lomas & Ursin,

2009). However, lecturers were asked directly about 'quality assurance' in the Finnish studies rather than 'quality', so the groups may not be comparable. Also, the concept of quality assurance was relatively new but increasing in Finland at this time with the formation of the European Higher Education Area and the Bologna Process, indicating a possible influence of Type 1 quality on these lecturers.

Comparison of current beliefs about quality, and what it ought to be, among Turkish and Australian business academics using a questionnaire-based interview showed that the majority of Turkish academics believed quality as excellence was the current and desired perception. In contrast, the majority of Australian academics viewed quality as fitness for purpose in their current situation but desired quality as transformation (Kalayci, Watty, & Hayirsever, 2012). A written questionnaire of Dutch academics' perceptions of quality indicated they viewed it as enhancement of student learning and improvement of the department rather than external compliance (Kleijnen, Dolmans, Willems, & Hout, 2013). Interviews of Dutch University academics' conceptions of quality, quality management and organisational values in three departments found similarities in quality viewed as a continuous improvement in education and staff valued human relations in organisations (Kleijnen, Dolmans, Willems, & van Hout, 2014). Effective departments were closely connected with their quality management and enacted their values, for example, cooperation and open communication. These studies suggest that the audit processes in Finland and the Netherlands may sit within quadrant 4 of Figure 1 rather than quadrant 3.

A questionnaire-based study of lecturers' views on quality assessment in Portugal strongly supported three purposes for quality assurance, improvement, communication and innovation, all aspects of quality enhancement (Rosa, Sarrico, & Amaral, 2012). Interviews of lecturers from the Netherlands and the UK showed that UK lecturers resented the emphasis on quality assurance and control whereas Dutch lecturers focused on dealing with the developments (Teelken & Lomas, 2009). A standardised quality assurance system has not been widely accepted by Italian universities; these are considered unusual in Europe and have been described as being academic oligarchies because of the relative power of the professoriate (Dobbins, 2015; Pompili, 2010).

The few studies on lecturers' views on quality show variations between different cultures. It is clear from the literature on the relationship between quality assurance and enhancement above that the importance of quality enhancement needs to be elevated in universities. Also, the connection to quality assurance needs to be made visible to lecturers and students if such systems expect lecturers and students to be active participants in the process of quality improvement. Type 2 quality, enhancement of student learning, is the focus of this study. Lecturers are key actors in the teaching and learning relationship, hence, it is important to determine their views on quality as these will influence the learning environment and teaching and learning relationship.

2.2.3 Quality is a complex problem

Quality is linked to policy-making and funding at macro and micro levels in higher education and yet is largely under theorised (Krause, 2012). Quality in education is also perceived as a 'wicked' problem: problems which are ill-defined, have stakeholder-dependent views, multiple interdependencies and causalities, change with time and context, and for which a solution may work one day but not the next (Krause, 2012). Wicked problems are not usually amenable to the linear problem-solving solutions applicable to 'tame' problems (Crowley & Head, 2017). Some examples of wicked problems include health promotion in New Zealand (Signal et al., 2013), land use systems in Scotland (Duckett, Feliciano, Martin-Ortega, & Munoz-Rojas, 2016), managing biological invasions (Woodford et al., 2016), managing ecosystems (Defries & Nagendra, 2017) and medical education (Varpio, Aschenbrener, & Bates, 2017). Krause suggests the 'complexity' of quality may not be amenable to a single theory and that 'there is scope for ambiguity and multiple theoretical perspectives in relation to quality' (Krause, 2012, p. 289).

Complexity thinking also helps to understand the complexity of quality. This considers whole systems and conditions that promote change, involve multiple interacting components with ill-defined boundaries in an open dynamic system, and may be applicable to quality (Davis, 2008; Davis & Sumara, 2010). A complex system is described as 'a system comprised of a large number of entities that display a high level

of interactivity. The nature of this interactivity is mostly non-linear, containing manifest feedback loops' (Richardson, Cilliers, & Lissack, 2001, p. 7). A complex system is also open to interactions beyond itself and adaptive as the agents respond to conditions depending on previous experiences, contributing to nonlinearity. Agents are part of feedback and feedforward loops giving the system iterative behaviour. Complexity thinking is advocated as a new science of qualities to complement the science of quantities applicable to social phenomena characterised by change and transformation (Horn, 2008). The key drivers for change in these complex systems are information flow, connectivity between agents and the diversity within and between agents (Horn, 2008). Indeed, complexity theory is advocated as a theory of change, able to investigate the social world holistically to help understand and research 'causation' in social research (Morrison, 2012). Complexity thinking involves investigating systems as a whole and as nested within each other to understand their interactions. In response to a given set of interactions and timeframe, a new form of organisation may emerge that is qualitatively different from the preceding system—this is the principle of emergence. A holistic view of the conditions in a given system is needed to help understand emergence as interactions between elements cause non-linear and unpredictable changes. Hence, complexity thinking helps suggest actions that promote conditions for emergence in a given context.

The important features of complex systems include system history, a diversity of behaviours, chaos and self-organisation. Importantly, they are incompressible and cannot be reduced or bounded without losing behaviours of possible importance; they are open systems where the interactions and relationships of the parts determine the characteristics of the whole (Richardson et al., 2001). Complexity thinking provides a way of thinking, based on complex systems, that focuses on the limits of knowledge and the provisional nature of understanding (Richardson & Cilliers, 2001).

Complexity thinking has been applied to several situations in the education sector, for example, in school leadership (Morrison, 2010). Morrison (2010) also highlights that complexity thinking is pragmatic, relates to a particular time and place and provides possibilities for the future rather than predictions. Lemke and Sabelli (2008) describe the development of a conceptual framework for analysing systemic change and

applied this to a state school system. Although these authors are interested in system modelling, they identify some key concepts for defining a system, structural analysis (for example, levels or social groups in the system), relationships among the subsystems and levels, and the drivers for change. In describing complexity thinking as a theory of change that focuses on people's connections with others, Morrison (2008) suggests school leaders and managers promote conditions for emergence including openness, trust and dialogue. Other conditions for promoting emergence (self-organisation) suggested for curriculum and learning in medical education include openness, interacting elements and non-linear local interactions (Mennin, 2010). Examples of these are students encountering new information and experiences daily showing the system is open to the outside, students and teachers continuously exchanging information providing interaction, and peer feedback producing change (Mennin, 2010). Complexity thinking is suggested as an alternative and inclusive way of thinking about educational research to qualitative and quantitative traditions that view a system in terms of interactions, process and effects, with a specific focus on context and differences (Figure 2) (Haggis, 2008). Building on wickedity and complexity thinking, Jordens and Zepke (2014) proposed conditions for researching undergraduate science education with the possibility of emergent transformational change.

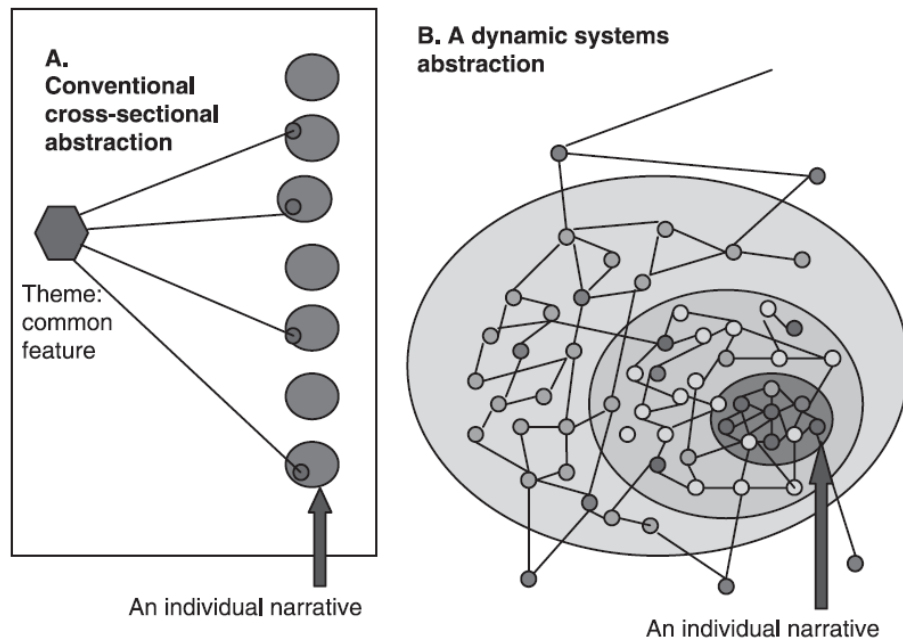


Figure 2. Comparison of conventional thematic-based analyses (A) and complexity-based analyses (B). Reprinted from 'Knowledge Must be Contextual: Some Possible Implications of Complexity and Dynamic Systems Theories for Educational Research', by T. Haggis, 2008, *Educational Philosophy and Theory*, Volume 40(1), p. 170. Copyright 2008 by Taylor & Francis. Reprinted with permission.

Kleiman (2011) suggests that by accepting we are working in a complex adaptive system in higher education opens up possibilities for learning creatively at the edge of chaos (Figure 3). Similarly, Cavanagh (2012) proposed this zone of innovation and creativity as the emergent space for post professional development in coaching psychology.

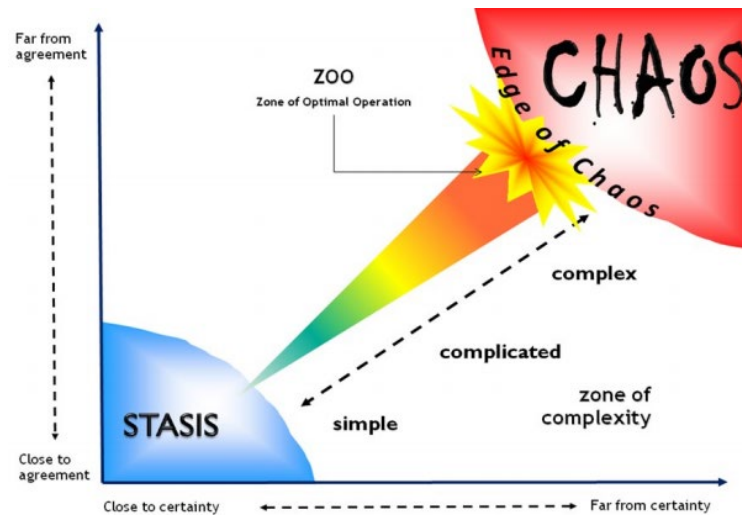


Figure 3. The complexity continuum showing complex systems near the edge of chaos. Uncertainty and creativity are high here and emergence a possibility if the right set of conditions are promoted. Reprinted from 'Learning At The Edge Of Chaos', P. Kleiman, 2011, All Ireland Journal of Teaching and Learning in Higher Education (AISHE-J), 3(2), p. 62.6. [CC BY-NC-SA 3.0](https://creativecommons.org/licenses/by-nc-sa/3.0/).

Wicked and complex problems are both non-linear and share other properties including interaction with largely distributed (rather than hierarchical) feedback. The key property of complexity-based systems that distinguishes them—and potentially makes them highly desirable (or undesirable)—is 'self-organisation', the emergence of novel and unpredicted characteristics. A key condition for emergence is a lack of equilibrium (or lack of certainty, see Figure 3) and complex systems need to be creative and adaptable in response to change; operating at the edge of chaos led to transformation of practice when applied to science teacher education (Laroche, Nicol, & Mayer-Smith, 2007).

Quality in education is described as a wicked and as a complex problem (Krause, 2012). Complex systems are open to external influences and have a large number of components that interact with each other through non-linear feedback (Haggis, 2008; Richardson et al., 2001). Complexity thinking considers systems as a whole and focuses on conditions that promote emergence (self-organisation) (Mennin, 2010; Morrison, 2010). I propose that quality is an emergent property in a specific higher education context, for example, undergraduate science education (Jordens & Zepke, 2014).

2.3 Quality teaching and learning

2.3.1 Student learning

Bradforth et al. (2015) argue that research about improving the quality of teaching in undergraduate science should be based on an understanding of how students learn. Hence, research about quality teaching must be based on clear assumptions about quality learning. However, research on student learning is varied and complex. Various theories have been developed describing learning, how students learn and the teacher's role in this. These learning theories can be categorised into the following groups with similar perspectives on the learning process: transmission, behaviourist, cognitivist and constructivist, transformational and connectivism (or 21st century theories) (Hunt & Chalmers, 2012; Kivunja, 2014; Steffens, 2015). The transmission theory originated in mediaeval times in universities and church schools in Europe and was based on the principle that knowledge is transferred from teachers to learners. This theory views the teaching process as transmission of knowledge and the role of the teacher to transmit knowledge to students as passive recipients. This traditional approach remains the dominant teaching style in science in many universities (Freeman et al., 2014).

Behaviourist learning theories in education became prominent in the 1950s, based on research in experimental psychology that showed reinforcement shaped behaviour (Skinner, 1953). These theories suggest that learning results from connections between environmental stimuli and human responses. However, Skinner viewed education at the time as a form of behavioural control by reinforcement (Skinner, 1953). Currently, outcomes based education is posited on students attaining specific cognitive, physical or attitudinal expertise, and is considered at least partly rooted in behaviourist learning theories as the focus is on rewarding required behaviours or actions. This is the predominant approach in Western medical schools, where evidence of its effectiveness is elusive (Morcke, Dornan, & Eika, 2013), and throughout higher education, illustrating the pervasiveness and persistence of behaviourist learning theories. Taxonomies of learning, originally described in the 1950s, based on the three learning domains, cognitive, affective and psychomotor domains, are widely used for

structuring learning objectives (or learning outcomes), especially in higher education (Seaman, 2011).

Criticism of the transmission and behaviourist learning theories includes the teachers assuming all power and knowledge and students treated as passive recipients of knowledge, although students may be more involved in the learning process in some outcomes-based education. Piaget criticised these learning theories for ignoring how information is processed mentally (as cited in Hunt & Chalmers, 2012). Cognitive theories focus on the relationship between the learner and the environment with students making their own sense of experiences by constructing mental schemes into which they add new material. Piaget proposed that for learning to get into a learner's mind, the learner has to construct the knowledge through active discovery; this formed the basis of 'active learning' and learning-centred teaching. Dewey also highlighted the importance of the environment, experience and reflection on experience for learning, forming the basis for 'learning by doing' (as cited in Tannebaum, Hall, & Deaton, 2013). These cognitive-based theories are also known as constructivism as they involve constructing mental schemes (Hunt & Chalmers, 2012).

Criticism of the transmission, behaviourist, cognitivist and constructivist learning theories included their focus on students learning as individuals. In particular, Vygotsky is associated with social constructivism although his ideas highlighted the importance of cultural, historical and social interactions in human development. Recent interpretations of Vygotsky's research suggest his concept known as the 'zone of proximal development' be more accurately described as the 'zone of next development' that describes a long term approach to learning and development (Smagorinsky, 2018). This recognises the value of culture and socialization in learning, an active role for the student, and the teacher and student working together.

An alternative approach focuses on significant personal change. Transformative learning was originally described as a process based on critical dialogue and critical self-reflection resulting in a change in a 'frame of reference' (perspective transformation) (Mezirow, 1997, p. 5). However, recent studies redefine transformative learning as a broader meta-theory based on a range of learning

outcomes in response to its usage in the literature and propose a new definition of: ‘transformative learning refers to processes that result in significant and irreversible changes in the way a person experiences, conceptualises and interacts with the world’ (Hoggan, 2016, p. 77). The themes revealed from this analysis of 12 years of literature published on transformative learning are shown in Table 1. This shows the expansion of the original definition to include, for example, changes in professional practices and more open epistemology. In contrast, Slavich and Zimbardo (2012) use the term ‘transformational teaching’ to describe intellectual and personal growth that includes a wide range of learning principles based on active learning and student-centred learning, and encompasses collaborative learning, experiential learning and problem-based methods. However, it is worth noting that these authors treat constructivism and social constructivism largely as pedagogical theories and avoid the complication of constructivism as a theory of knowledge. Interestingly, a Māori-specific pedagogy described recently (Stucki, 2012) includes a strand referring to a socio-constructivist learning theory which is consistent with the importance of relationships in the Māori worldview. Worldview-based views of learning and teaching would fit with the revised definition of transformative learning (Hoggan, 2016) (Table 1).

New learning theories have been advocated for the 21st century in response to the impact of digital technology on teaching and learning (Brown, 2015; Steffens, 2015). Navigationism, connectivism and generativism are based on the notion that the availability of information and communication technologies have changed the nature of knowledge (to more temporal) and the way students learn. Brown suggests a navigationist learning theory in which, ‘learners should be able to find, identify, manipulate, and evaluate information and knowledge, integrate this knowledge into their world of work and life, solve problems, and communicate this knowledge to others’ (Brown, 2015, p. 232). In contrast to what is known (declarative knowledge) connectivism focuses on where to find knowledge, and the process of recognising patterns or connections between knowledge, through networked technologies (Siemens, 2005); this approach has recently been enriched by the addition of dialogue (Ravenscroft, 2011). Steffens (2015) also suggests that future societies will be learning-

based societies where learning will be more focused on service, values and generating meaning (generativism).

Table 1. Personal changes described in the transformative learning literature.

Themes	Codes	# Articles	Total articles	Cumulative excerpts
Worldview	Assumptions, Beliefs, Values, Expectations	144	173	310
	Ways of interpreting experience	84		
	More comprehensive or complex Worldview	51		
	New awareness/New understandings	31		
Self	Self-in-relation to others/World	72	141	245
	Identity/View of Self	52		
	Empowerment/Responsibility	52		
	Self-knowledge	50		
	Personal narrative	8		
	Meaning/purpose	7		
	Personality	4		
Epistemology	More discriminating	40	95	165
	Utilising extra-rational ways of Knowing	39		
	More open	37		
	Shift in thoughts and ways of thinking	21		
	Autonomous	16		
	More complex thinking	12		
Ontology	Affective experience of life	29	56	73
	Ways of being	27		
	Attributes	17		
Behaviour	Actions consistent with new perspective	50	113	158
	Social action	39		
	Behavior	37		
	Professional practices	17		
	Skills	15		
Capacity	Cognitive development	30	58	72
	Consciousness	29		
	Spiritually	13		

Note. Reprinted from 'A Typology of Transformation: Reviewing the Transformative Learning Literature', by C. Hoggan, 2016, *Studies in the Education of Adults*, Volume 48(1), p. 70. Copyright 2016 by Taylor & Francis. Reprinted with permission.

The learning theories above vary in their nature of knowledge and in their implications for learning and teaching. Learner-centred teaching is often assumed to be based on a constructivist view of knowledge and learning (Collins & Pratt, 2011) although constructivism pertains to both a theory of knowledge and a theory for learning (Kotzee, 2010). Constructivism as an epistemology implies ontological relativism, posing an issue for many science lecturers who are the focus of this thesis. This association can be (is) a significant obstacle for changing conceptions of learning and teaching in lecturer educational development. A focus on learning in the cognitive,

affective and psychomotor domains, or transformative learning, avoids this and may be preferable for this group. The newer learning theories proposed for the 21st century treat knowledge as transient, value technical and social connections, and generating new ways of meaning to enhance society. The challenge for the future will be to embrace these new learning theories across the disciplines, including science.

In addition to wider student participation, a move to performativity and a need for public accountability in higher education over the last 30 years (section 2.2), digital technologies have also played an increasingly important role. These technologies have been proposed to enhance the quality of student learning when used as a participatory communicative tool but their impact in universities has been limited (Lai, 2011). Focusing on teaching as a labour process, Sappey and Relf (2010) suggest that staff assistance has been inadequate for digital technologies to fulfil their potential in teaching and learning. More recently, digital technologies have been described as fuelling a third 'engaged' paradigm of education that changes several important aspects of teaching and learning including the direction of communication—many to many—and the level of interactivity—high (Pavlik, 2015). Researchers in the US college and university sector urge institutions to consider the core purposes of education in this new context and the role of digital technologies in transforming institutions, rather than a focus on the tools (Bass & Eynon, 2017). Hence, these technologies have the potential to profoundly impact teaching and learning, and the role of lecturers and students. At present they are underutilised in many institutions where lecturers lack support to integrate these into their teaching practice. At the start of this study, I considered the role of digital technologies in universities to be largely for enabling distance learning (online courses) and supporting internal (face-to-face) learning. As the usual mode for undergraduate science was face-to-face learning, I chose to focus on this mode and did not consider digital technologies further in my study.

2.3.2 Relationship between learning, teaching and the role of the lecturer

Student-centred teaching

A profound shift in thinking in undergraduate education from a focus on teaching to a focus on learning was heralded in the 1980s and 1990s (Barr & Tagg, 1995; Chickering & Gamson, 1987). The importance of what the student does in the teaching-learning relationship is central to Biggs' constructive alignment, first described in 1996 (Biggs, 1996). This model indicates how teachers can align intended learning outcomes, teaching-learning activities and assessment of the learning outcomes to promote student learning and is widely promoted in tertiary teacher educational development (Biggs, 2011; Kandlbinder, 2014). Although used widely in higher education, Biggs' constructive alignment lacked relationship and sociocultural dimensions (Cousin, 2012). The importance of relationships in teaching and learning has been highlighted by several authors, for example, the importance of values and teaching cooperation and teamwork as a basic skill was proposed over 30 years ago (Astin, 1987). Similarly, large studies in the United States showed the importance of encouraging learning communities and the centrality of the classroom to be important for student success, especially for non-traditional students (Kuh, Kinzie, Schuh, & Whitt, 2005; Tinto & Carnegie Foundation for the Advancement of Teaching, 2008).

Research on what influences the quality of student learning indicates a complex inter-relationship of factors that together make up the whole teaching and learning environment. Entwistle (2003) introduced a systems-based conceptual framework showing multiple influences and recognised the importance of the whole teaching environment on student learning (Figure 4). Similarly, Bryson and Hand (2007) proposed multi-faceted engagement by students and teaching staff to optimise student learning. A standout presence in this web of quality factors is what the teacher does, shown in the lower portion of Figure 4 (Entwistle, 2003).

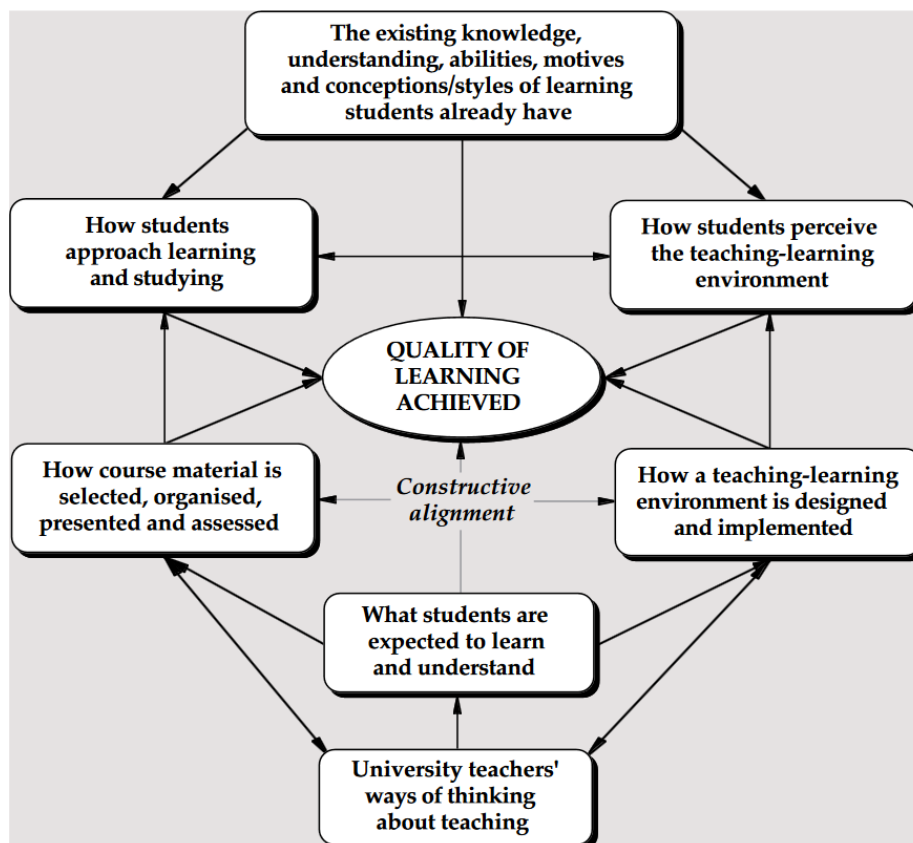


Figure 4. Conceptual framework indicating influences on student learning. Reprinted from 'Concepts and Conceptual Frameworks Underpinning the ETL project', by N. Entwistle, 2008, <http://www.etl.tla.ed.ac.uk/docs/ETLreport3.pdf> p.1. Copyright 2003 by the ETL project. Reprinted with permission.

The importance of teachers' conceptions (views) of teaching and learning

Figure 4 highlights the significance of the role of the university teacher in learning, and that how he/she teaches is underpinned by his/her conceptions (ways of thinking) about teaching. Similarly, science lecturers' views of quality science teaching and learning will influence their teaching.

Teachers' conceptions vary and are described by various models or frameworks. Interview-based studies showed that how teachers taught was determined by what they believed was the purpose, or intention, of the teaching activity (Trigwell & Prosser, 1996). Findings from interviews with first year university physics and chemistry lecturers led to the characterisation of the intention of the teacher as either information transfer (IT) or conceptual change (CC) and these were associated with largely teacher-focused (TF) or student-focused (SF) teaching strategies, respectively

(Trigwell & Prosser, 1996). These findings were used as the basis to construct the approaches to teaching inventory (ATI), a self-report questionnaire that has been widely used to categorise teaching intention and strategy, although its use outside the science context for which it was designed has been criticised (Meyer & Eley, 2006; Stes, De Maeyer, & Van Petegem, 2010). Prosser et al. (2003) used an abridged version of the ATI and a questionnaire relating to the teaching environment to explore the relationship between teaching approaches and student learning experiences. These authors showed a majority of teachers in science and engineering were associated with poorer student learning experiences and the results suggested that most teaching approaches were IT-TF (Prosser et al., 2003). Combinations of intentions and strategies other than IT-TF and CC-SF were also identified and labelled as dissonant and incoherent; these authors suggest dissonance may be more prevalent in teaching science and engineering than in arts and social sciences and responsible for the relatively poorer student experiences, at least in their context.

Many studies and individual teachers have used the Teaching Perspectives Inventory (TPI), developed from many lengthy interviews, to characterise teaching approaches (Collins & Pratt, 2011). The TPI describes perspectives as transmission, apprenticeship, developmental, nurturing and social reform according to their focus on subject matter, modelling practice, ways of thinking, self-efficacy or critical theory, respectively (Pratt, 1998, 2002). In addition to describing these five perspectives on good or effective teaching for a specific context, this inventory provides subscores on beliefs, intentions and actions that can be examined for internal consistency. Each perspective is reported to have the potential to be good teaching in the appropriate context but it is proposed that 'one size does not fit all' and that there are likely to be many ways of good teaching (Pratt, 2002). The TPI showed that most teachers have one dominant teaching perspective, a backup they use sometimes, and a 'recessive' approach that they use very rarely (Collins & Pratt, 2011). Application of the TPI to a research extensive university in the United States showed 73% of faculty (lecturers) had one dominant perspective (perspectives not stated), 4% had two or more dominant perspectives and 24% had no dominant perspective among 131 teachers (17 in basic

science), supporting the idea that one dominant perspective is typical (Deggs, Machtmes, & Johnson, 2008).

More than 100,000 teachers worldwide have completed the TPI, although only one study is from New Zealand and this is from the primary school sector. Interestingly the results showed these primary school teachers were positive about the nurturing and apprenticeship-developmental perspectives, somewhat positive about the social reform perspective and disagreed with the transmission perspective (Brown, Lake, & Matters, 2009). These findings were in accord with the main policies and practices in the New Zealand schools sector at the time.

Recent research suggests there may be a relationship between teaching perspective and discipline or culture. Comparison of dominant teaching perspective and discipline indicated a significant difference between disciplines for the 'apprenticeship' perspective (Deggs et al., 2008). A very recent study used the TPI to explore the relationship between lecturers' teaching perspectives and disciplines classified as pure/applied, hard/soft or life/non-life (Rotidi, Collins, Karalis, & Lavidas, 2017). More lecturers favoured the transmission model from non-life disciplines than life disciplines. In contrast, there were no significant differences in the transmission teaching perspective scores between academics from hard and soft, or pure and applied disciplines. More lecturers from the life disciplines favoured the developmental, nurturing, apprenticeship and social reform perspectives than non-life disciplines. Similarly, more lecturers favoured the apprenticeship perspective from the applied disciplines than the pure disciplines but there were no significant differences between these scores from hard and soft, or life and non-life disciplines. The study also found that Greek academics preferred transmission, nurturing and social reform perspectives, compared with an international sample. The authors conclude that disciplinary differences are probably small compared to interpersonal or cultural differences. Overall, the findings suggest an association between non-life/life disciplines with transmission/other perspectives, and applied/pure disciplines with apprenticeship/other perspectives, and a role for culture in teaching preferences.

Other research has indicated the importance of multiple factors on teachers' approaches to teaching. The ATI and a motivation questionnaire showed that approaches to teaching were affected by discipline, context (course) and self-efficacy beliefs of teachers (Lindblom-Ylänne, Trigwell, Nevgi, & Ashwin, 2006) with exploration of consonant and dissonant teaching approaches suggesting the importance of context and the possibility of development towards consonant profiles. The finding of only moderate relationships between conceptions (perceptions or beliefs) and teaching strategies suggested the importance of personal and contextual constraints or response to students' needs (Donche & Van Petegem, 2011).

It has been suggested that changing underlying teaching conceptions is likely to be more effective than educational development focused on the mechanics of teaching and teaching activities for enhancing teaching and learning (Åkerlind, 2008). For example, the scope of conceptions of teaching held by 88 doctoral students (viewed as potential lecturers) from a range of disciplines (including 8 in science) was investigated using a questionnaire and open questions before and after a formal course on course design and teaching. Four conceptions of university teaching and learning that varied on the goal of teaching and the nature of learning were identified: (1) transmitting knowledge, (2) preparing context/managing teaching, (3) promoting course learning and (4) promoting life-long learning. A marked shift from categories 1 and 2 to categories 3 and 4 was detected after the course. Categories are described as distinct and building on each other with the last extending from content to include transferable thinking skills and attitudes. The group are potential academics and the conceptions identified agree with much of the literature (Saroyan, Dagenais, & Zhou, 2009). Interestingly, student-centred teaching has been advocated as a threshold concept for lecturer educational development; transformative in this context was defined as a significant shift in the perception of a subject (Blackie, Case, & Jawitz, 2010).

Reflective practice is promoted as key to changing teaching conceptions and actions and forms the basis of current higher education teaching certification programs (Šaric & Šteh, 2017; van der Sluis, Burden, & Huet, 2017; Zepke, 2011a). Reflective practice is the process of thinking about—or reflecting on—an experience, comparing it to

previous experiences and expectations and planning changes for improvement. Critical reflection challenges and questions the teacher's personal views and the world around them (Zepke, 2011a). This includes values, emotions, spirituality and dominant ideologies (in particular prevailing political ideologies). Its aim is to create intellectual and social change. Critical reflection is an important part of reflective practice in higher education.

Research reviewed here indicates that the whole learning environment influences student learning. The teacher has a vital role in enabling student success through his/her teaching approach and relationships with students by encouraging students to engage with all aspects of their learning. However, the teacher's conceptions of learning and teaching influence his/her teaching approach and these vary with individuals, culture, context and discipline. Lecturer self-efficacy and motivation also contribute to his/her teaching approach. These factors all influence the teaching and learning environment and hence the quality of student learning.

Student engagement and the role of the lecturer

Research suggests students show a variety of approaches to learning, including deep and surface learning, and a range of learning preferences. Recently, Vermunt and Donche (2017) proposed a learning patterns perspective that combined aspects of these learning approaches and preferences into a single model. Although the concept of 'learning styles' has been strongly critiqued (Willingham, Hughes, & Dobolyi, 2015), Vermunt and Donche (2017) argue that their pattern-based approach encompasses a range of factors, including motivation, and does not assume that a student uses only one approach at all times. Students' approaches to learning are influenced by lecturers' teaching practice, as highlighted in a study of university physics in Sweden using interview-discussions to explore how lecturers framed their teaching to optimise student learning (Linder & Kung, 2011).

However a student prefers to learn, research suggests they learn best when engaged in learning. Student engagement serves as a heuristic shortcut for understanding the complex behaviours, thinking and emotions that lead to successful learning (Reschly & Christenson, 2012). The overriding purpose of teaching is to enable students to be

successful learners so they achieve outcomes expected by academic programmes, the institution, industry, society and themselves. Researchers on student engagement have defined the construct in a variety of ways that includes students' motivation, transactions (social factors), support from institutions and active citizenship (Leach & Zepke, 2011). Student engagement has also been described as, 'multidimensional and extends . . . beyond learning behaviours to a broad range of campus activities with and beyond the classroom' (Groccia, 2018, p. 13). To achieve success (desired educational outcomes) he suggests students need to engage with the learning process on behavioural, cognitive and emotional levels through persistent effort, interest and motivation, and connect the experience mentally to prior experiences (Groccia, 2018). These two models of student engagement share similarities although presented very differently in the literature. For example, 'active citizenship' in the conceptual organiser described by Leach and Zepke (2011) shares similarities with 'engagement with the community' in the model described by Groccia (2018). Similarly, 'transactional engagement' (social factors) and 'engagement with faculty and staff' / 'engagement with other students' share similarities in the two models. A recent meta-analysis showed a moderately strong and positive correlation between overall student engagement and academic achievement in behavioural, emotional and cognitive domains (Hao, Yunhuo, & Wenye, 2018).

Like all learning and teaching, student engagement is complex. This lies, first, in its generic and applied nature. It offers ways of teaching and learning that can be interpreted for and adapted to many different contexts (Reschly & Christenson, 2012). Second, it melds learning and teaching and does not separate them. Barr and Tagg (1995) introduced the term 'learning paradigm' in which students are not just receptacles for teachers' words, but co-producers of knowledge with shared responsibility for their learning. Learning-centred teaching involves both students and teachers engaging with the learning process to enable student success. This joint engagement leads to powerful results. Numerous syntheses of research on student engagement have produced many propositions for application e.g. (Kuh et al., 2005; Lawson & Lawson, 2013; Trowler, 2010; Zepke & Leach, 2010). Zepke (2017) abstracted 10 emergent and generic propositions from the engagement literature.

These address 'how research suggests we should act' as teachers and learners under three headings: (i) students invest in their own learning (student self-belief is vital for success; students' motivation grows from self-belief; social and cultural capital enhance engagement); (ii) institutions are vital enablers of engagement (engaged learners are deep learners; quality teaching and institutional support enhance engagement; disciplinary knowledge engages students; adapt to changing student expectations); and (iii) engagement is assisted by enabling external environments (engagement occurs across the life-span; is linked to subjective wellbeing; active citizenship is important for student engagement).

General principles of good teaching

The identified importance of the teacher has stimulated some general principles of quality teaching that are widely regarded as good practice for undergraduate education. These principles are drawn from a rich and diverse body of work: Chickering and Gamson's 'Principles for good practice in undergraduate education' (Chickering & Gamson, 1987); Biggs' constructive alignment (Biggs, 2011); surface, strategic and deep approaches to learning (Entwistle & McCune, 2004); and a very large literature on student engagement including Kahu (2013), Kuh (2009), Zepke and Leach (2010), Leach (2016), and Groccia (2018) among others. In particular, the seven principles of good practice described by Chickering and Gamson (1987) have been widely accepted across the higher education sector. These include encouraging staff-student contact, developing cooperation among students, using active learning techniques where students are involved in peer discussion or projects rather than passive recipients of information, giving prompt feedback, emphasising time on task, communicating high expectations and respecting diversity. In practice these principles can stand for quality in teaching and indicate how quality can be enhanced. They also suggest a need for governance and management that helps shape a favourable environment for quality teaching.

Chickering and Gamson's principles promise the emergence of long and diverse lists of possibilities for quality teaching practice. The following list of expected outcomes of good teaching reported by Ramsden and Callender (2014) from the student

engagement literature allows for a generic overview of quality teaching in higher education. According to their list, quality teaching:

- Engages students more effectively in shaping their own learning experiences;
- Activates the 'student voice';
- Facilitates participation in activities that lead to learning and development gains;
- Creates a sense of belonging to (rather than disjunction from) an institution;
- Stimulates learning with and from other students;
- Enables learning on campus in a social community;
- Achieves a sense of accomplishment from successful academic learning;
- Stimulates a deep approach to learning when undertaking academic tasks;
- Encourages self-efficacy in learning and intrinsic motivation
- Combats alienation especially among non-traditional students by minimizing the effects of academic power and culture or market-driven changes to HE;
- Engages the whole person;
- Enables emotional attachment to learning deriving from good teaching, curriculum, assessment, resources and support;
- Encourages 'student-centred' education (teaching that focuses on students' needs);
- Extends student involvement in learning by encouraging them to spend time on task, participate in extra-curricular activities, to enjoy learning and expand interests.

While instructive, this profusion of understandings makes a singular and definitive definition of quality teaching difficult to construct. While engagement and quality teaching are integral to every context, how they are best enacted will depend on the context, for example, the discipline.

2.3.3 Teaching and learning in science

The quality teaching literature discussed so far focuses on generic ideas of what works in quality teaching without referencing particular disciplines. Yet, there is considerable support for the idea that disciplines like those in the sciences have their own

approaches to quality teaching. This is shaped by the specific knowledge underpinning disciplines. The growing literature around threshold concepts also supports the notion that discipline content impacts on how quality teaching is practised. Threshold concepts are 'akin to a portal, opening up a new and previously inaccessible way of thinking about something' (Meyer & Land, 2003, p. 1). Threshold concepts belong in a discipline, focus on disciplinary understandings and have the ability to transform learners' views of the content. Quality teaching brings learners through a liminal space to the threshold of new understanding in the discipline.

However, a range of views debate the extent disciplines influence quality teaching. Some researchers emphasise generic principles of quality teaching (Chickering & Gamson, 1987); others recognize differences between 'hard' and 'soft' disciplines (Kember & Leung, 2011; Krause, 2012); others again see disciplines central to understanding quality (Meyer & Land, 2003), or understand sub-disciplinary influences and even individual professor-student relationships as critical factors (Becher & Trowler, 2001; Gross et al., 2015). One way forward in this debate is that quality teaching in the sciences draws on both generic pedagogical and specific subject related ideas (or discipline knowledge translated for student understanding—known as pedagogical content knowledge (Shulman, 1987)). Wittgenstein's metaphor of family resemblances across the science disciplines seems useful here for considering the natural sciences collectively (Trowler, 2014).

There is a large body of research on science education in the schools sector but less in the post-secondary sector. Across all sectors there are some science relevant teaching strategies that have been well researched including the use of demonstrations, explanations, questioning, scientific reasoning and representational learning (Treagust & Tsui, 2014). Such strategies are widely used in the university sector but the effectiveness with which they are used varies. For example, questioning has been found to be most effective when it involves peer discussion (Smith et al., 2009). Representational learning—analogy and metaphors, visualisations, and model-based learning—is widespread but again its effectiveness depends on how well the teacher can translate discipline knowledge for student understanding (pedagogical content knowledge (Shulman, 1987)). Interestingly, a recent Australian study explored the

notion of pedagogical content knowledge among science lecturers in higher education and found they thought it a potentially useful concept for understanding and enhancing their understanding of quality teaching (Fraser, 2015).

Much of the research in schools is transferable to higher education, for example, Bayerl (2007) embedded literacy skills in coursework and introduced an interactive science notebook originally from a secondary school to early college in the USA as preparation for college. As discipline focus increases in higher education, so does the importance of learning discipline related attitudes, values and beliefs (Coppola & Krajcik, 2013; Entwistle, 2005). In their analysis of contemporary teaching approaches, Slavich and Zimbardo (2012) proposed a transformational teaching model describing the theoretical underpinnings and strategies involved for developing these learning related attitudes, values and beliefs. As discipline practitioners, university staff possess these skills but little is known about if, or how, these skills are taught in universities or in specific disciplines.

Advocates for reform of undergraduate science education often refer to 'scientific teaching' or evidence-based teaching in an attempt to encourage university staff to change from traditional teacher-centred to more effective student-centred active learning strategies (Handelsman et al., 2004). For example, a large and comprehensive meta-analysis of 225 studies compared lecturing and active learning approaches in undergraduate science, engineering, and mathematics (STEM) courses (Freeman et al., 2014; Wieman, 2014). This showed that active learning increased student achievement in all STEM disciplines. Similarly, undergraduate programmes including laboratory-based research projects have been shown to enhance student learning gains compared with laboratory courses without a research component (Brownell & Kloser, 2015; Lopatto et al., 2008). Despite this evidence, adoption of such practices in many universities has been slow (Handelsman et al., 2004).

In light of the slow uptake of student-centred and active learning in undergraduate science education, it is important to explore the conceptions of quality teaching in undergraduate science held by science lecturers as these influence their teaching practice. A relationship between teachers' beliefs about their discipline and their

beliefs about teaching and learning has also been identified (Åkerlind, 2008; Van Driel, Bulte, & Verloop, 2007). There are few science discipline-specific studies of university lecturers' conceptions of teaching. A recent questionnaire-based study of 47 university teachers in the biosciences in Finland showed teachers' views of teaching were largely based on becoming an expert in the biosciences discipline (Virtanen & Lindblom-Ylänne, 2010) with most regarding their role as guiding students to think and practice in the ways of that discipline. These university teachers viewed learning as changing one's view of a phenomenon.

There are calls for reforms in undergraduate science teaching but few signs of moving to student-centred teaching. Research on science lecturers' conceptions of teaching and learning is very sparse and suggests science lecturers' views are based on the students they teach becoming discipline experts. Further research on lecturers' views on teaching and learning and the lack of change is warranted to fill this gap.

2.3.4 Science lecturers' views of quality teaching and learning

With the important contribution to quality in teaching assigned to teachers working in specific disciplines, it seems important to investigate science lecturers' views on this topic. This enables practitioner perceptions of quality teaching to be highlighted in a field usually dominated by educational theorists and researchers. But there are few studies on science lecturers' conceptions of quality teaching and learning, although there are some studies on good, effective or award-winning teaching.

A multidisciplinary interview-based study of 18 university lecturers (including five in science) investigated the meaning of 'good teaching' (González, 2011). The four emergent categories were: transmitting discipline information, transmitting lecturers' understanding, developing students' understanding and changing students' understanding/developing critical thinking. Within these, four dimensions of variation were identified: the role of the lecturer, the role of the students, content, and motivation (González, 2011). Of these, motivation represented a new dimension to those previously reported in science.

The best teaching practices perceived to provide optimal conditions for teaching and learning at Flinders University in Australia included providing timely, constructive feedback and classes that were organised and focused (Glenn et al., 2012). Perceptions of effective teachers suggested these were approachable, knowledgeable and adaptable, and effective teaching practices included organised delivery, mentoring and constructive alignment. In this study, 10% of the teachers were in science and engineering.

Experts' views of quality teaching

Interviews of 20 university teachers from teaching award-winning units in Finland revealed a gap between their descriptions of ideal and practised teaching with more dimensions in their descriptions of ideal teaching than in their current practice (Parpala & Lindblom-Ylänne, 2007). No laboratory-based science departments were included although five were medicine which has some similarities. Six themes were described within good teaching: practice, context, student's role, teachers' role, atmosphere and physical environment. The extra dimensions emerging from ideal teaching included the student role (motivated), physical environment and atmosphere. The authors also noted the lack of any reference by the teachers to a role for assessment, indicating a gap in alignment-related criteria.

A small study of eight university teachers in the UK explored their narratives on conceptions of effective teaching using interviews (Carnell, 2007). The interviews in this study were based on the appreciative inquiry method and focused on affective aspects and avoided focusing on problems. All eight teachers focused on student-learning in their example of effective teaching. The results suggested that conceptions of effective teaching in university contexts are richer than previously reported and include dialogue for learning, learning community, and meta-learning. A co-constructed approach emerged as new. A variety of priorities emerged from the interviews including learning as transparent, dialogue enables learning, and a community of learners generates knowledge. In contrast to rigid categories, Carnell (2007) proposed a framework encompassing the complexity of different approaches to teaching and learning that described four approaches—didactic, empowering, co-

operative and community—based on two continua—how knowledge is seen (objective or subjective) and the dynamics of teaching and learning (individual or collective). This encompasses some of the characteristics of the approaches to teaching inventory (ATI) (Trigwell & Prosser, 1996) as the knowledge continuum could relate to the information transfer (IT) and conceptual change (CC) intentions. Similarly, the dynamics of teaching continuum could apply to the teacher or student focus described in the ATI. Each approach described by Carnell (2007) was associated with different aims, approaches and teacher/student roles. The narratives strongly suggested that a community approach—associated with collective knowledge construction and learning through co-constructed dialogue where teachers and learners have joint responsibility for learning—is associated with effective teaching in these teachers. These respondents were all education specialists with teaching backgrounds in different disciplines at a post-graduate institution; they could therefore be viewed as ‘experts’ and their views may not be transferable to other groups of University lecturers.

An interview-based study of teaching excellence award winners in the UK comprising lecturers recognised by their university for their outstanding contributions to student learning, described conceptions of quality teaching associated with transformative learning such as facilitating changes in students’ skills related to a specific profession, increased self-confidence and achievement, critical thinking skills and metacognition (Cheng, 2011). Of particular note is that quality teaching was considered different from good teaching by nearly half of the award-winners in this study; disciplines of participants was not stated.

In the absence of research on science lecturers’ views of quality teaching and learning, views of good, effective or award-winning teaching that include some science lecturers may be helpful. The research on lecturers in general highlights a focus on teaching practices in the classroom. In contrast, education ‘experts’ and university award winning lecturers have a more complex view including aspects of transformative learning.

2.4 Other influences on lecturers' teaching

The research on lecturers' conceptions or approaches to teaching described above generally focuses on a specific teaching example and it is likely that teaching is influenced by the wider context that constitutes the complex higher education system (Zepke, 2011b). In contrast to research on specific contexts, there has been little research on the influence of the wider context on lecturers' teaching. The global changes from Keynesian welfare state regimes in the period post World War II to Schumpeterian Workfare States had massive effects on the governance and funding of public institutions including higher education (Jessop, 1999). Knight and Trowler (2000b) summarise the influence of these social changes on academic work and quality as including the use of fixed term contracts, modularisation leading to increased workload, increased heterogeneity of the student body, increased paperwork, increased accountability and compliance, increased productivity requirements and broader roles as universities become more subject to market demands.

In the New Zealand context, recent research on what helps and hinders Māori student success in university health science programmes highlighted the importance of both cultural responsiveness and teaching and learning approaches that engage these students (Curtis, Wikaire, Kool, et al., 2015). This includes the need to provide additional academic and pastoral support specifically for Māori students, emphasising the influence of kaupapa² Māori on New Zealand lecturers' teaching.

Through interviews in several English-speaking countries, internal changes and external pressures were shown to produce erosion of trust, longer hours of work, reduced collegiality and threats to academic self-identity resulting in negative effects on teaching (Knight & Trowler, 2000a). Using interviews and focus groups to explore the teaching experiences of lecturers in the higher education context in England, Lea and Callaghan (2008) also suggested several external factors influenced lecturers'

² kaupapa Māori is a way of doing things from a Māori worldview

teaching. These included the research assessment exercise (equivalent to the Performance Based Research Fund in New Zealand), decreased state funding, widening student participation, nature of secondary education, and external control of curricula.

2.5 Conclusion

Research shows that lecturers have a significant role in enabling student learning through their teaching approaches; these are underpinned by their conceptions of teaching and learning. Traditional lectures and recipe-style laboratory classes remain the default for many university science courses despite the high-level call for change to student-centred teaching. The sparse literature on lecturers' views of quality teaching and learning in science suggests science lecturers' views are based on students becoming a discipline expert. However, there seems to be a disconnection between the practice of science and the teaching of science at university undergraduate level.

The socio-political changes at the end of the 20th century profoundly affected higher education. Widening student participation, marketisation of higher education as a commodity and competitive funding depending on research outputs has drastically increased the workload of university lecturers. Research suggests this has negatively impacted lecturers' teaching. However, there is little research on the specific nature of the impacts on lecturers' teaching.

To enhance student learning in science at university, there is therefore a need to investigate science lecturers' conceptions of quality teaching and learning and the influences on their teaching. An exploration of lecturers' views and influences on their teaching would contribute to an understanding of this topic and enable recommendations for action, for example, in science lecturer educational development and institutional management. The details of how I planned and conducted this exploration are the subject of Chapter 3.

CHAPTER 3: METHODOLOGY AND METHODS

3.1 Introduction

This chapter describes the theoretical principles behind, and the methods used to conduct, my research on university science lecturers' views on quality in undergraduate science teaching and learning. As this research was driven by the research questions, I begin with an outline of the nature of these questions and their implications for the subsequent choices of research approaches. Then I present my theoretical framework for studying quality as an emergent property, based on sensitising concepts drawing on complexity thinking and wickedity. I follow this with a justification of the philosophical underpinning for the proposed mixed methods research approach. I advocate pragmatism, in particular that of John Dewey, as an appropriate philosophical stance for my mixed methods research approach and highlight links between some of Dewey's ideas and complexity thinking. Finally, I outline the multiphase mixed methods design and provide the rationale for the two phases. In the second part of the chapter, I describe the methods that I used to implement this design.

3.2 Research Methodology

Research in the social sciences involves the following four domains of issues and assumptions: philosophical assumptions and stances; enquiry logics encompassing questions, strategy and designs; guidelines for practice (methods); and sociopolitical commitments (Greene, 2006). My research was committed to enhancing undergraduate science teaching and learning. It aimed to do this through proposals for action arising from the research. As my research was driven by the research questions (Chapter 1), I start by showing how the nature of the questions led to the subsequent choices.

3.2.1 Research question-led research

The nature of the research questions

Based on my experiences as a practising research scientist and a university science lecturer, I was perplexed at the differences between the environment in professional laboratories and many undergraduate science courses, especially undergraduate laboratory classes. This led me to question why undergraduate science was taught the way it was and what lecturers, the teaching staff most directly involved, considered 'quality' in this context. Hence, my research aimed to explore the meanings that university lecturers ascribed to quality teaching and learning in undergraduate science, and to use these to make proposals to enhance science teaching and learning and enable the emergence of quality.

As stated in Chapter 1, the main research question was:

What do university science lecturers in New Zealand consider to be quality teaching and learning in undergraduate science?

To inform this question, I developed the five sub-questions:

1. What do national award-winning tertiary teachers consider to be quality teaching and learning in undergraduate science?
2. What do a larger sample of university science lecturers consider to be quality teaching and learning in undergraduate science?
3. What are the main influences on lecturers' views on teaching?³

³ The focus of this sub-question changed during the study. In Phase 1, the focus was initially on development as a teacher. In response to survey findings in Phase 2, and because I didn't want to ask interviewees a leading question about educational development, this was expanded to explore broader influences on teaching. Therefore, I subsequently modified the question to 'What are the main influences on lecturers' quality teaching'.

4. What implications do these findings have for university science lecturer educational development programmes?
5. What other proposals for action arise from this?

Research questions 1 and 3 sought to explore in depth the views of a specific group of people (teaching award winners) or on a specific topic (influences on teaching) indicating that research approaches providing qualitative data would be most appropriate. In contrast, research question 2 sought the views from a large sample of people and on a broad topic indicating that research approaches providing quantitative data would be more appropriate. Research questions 4 and 5 focused on the proposed actions arising from this research.

The complex nature of the research questions, requiring a combination of approaches to attain both breadth and depth of understanding, in combination with a focus for action, showed that mixed methods research was likely to be the most appropriate approach (Johnson, Onwuegbuzie, & Turner, 2007). One of the characteristics of mixed methods research is that the research questions drive research choices and decisions. However, before deciding on the details of the research design, I needed to establish a strategy or ‘theoretical framework’ in which to work—my theoretical view of quality for investigating it—as part of the enquiry logics (Greene, 2006). I present this theoretical framework next.

Theoretical framework based on complexity and wickedity

Quality in higher education has many characteristics of a complex system including multiple interacting components with ill-defined boundaries in an open dynamic system (Davis & Sumara, 2010). As highlighted in Chapter 2, complexity theory offers a way of thinking about quality in terms of conditions that promote emergent transformational change. Also, quality is perceived as a ‘wicked’ problem. These are not usually amenable to the linear problem-solving solutions applicable to ‘tame’ problems (Crowley & Head, 2017).

The contested, complex and ‘wicked’ nature of ‘quality’ in higher education indicated that a framework that considered whole systems, issues or problems was needed for this study. To apply complexity thinking and wickedity to lecturers’ views on quality, I

chose Blumer's sensitising concepts (Blumer, 1954). Blumer suggested that sensitising concepts (or lenses) give 'a general sense of reference and guidance . . . [and] suggest directions along which to look' (Blumer, 1954, p. 7). I developed six lenses, based on the conditions for self-organisation in complexity thinking (Davis & Sumara, 2006; Mennin, 2010) and lenses previously proposed for researching quality in higher education as a wicked problem (Krause, 2012), to provide insight into the conditions that may lead to the emergence of quality in undergraduate science teaching and learning. Table 2 summarises these lenses.

Table 2. Sensitising lenses for conditions to promote self-organisation based on complexity thinking and wickedity.

Sensitising concept (lens)	Description of lens for researching quality teaching and learning in undergraduate science
1. Problem definition lens ^a	Problems with defining quality: the reasons for difficulty in defining quality in teaching and learning in undergraduate science. For example: what/whose definition of quality in HE
2. Openness lens ^b	Quality as boundary hopping: free to interact/encounter new information and experiences (with things). For example, scientific research.
3. Social complexity lens ^{a,b}	Quality as relationship: interactions promoted between groups of people involved - exchanging information between people. For example, ill-defined boundaries between lecturers and students co-producing knowledge, e.g. through discussion
4. Nonlinearity lens ^b *	Quality as change: agents changing through multiple non-linear local interactions. For example: self-reflection or informal/formal feedback on teaching
5. Multiple 'causality' lens ^a	Quality as influence: for example, the (conflicting) goals and concerns of, and influences on, all groups involved (lecturers, students, stakeholders, managers, Institution . . .)
6. Problem resolution and emergence of quality lens ^{a,b}	Findings about quality: strategies/proposals for all groups involved to engage with the problem with the aim of reaching resolution/quality enhancement (problem engagement strategies) and proposals for action

^abased on wickedity (Krause, 2012)

^bbased on complexity thinking (Mennin, 2010)

*local interactions causing change, often small changes having big effects.

I designed the first five lenses to help me explore and analyse data from a variety of reference points. The first lens, the problem definition lens, originated from wickedity (Krause, 2012), and was intended to aid understanding of quality in undergraduate science from university science lecturers' perspectives as these have a major influence on teaching and learning of undergraduate science students (Chapter 2). Wicked problems are difficult to define as definitions may vary with different communities (or stakeholder groups) and how they view the problem. Consequently, these groups view different 'solutions', or resolutions, as appropriate, making wicked problems extremely difficult to resolve and specific solutions are required for each problem. Exploring views within one key group may enable an understanding for which resolution(s) can be addressed. According to Rittel and Webber (1973, p. 161), 'The formulation of a wicked problem *is* the problem!' (emphasis in the original).

The second lens, the openness lens, was based on one of the key ideas of complexity thinking, openness, to establish the extent of the openness of university undergraduate science teaching and learning to the flow of new information and experiences. Open systems operate far from equilibrium exchanging energy with the environment and both influencing each other, for example, staff and the students were free to 'come and go' in a medical curriculum environment (Mennin, 2010, p. 24).

The social complexity lens combines ideas from both wickedity and complexity thinking that recognise the key role of promoting relationships and interactions across organisational boundaries that render these boundaries 'fuzzy'. Key processes in complex systems are the feedback loops between the interacting components that enable the core process of complexity, self-organisation, and the emergence of novelty (Haggis, 2008; Mennin, 2010). Examples of important relationships in medical education include those between students and teachers, and between these and patients, with 'fuzzy' boundaries in rules of ethics (Mennin, 2010).

The fourth, or nonlinearity lens, originates in complexity thinking and focuses on agents changing through multiple local interactions, in particular, where large changes have little effect and small changes have major effects on system evolution. Nonlinear interactions in complex systems contributing to emergence include redundancy among

agents, internal diversity, neighbour interactions and decentralised control (Davis & Sumara, 2005). Specific examples of these in medical education included formative assessment and feedback, and the exchange of ideas in group discussion influencing outcomes (Mennin, 2010).

The fifth, or multiple causality lens, is based on wickedity and considers the influences that affect the views of the group involved. Conflicting goals and concerns among the groups involved will influence approaches to resolving the problem and may necessitate compromises (Krause, 2012).

The sixth, or problem resolution and emergence of quality lens, aimed to bring the findings from the other lenses into focus enabling resolution and possibilities for the emergence of quality. Therefore, my sixth lens was designed to enable proposals for action that emerged from within the broad university science lecturer community itself, based on their views of what quality should look like. Hence, this lens would function in the discussion and recommendations chapters.

Quality has some characteristics of a wicked problem and a complex problem. These problems share important characteristics of interaction with largely distributed (rather than hierarchical) feedback loops. However, one significant difference between wicked and complex problems lies in how clearly the problem can be defined. In this study, I will use lecturers' views to provide a framework for understanding quality teaching and learning in undergraduate science. Combining approaches from complexity thinking and wickedity in sensitising lenses will enable a view of quality in teaching and learning in undergraduate science as a whole system of interacting components that functions as more than a sum of its parts. A wicked problem approach will aid clarification of the problem definition, helping to overcome the highly contextual and temporal nature associated with resolving problems that is due to the lack of problem clarity. With problem clarity, quality is no longer a wicked problem; it can be viewed as a complex system and conditions likely to promote its emergence can be identified. Hence, it will be possible to propose conditions that could contribute to the special property of emergence in complexity-based systems. Figure 5 shows some of the social

interactions in higher education from which quality may emerge given the coalescence of appropriate conditions for a given context.

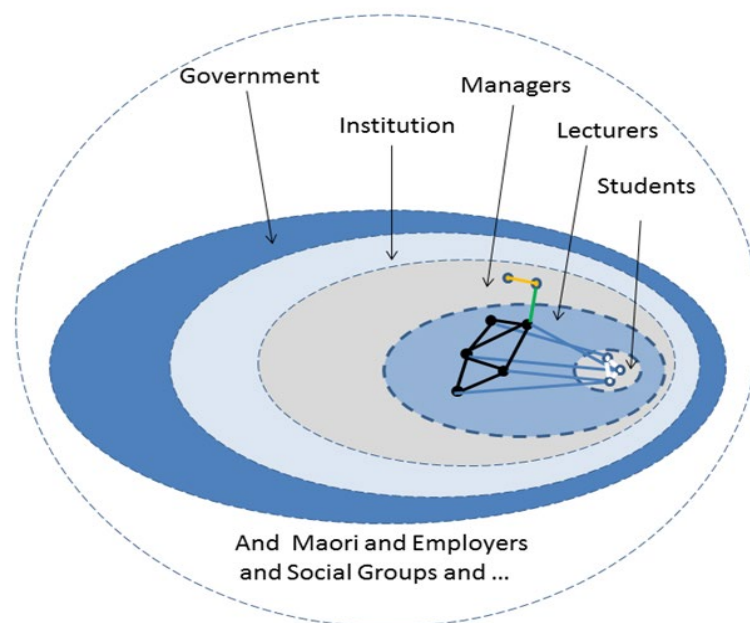


Figure 5. Quality as a complex system. Communities involved in teaching and learning science at University viewed as interacting levels (ovals) in a complexity framework. The dashed lines indicate 'fuzzy' boundaries and the openness of the system. Lines connecting circles represent interactions between lecturers, students and managers. The whole contributes to the emergence of quality. Adapted from 'Knowledge Must be Contextual: Some Possible Implications of Complexity and Dynamic Systems Theories for Educational Research', by T. Haggis, 2008, *Educational Philosophy and Theory*, Volume 40(1), p. 171. Copyright 2008 by Taylor & Francis. Adapted with permission.

However, complexity-based problems may deteriorate into wicked problems, for example, when interactions don't function effectively. Investigating the interactions in this study, and the conditions under which quality emerges, may contribute to a better understanding of the relationship between wicked and complex problems. Therefore, combining complexity and wickedity in thinking about quality in higher education may help identify conditions or factors contributing to the emergence of quality, or alternatively with quality remaining a wicked problem.

The concepts encompassed by the lenses guided all subsequent choices in my study, in particular, the concept of openness. This meant that I chose research approaches and methods that enabled the exchange of information and experiences between participants and myself, and (where possible) between participants themselves, and I remained open to change throughout the study.

Also, the focus on lecturers' views indicated my sociopolitical commitment to valuing the meaning that lecturers ascribed to quality, and our collective roles as knowledge producers in the sector (Greene, 2006), as I endeavoured to interpret their meanings in this study.

The nature of the research questions had indicated that a research approach with the potential to provide both breadth and depth of understanding was needed. My theoretical framework highlighted the need for a research approach that was open to information and interactions. Mixed methods research offered an approach that was responsive to all these requirements. The reasons for selecting this approach, together with its philosophical underpinnings and my personal philosophical assumptions, are discussed next.

Selecting a mixed methods research approach

Mixed methods research is recognised as a third model of research in the social sciences, along with qualitative and quantitative research (Johnson et al., 2007; Ponce & Pagán-Maldonado, 2015), and is increasingly being used to investigate complex issues in various education and healthcare contexts (for example, Johnson & Onwuegbuzie (2004), Johnson & Schoonenboom (2016), Rudd & Johnson (2010)). Mixed methods research attempts 'to systematically dialogue with, engage, understand, respect, and combine/integrate multiple concepts and perspectives (e.g. about meaning, epistemology, ontology, what is 'seen', what is important, emic vs. etic viewpoints etc.' (Johnson, 2011, p. 31)). To investigate research questions in education, philosophical stances—or paradigms—are used to guide subsequent choices of research methods (Hall, 2013; Johnson, 2011). Three main theoretical (philosophical) positions have been advocated for mixed methods research—no stance, multiple stances, or a single stance—with many researchers favouring a single

stance of pragmatism, with its focus on the research problem and its outcome, or, occasionally transformation with its emancipatory objective. Versions of realism have also been proposed (Feilzer, 2010; Hall, 2013). However, a need for multiple stances—or ‘pluralism’—that enable researchers in teams to engage in their differences, has recently been highlighted and a dialectical pluralism framework advocated for this (Johnson, 2017). Interestingly, Burke Johnson changed his original position in which he advocated a single philosophical stance such as pragmatism, to advocating dialectical pluralism (Johnson, 2011), highlighting the emergent and changing nature of this field of research.

Pragmatism as a philosophy for mixed methods research

For my research, a single philosophical stance of pragmatism aligned most closely with my research aims and initial worldview. The key principle that differentiates pragmatism from other philosophies is the importance of practical consequences. I chose Dewey’s pragmatism as the theoretical stance for my research because, in addition to a focus on the importance of the practical outcome, Dewey based his logic of enquiry (the term he preferred to epistemology) on naturalistic adaptation to experience, preferring continuities to dualisms (Johnson, de Waal, Stefurak, & Hildebrand, 2017). Dewey describes the overlapping subjective worlds of individuals as intersubjective worlds and truth as the outcome of enquiry (warranted assertions). His view of knowledge is transactional, based on experience plus action. This view of knowledge as relational and interacting with the environment such that both are changed resulting in growth accords with the principle of feedback contributing to self-organisation and emergence in complexity thinking (Semetsky, 2008), the key theoretical principle underpinning the notion of quality in this study. Hence, Dewey’s pragmatism provides carefully considered epistemological and methodological bases for new approaches to research such as mine.

By adopting Dewey’s pragmatism as my philosophical stance I have privileged the research problem and intended outcome—in terms of proposed actions enabling the emergence of quality. With this focus on the research questions and the actions resulting from the research, I am committed to adopting methodologies that would

best address and enable these. But what philosophical assumptions did I hold that may influence these choices and actions?

My personal ontology and epistemology

Because research in the social sciences generally involves someone studying other people, it is important that the person doing the research is aware of his/her philosophical assumptions and how these may influence the choice of research project, research design and what he/she actually does during the research process (Biesta, 2010). By articulating my assumptions I can make it clear to myself and others which influences I am aware of and, by inference, those unstated assumptions of which I remain unaware. Feilzer (2010) urges pragmatic researchers to be reflexive in asking how their values may influence the research or its outcome.

I lived and worked as a practising scientist for at least 30 years of my life, from secondary school until I became a university lecturer in science (microbiology). I thought like a scientist, I was educated and trained as a scientist and educated and trained others to become scientists. It was only when studying postgraduate papers in education that I came to understand and accept there were valid ways of thinking and forms of knowledge other than the scientist's traditional view of a real physical world (realist ontology) where an objective causal explanation (positivist epistemology) was the only knowledge of value. I was transformed by this experience. My natural curiosity now knew no bounds and I was eager to explore some of these other ways of thinking that I had discovered in the humanities discipline of education. As I came from a scientific background where quantitative data was the only data perceived to be of any value I was especially keen to embrace an entirely different type of research in education. I sought to understand rather than explain and therefore ascribed to an interpretive epistemology. My epistemology had become 'soft relativist . . . respecting the opinions and views of different people and different groups' (Johnson & Onwuegbuzie, 2004, p. 16). However, I struggle(d) more with the nature of reality. The acceptance of ontological relativism in which reality is socially constructed, and differing from person to person as each constructs their own reality based on their

senses and consciousness (Scotland, 2012), was a significant change in thinking for me (see personal reflection).

My worldview includes individually and socially constructed realities, and I seek to understand others' views through interpretive enquiry. I adopted Dewey's philosophical pragmatism with its focus on my research problem and intended outcomes. With my overarching theoretical framework based on complexity thinking and wickedity guiding my research approach, I then proceeded to select an appropriate mixed methods research design for the study.

3.2.2 Selecting the mixed methods research design

Mixed methods research (MMR) enables qualitative and quantitative data to be combined in a way that contributes to a better understanding of a research problem than the findings from each dataset separately (Creswell, 2015). As a research approach, MMR involves collecting both quantitative and qualitative data, integrating these and making interpretations 'based on the combined strengths of both sets of data to understand research problems' (Creswell, 2015, p. 2). The main principle of this approach is that a better understanding of a research problem results from the combination of statistical trends and personal experiences than from either approach on its own. Collecting both qualitative and quantitative data confers the inherent advantages of each to a study, while complementing some of the weaknesses of the other. For example, qualitative data can be in the form of detailed interview transcripts but from only a few participants, whereas quantitative data in the form of a survey can be from large numbers of participants but without details. Hence, the former provides a depth of understanding, the latter provides breadth and, by integrating the data, MMR combines the advantage of both.

The aim of mixed methods research is to combine qualitative and quantitative research components to strengthen the findings of a study and answer the research questions with multiple validities legitimization (Schoonenboom & Johnson, 2017). To achieve this, these authors urge consideration of seven primary (or major) dimensions when selecting and designing mixed methods research including purpose, theoretical drive, timing, point of integration, design approach, type of design and complexity. I

will now demonstrate each of these dimensions for my study. My purpose for this study was to make proposals for undergraduate science teaching and learning that would help lead to quality, based on views from science lecturers. This needed an in depth exploration of views that could be generalizable for the discipline of science. The purpose of mixed methods therefore *expanded* the breadth and range of enquiry. Another purpose was *development* as one component would inform the development of others. In terms of theoretical drive, the intention of this study was primarily exploration-and-description rather than testing-and-prediction; this is characterised as qualitative dominant (QUAL in Morse notation) (Johnson & Onwuegbuzie, 2004; Johnson et al., 2007; Schoonenboom & Johnson, 2017). The dimension of timing refers to the order in which the methods are conducted, either sequentially or concurrently, and may include the notion of dependence; this study was entirely sequential as it involved dependence. An important dimension of mixed methods research is the point at which quantitative and qualitative components are integrated. The present study aimed to integrate the findings from the whole study through the use of the same theoretical framework for analysis at the final discussion stage.

A multiphase design

I designed a multiphase mixed methods study with two sequential phases: Phase 1 was a Delphi method with an exploratory sequential design; and Phase 2 was an explanatory sequential design consisting of a survey followed by interviews. The design typology is illustrated in Figure 6.

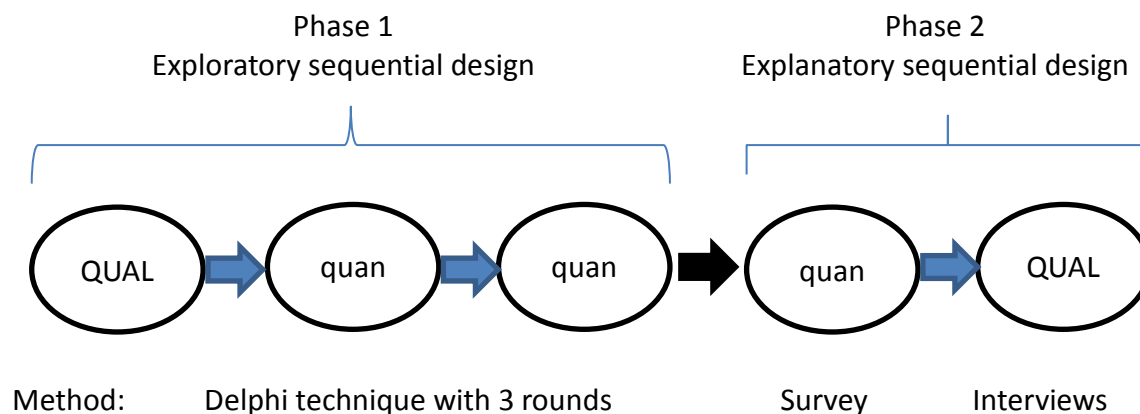


Figure 6. Typology of the multiphase design in Morse notation. Note. QUAL (in capitals) indicates the dominant component is qualitative. Arrows (rather than +) indicate the sequential (rather than concurrent) timing of components.

I provide the rationale for each of these phases and their methods next.

Phase 1: Delphi study

Because there was no single standard or agreed good practice guidelines for teaching and learning in undergraduate science that I could use as the basis for the lecturer survey, I first needed to establish a view of quality teaching and learning in undergraduate science from which to construct a suitable survey. For this I chose a Delphi study with a panel of tertiary teaching excellence award winners in science. The Delphi technique, developed in the 1950s, remains popular for trend identification, planning and policy evaluation (Coates, 1996, 1999). Originally it focused on developing a consensus but a number of modifications emerged including the dissensus method that aims to capture all possible views on a particular topic from a panel of experts and serves as an exploratory tool (Steinert, 2009). I chose this dissensus Delphi method as it is in accord with the key complexity concept of being open to emergent findings. The advantages of the Delphi method include that the respondents are considered to be experts. This gives weight to their recommendations and conclusions without suggesting generalisability. Because panellists are spatially separate and anonymous to each other, communications are without direct conflict. This dampens the voices of strong personalities and makes it difficult for the powerful to gain dominance over the quality of reasoning. Delphi is also relatively cost effective

and its flexibility enables the tool to be adapted to suit a variety of research purposes, for example, it can be conducted entirely online. Among the disadvantages are that the results will always be biased towards panel members' views, the relatively small number of participants involved can have a limiting influence on the richness of outcomes, and that the multiple responses required may lead to participant fatigue and reduce response rates (Bolger & Wright, 2011; Rowe & Wright, 2011).

A key characteristic of Delphi methods is the use of multiple iterations (rounds) with feedback comments giving reasons for disagreement being collated and circulated to panel members. Panel members are therefore aware of others' arguments for their views and able to change their own in subsequent rounds. Importantly, the focus in the dissensus Delphi method is on exploring the range of views, similar to the concept of 'brainstorming', and no consensus is sought (Steinert, 2009). I planned to ascertain panel members' views in three rounds: the first round requiring responses to open questions followed by two rounds of surveys with statements requiring Likert-type scale responses. I chose a five-point scale to explore the range of views without overloading respondents with choices (Steinert, 2009). This combination of open responses followed by surveys constitutes an exploratory sequential design. The planned procedures for each of the three rounds are outlined in Table 3.

I chose national tertiary teaching excellence award winners from science disciplines to be on the Delphi panel as they are recognised publicly for the quality of their teaching, based on evidence that the teacher is:

student-centred and has maintained, over a significant time-frame, teaching practices which are characterised by excellence and which engage students and promote effective learning appropriate to the subject level and the background of the students; is proactive in their professional development as a teacher; has had a positive influence on the teaching practice and/or the professional development of colleagues with respect to teaching and learning – either within their organisation or more widely; demonstrates sustained excellence, innovation, and a unique contribution in their role as teacher (Ako Aotearoa, 2016).

This is an example of purposive sampling where the participants meet specific criteria (Lavrakas, 2008) associated with quality teaching in this case.

Table 3. The procedures planned for Phase 1: the exploratory sequential design Delphi study. Based on Ivankova, Creswell, and Stick (2006) and Creswell (2015).

<i>Round</i>	<i>Purpose</i>	<i>Procedures</i>	<i>Products (outputs)</i>
<i>Round 1</i>	Qualitative data collection	<ul style="list-style-type: none"> • Open text questions 	<ul style="list-style-type: none"> • Text database
	Qualitative data analysis	<ul style="list-style-type: none"> • Coding and thematic analysis based on sensitising lenses • Cross comparison 	<ul style="list-style-type: none"> • Illustrative statements representing all themes from round 1 form questionnaire for round 2
<i>Round 2</i>	Quantitative data collection	<ul style="list-style-type: none"> • Likert-type scale questions 	<ul style="list-style-type: none"> • Statistical data in graphs
	Qualitative data collection	<ul style="list-style-type: none"> • Open text questions for justification of responses 	<ul style="list-style-type: none"> • Text database
	Quantitative data analysis	<ul style="list-style-type: none"> • Descriptive statistics 	<ul style="list-style-type: none"> • Provisional identification of characteristics associated with quality
	Qualitative data analysis	<ul style="list-style-type: none"> • Coding and thematic analysis based on sensitising lenses • Cross comparison 	<ul style="list-style-type: none"> • Refined statements and questionnaire for round 3
<i>Round 3</i>	Quantitative data collection	<ul style="list-style-type: none"> • Likert-type scale questions 	<ul style="list-style-type: none"> • Statistical data in graphs
	Qualitative data collection	<ul style="list-style-type: none"> • Open text questions on format of questionnaire 	<ul style="list-style-type: none"> • Text database
	Quantitative data analysis	<ul style="list-style-type: none"> • Descriptive statistics 	<ul style="list-style-type: none"> • Characteristics associated with quality clarified
	Qualitative data analysis	<ul style="list-style-type: none"> • Coding and thematic analysis. • Cross comparison 	<ul style="list-style-type: none"> • Construction of draft lecturer survey for phase 2 of study

Phase 2: Lecturer survey and interviews

Lecturer survey. To find out what university science lecturers in New Zealand considered to be quality teaching and learning in undergraduate science, I planned to use a survey with a combination of Likert-type scale and open ended questions. I chose a survey to obtain sample breadth, aiming for generalisability of findings, and included open questions to remain open to emergent findings, in accord with the key complexity idea of openness. To obtain as large a sample as possible to increase generalisability, I planned to send the survey to all university lecturers in experimental sciences in New Zealand so they could then choose whether to participate or not. This self-selection (or volunteer) sampling method has the potential advantage of reaching a large audience but is prone to a bias towards groups with particular interests in a topic (Lavrakas, 2008).

Lecturer interviews. To add to the findings from the Delphi study and investigate ideas arising from the survey, I planned to interview a sample of survey respondents based on criteria collected in the survey to ensure breadth of disciplines, institutions, and a minimum teaching experience of 2 years. I chose semi-structured interviews to gather in-depth views, in preference to alternatives such as a detailed written survey because a guided (semi-structured) interview enables views on the topic of interest to be elicited and probed further as themes of particular interest arise, especially when these are new or unexpected. Semi-structured interviews also help keep the interviews focussed on the topic whilst allowing the interviewee to freely express their views rather than just 'chatting'. Having a structure in interviews also provides comparable data across interviewees and topics (Lavrakas, 2008). For in-depth responses to questions, and to explore views, qualitative interviews with individuals or focus group interviews are the main methods of choice (Blaxter, 2010; Glesne, 2005). Individual interviews were chosen in preference to focus groups as the latter can suffer from the disadvantages of a dominant, influential character, or majority opinion, swaying members' opinions (causing 'groupthink'). Although interviews can be a highly effective way of obtaining in-depth information on a topic (Blaxter, 2010), they are very dependent upon the skills of the interviewer and the structure or format of the interview. I previously had conducted three semi-structured interviews of lecturers

using an earlier version of the planned interview schedule in a small pilot study. I also intended to conduct interviews in the spirit of appreciative inquiry by focusing on positives and aspirations for the future, to encourage and enable open and deep responses (Carnell, 2007), again in agreement with the complexity concept of openness, and also to make the experience as constructive as possible for interviewees. The combination of survey followed by interviews constituted an explanatory sequential mixed method design. The planned procedures for each stage of this phase are outlined in Table 4.

Table 4. The procedures planned for Phase 2: the explanatory sequential design lecturer survey and interviews. Based on Ivankova, Creswell, and Stick (2006) and Creswell (2015).

	<i>Purpose</i>	<i>Procedures</i>	<i>Products (outputs)</i>
<i>Surveys</i>	Quantitative data collection	<ul style="list-style-type: none"> • Likert-type scale questions 	<ul style="list-style-type: none"> • Database with variables
	Qualitative data collection	<ul style="list-style-type: none"> • Open text questions 	<ul style="list-style-type: none"> • Text database
	Quantitative data analysis	<ul style="list-style-type: none"> • Clean database • Descriptive statistics • Exploratory factor analysis 	<ul style="list-style-type: none"> • Statistical graphs • Underlying Factors • Significance results (ANOVA) • Interviewees selected by criterion sampling
	Qualitative data analysis	<ul style="list-style-type: none"> • Coding and thematic analysis based on sensitising lenses • Cross comparison 	<ul style="list-style-type: none"> • Characteristics associated with quality, or influencing lecturers' teaching, provisionally identified • Findings added to those from Phase 1
<i>Interviews</i>	Qualitative data collection	<ul style="list-style-type: none"> • Semi-structured interview questions • Characteristics in the survey associated with quality, or influencing lecturers' teaching, explored in-depth 	<ul style="list-style-type: none"> • Interview transcripts • Text database in NVivo for easy coding
	Qualitative data analysis	<ul style="list-style-type: none"> • Coding and thematic analysis based on sensitising lenses • Cross comparison 	<ul style="list-style-type: none"> • Broaden and deepen the findings from Phase 1 and Phase 2 survey • Characteristics associated with providing conditions for the emergence of quality, or influencing lecturers' teaching, revealed

3.2.3 Data analysis

Phase 1: Delphi study

I planned to analyse all qualitative data from Phase 1 Round 1 and the open text comments from Rounds 2 and 3, with the sensitising lenses I designed, for themes and patterns related to the lenses. The use of predefined themes to categorise all the data in a dataset, constitutes a theoretical thematic analysis that is appropriate when the research is driven by a theoretical interest, such as the framework in this study. It also provides a detailed analysis of a specific topic suitable for under-researched areas, albeit less rich than an inductive approach (Braun & Clarke, 2006). I intended to interpret the underlying (or latent) meaning of responses within the themes based on the literature and my experiences. Computing software NVivo 10 (QSR) would be used to aid this analysis.

I planned to use descriptive statistics to analyse the Likert-type scale data from Delphi Rounds 2 and 3, illustrate the frequency of these responses, and use the range of responses as an indication of the extent of consensus among the panel. Descriptive statistics, in particular graphs, help 'reveal the underlying message of the data' (Field, 2013, p. 122).

Phase 2: lecturer survey and interviews

I planned to use descriptive statistics to analyse data from the lecturer survey, illustrate the relative frequency of these responses, and use the range of responses as the basis for classifying statements according to the extent of consensus. Descriptive statistics, in particular graphs, help 'make large datasets coherent [and] reveal the underlying message of the data' (Field, 2013, p. 122).

I chose to use exploratory factor analysis because it would identify the possibility of lecturers' responses to the large number of items on the survey being a reflection of a small number of 'latent variables' or underlying factors (Field, 2013, p. 666) and is useful for reducing large numbers of variables from questionnaires into meaningful categories (Yong & Pearce, 2013). Exploratory factor analysis was appropriate as my research aimed to reveal patterns by exploring the dataset whereas confirmatory

factor analysis aims to confirm hypotheses (Yong & Pearce, 2013). The software IBM SPSS Statistics version 23 would aid statistical analyses.

I intended to use theoretical thematic analysis based on the sensitising lenses to analyse the open text comments on the lecturer survey and the lecturer interview transcripts. For large volumes of data, the initial lens-based coding would be followed by inductive coding within each lens category to enable the identification of themes within these categories and allow for emergent findings.

3.2.4 Legitimation

The quality criteria for mixed methods research—also referred to as mixed research—has evolved as the field has developed and become more clearly defined (Collins, Onwuegbuzie, & Johnson, 2012; Onwuegbuzie, Johnson, & Collins, 2011). A typology of nine types of mixed research legitimation has been widely adopted, and has been extended to include the concepts of philosophical clarity and dialogue with values and perspectives of multiple communities of practice to provide a ‘holistic and synergistic legitimation research process’ (Collins et al., 2012, p. 862). By outlining my personal worldview (ontology and epistemology) and using Dewey’s pragmatism as the philosophical stance for this study, I have provided philosophical clarity. Although this is a PhD study conducted by myself alone, it has been essential for me to dialogue openly and constructively with values and perspectives of individuals in different communities of practice within education for the planning and the design stages of this study. I needed to extend this dialogue to different communities of practice within the sciences for subsequent stages of the study. The nine types of legitimation outlined by Onwuegbuzie et al. (2011) are given in Table 5 together with the measures taken to address these.

Table 5. The types of mixed methods legitimation (Onwuegbuzie & Johnson, 2006) and how they were addressed in this study.

Legitimation type	Description	How this was addressed in my research
Sample integration	The extent to which the relationship between the quantitative and qualitative sampling designs yields quality meta inferences	Meta inferences were created at a dedicated analysis step when all the data, quantitative and qualitative, were analysed to yield a view of the findings as a 'whole'. There was no sample integration.
Inside – outside	The extent to which the researcher accurately presents and appropriately utilizes the insider's view and the observer's views for purposes such as description and explanation	As a Tertiary Teaching Excellence Award recipient and a science lecturer I have an 'insider's' view of the topic under study. I was open about this to participants whilst focusing on their views (observer's view).
Weakness minimisation	The extent to which the weakness from one approach is compensated by the strengths from the other approach	The weakness of surveys (collecting largely quantitative data) to explore the meaning of quality teaching can be addressed by the strengths of interviews (qualitative data) to obtain detailed/depth of meaning. The contextual constraints of the small sample sizes in interview-based studies (qualitative data) can be addressed by the strengths of surveys that can manage large volumes of quantitative data.
Sequential	The extent to which one has minimized the potential problem wherein the meta-inferences could be affected by reversing the sequence of the quantitative and qualitative phases	Because of the dependent nature of the components, the overall sequence was essential to the design of the study; the sequence could not be reversed.
Conversion	The extent to which the quantizing or qualitzing	Not relevant to this study as no data was converted.

	yields quality meta-inferences	
Paradigmatic mixing	The extent to which the researcher's epistemological, ontological, axiological, methodological, and rhetorical beliefs that underlie the quantitative and qualitative approaches are successfully (a) combined or (b) blended into a usable package	This research was guided by my research questions (RQs). My philosophical stance and the theoretical framework underpinned the choice of MMR as the methodological approach to address the complex nature of the RQs.
Commensurability	The extent to which the meta-inferences made reflect a mixed worldview based on the cognitive process of Gestalt switching and integration	I was able to negotiate cognitively between quantitative data and qualitative data and interpret meaning based on integrating both. This was supported by my experiences in science and education, and the philosophical and theoretical stances underpinning this study
Multiple validities	The extent to which addressing legitimization of the quantitative and qualitative components of the study result from the use of quantitative, qualitative, and mixed validity types, yielding high quality meta-inferences	The most appropriate strategies (methods) were adopted in the design. The validity of the Delphi, survey and interviews was considered separately for each technique and good practice was followed according to the relevant literature. The whole design addressed the research questions; this would not have been possible with any fewer components or simpler design.
Political	The extent to which the consumers of mixed methods research value the meta-inferences stemming from both the quantitative and qualitative components of a study	The intended audience for this research was university science lecturers. There may be a challenge in persuading science lecturers to value the qualitative data from this study. As findings are generated from within this community, and because it is mixed methods research, it is hoped the findings will be perceived to be of value.

3.2.5 Ethical considerations

As this research involved human participants, and specifically interviews with them, permission was required from Massey University Human Ethics Committee (MUHEC). Massey University highlights eight major ethical principles to be considered when undertaking research involving human participants: a) respect for persons; b) minimisation of harm to participants, researchers, institutions and groups; c) informed and voluntary consent; d) respect for privacy and confidentiality; e) the avoidance of unnecessary deception; f) avoidance of conflict of interest; g) social and cultural sensitivity to the age, gender, culture, religion, social class of the participants; and h) justice. I considered that four of these principles were particularly relevant to my study and discuss these next.

Minimisation of harm

There was a risk that Delphi panel members or interviewees may experience mild discomfort or embarrassment about their responses, such as is associated with the process of self-reflection on teaching and learning. Similarly, the association of particular responses with specific institutions may cause embarrassment to those institutions. There was also a risk that I would be alienated by my science colleagues who may feel threatened by this research, and that I may suffer stress when faced with difficulties during the research process. To address these concerns, care would be taken to explain that all views were valued and interview transcripts would be returned for approval, editing and further comments. If stress was observed in participants, details of the universities counselling system would be sensitively provided. To address any issues of stress than I may feel, I would discuss issues with my supervision team.

Informed and voluntary consent

Participation in this research was entirely voluntary, and written informed consent would be obtained from members of the Delphi panel and interviewees. Written consent would also be obtained for use of interview transcripts. For the survey, completion of the survey would constitute consent. Information sheets with details of the study included its voluntary nature, an outline of the purpose of the study,

expectations of participants and the people involved in the study. Participants had the right to withdraw at any stage, with the exception of survey participants, as it would not be possible to identify and exclude these after submission to SurveyMonkey. Information sheets were designed for each group of potential participants (senior managers for access to each university, members of the Delphi panel, lecturer survey participants and interviewees (see Appendix A).

Respect for privacy and confidentiality

When conducting interviews, it was necessary to consider the need for privacy. Because it was possible to identify members of the Delphi panel, and the lecturer survey participants who were willing to be interviewed and provided email contact details for this purpose, this information needed to be treated as confidential and not divulged to other parties. Interviewees and institutions would be anonymized. Secretaries transcribing interviews would sign confidentiality agreements (Appendix A).

Avoidance of conflict of interest

As a senior lecturer in the sciences at a New Zealand university, I had a potential conflict of interest with colleagues in the same teaching programmes. These colleagues would therefore not be considered as potential interviewees.

3.2.6 Methodology summary

In the first part of this chapter I have presented the philosophical underpinnings for the mixed methods research and my philosophical assumptions. My enquiry logics consisted of a theoretical framework of sensitising lenses based on complexity thinking and wickedity to guide the exploration of lecturers' views through a multistage research design. The research design is summarised in Figure 7 and the relationships between the research questions, proposed method and lenses, are summarised in Table 6.

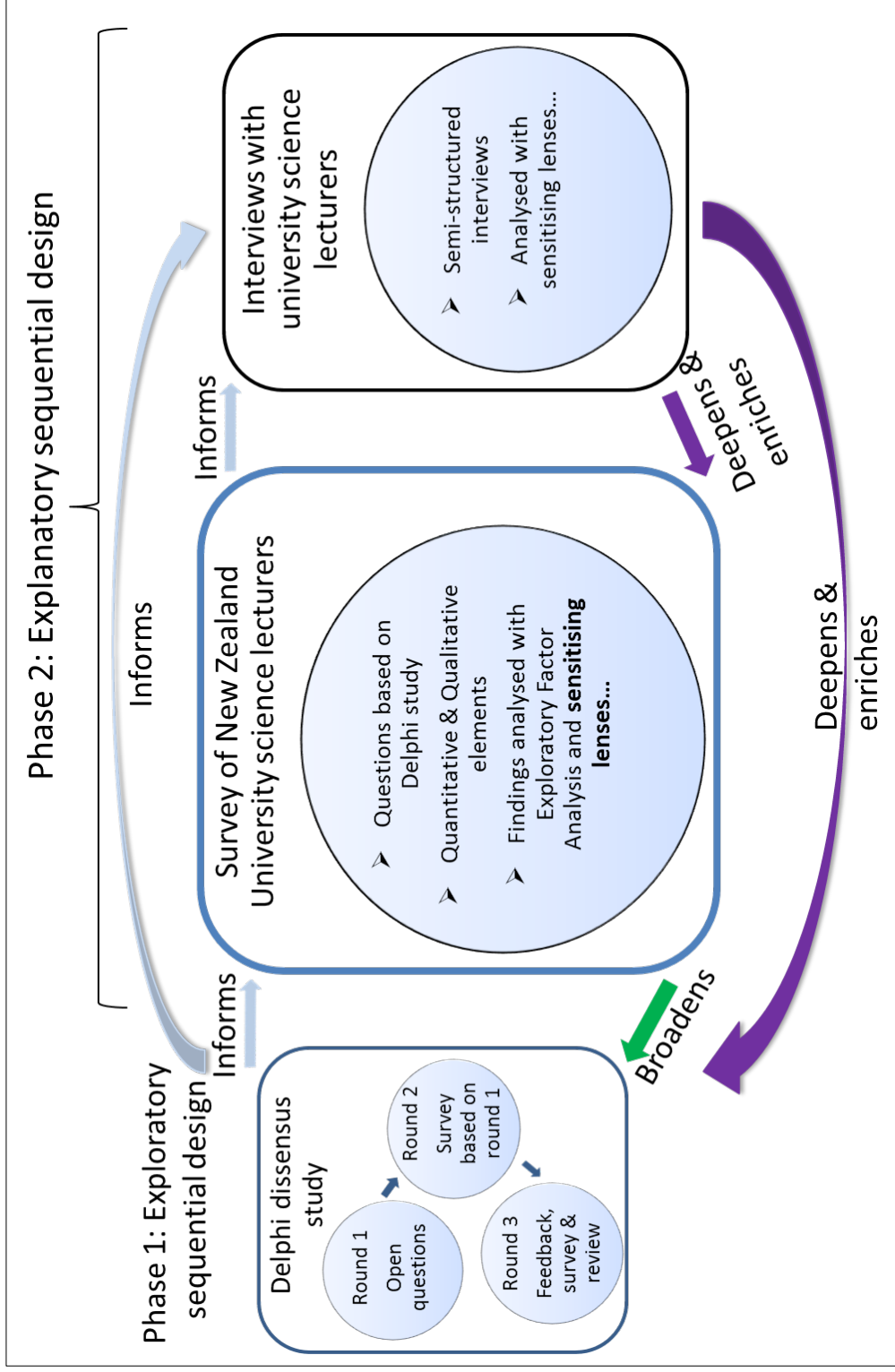


Figure 7. Summary of my multistage research design.

The exploratory sequential design Delphi study in Phase 1 is followed by the explanatory sequential design of the large scale lecturer survey and interviews. The arrows going back highlight the breadth (green arrow) and the depth (purple arrows) contributed by quantitative and qualitative data, respectively, from Phase 2 of the study.

Table 6. Relationships between research questions, methods and sensitising lenses.

Research question (RQ)	Method chosen to address the RQ	Lens used as exploration guide and analysis tool*
1. What do national award-winning tertiary teachers consider to be quality teaching and learning in undergraduate science?	Dissensus Delphi of tertiary teaching excellence award (TTEA) winners	1 - 3
2. What do a larger sample of university science lecturers consider to be quality teaching and learning in undergraduate science?	1. Survey of science lecturers at New Zealand universities 2. Semi-structured Interviews of science lecturers at New Zealand universities	1 - 3
3. What are the main influences on lecturers' views on teaching? Note: this question was modified for Phase 2 to: What are the main influences on lecturers' quality teaching?	1. Dissensus Delphi of tertiary teaching excellence award (TTEA) winners 2. Semi-structured Interviews of science lecturers at New Zealand universities	4, 5
4. What implications do these findings have for university science lecturer educational development programmes?	1. Dissensus Delphi of tertiary teaching excellence award (TTEA) winners 2. Survey of science lecturers at New Zealand universities 3. Semi-structured Interviews of science lecturers at New Zealand universities	6
5. What other proposals arise from this?	As for RQ 4 above	6

*Lenses described in Table 2

3.3 Methods

3.3.1 Ethical considerations

I obtained a full ethics approval to conduct this study from the Massey University Human Ethics Committee (MUHEC) in February 2014, prior to data collection (Southern B Application 14/01 - Appendix A). No changes were made to this during the study.

Permission (access to individual universities and staff)

To access lecturers for phase 2 of this study (lecturer survey and interviews) I had to ascertain the appropriate procedures at each university. Additional ethical permission was required to access staff for research purposes at one university. I applied for this permission and it was granted. Permission to access staff was required and obtained from appropriate senior managers at all but one New Zealand university, despite considerable help from the chair of that university's ethics committee. For most universities I then had to seek permission from individual heads of departments to contact lecturers in their department. Most heads of departments gave me permission to do this, and for an administrator to circulate the covering email containing the study information and survey link, but no response to my request was received from two departments (physics and chemistry) at one university, despite a reminder, so I was unable to access those departments. One university and one department within another university allowed me to access staff but were unable to provide administrative support so for these I emailed the lecturers directly based on staff lists available on the University websites.

Informed and voluntary consent

I sent a brief covering email and a full information sheet describing the study to the senior managers who I needed to ask for permission for access and all potential participants (Appendix A). For the Delphi study and lecturer interviews, I obtained signed informed consents from participants. For the lecturer survey, completion was deemed to constitute consent. Delphi panel members and interviewees had the right to withdraw from the study at any stage until data analysis had commenced.

Minimisation of harm

Names of interviewees and institutions were anonymized in all presentations and this thesis. I returned interview transcripts to interviewees for approval and editing, and invited further feedback, together with a transcript release form for written consent to authorise use of the transcript.

Privacy, anonymity and confidentiality

I conducted most interviews face-to-face in the interviewees' own office at their request. To ensure privacy in one institution where I was known, I organised a small meeting room in a quiet area of the campus that could be considered 'neutral territory'.

Delphi panel members were anonymous from each other but not from me. As this group of award winners is small they would have known who was likely to be on the panel. However, feedback responses were anonymous. Lecturer survey participants remained anonymous through the use of survey monkey to distribute the survey and collect responses. The exception to this was survey participants who expressed their willingness to participate further in the study (i.e. potential interviewees) and included a contact email for this purpose.

I assured interviewees that care would be taken to ensure that they could not be identified, nor could their institutions. Confidentiality agreements were obtained from the professional secretaries who transcribed the interviews (Appendix A). All responses remained confidential to myself and my supervision panel as required by the ethical approval.

Conflict of interest

Survey respondents expressing a willingness to be interviewed and with whom I co-taught at one institution were excluded as potential interviewees.

3.3.2 Data collection

Phase 1: Delphi study

Participants. I invited 16 Ako Aotearoa Tertiary Teaching Excellence Award (TTEA) winners in the sciences from 2002, when the awards began, to 2013 to take part in the Delphi study by email. I included disciplines in the experimental sciences with a ‘wet’ laboratory component, for example, biology, chemistry and physics and excluded computer, mathematical and statistical sciences. Seven TTEA winners agreed to participate in the study with six completing all three rounds.

Delphi method. The Delphi study involved the use of three questionnaires each building on and developing from findings in the previous survey. The first questionnaire—sent to panel members by email—was open-ended in asking for panel members’ responses to the questions:

1. From your experience, how do you think students learn science?
2. What do you consider to be quality teaching in science at university? Please describe two or three examples that come to mind.
3. How well, and in what ways, do you think that current methods of teaching science prepare students for the wider world of using science/working in the science field?
- 4a. What have been the main positive influences on your development as a university/tertiary teacher? Please describe the impact of these influences on your teaching.
- 4b. What have been the main negative influences on your development as a university/tertiary teacher? Please describe the impact of these influences on your teaching.

Panellists’ views emerging from their responses to questions 1, 2 and 3 became the basis for 27 statements focused on teaching and learning to test in the second questionnaire—sent to panel members via survey monkey (Appendix B). In this, panel members were asked their extent of agreement or disagreement with each statement on a five-point Likert-type scale (strongly agree, agree, neither, disagree, strongly

disagree). Further feedback on the statements in the form of open text comments was encouraged; I used this feedback to modify the questionnaire for the third round.

In the third round, feedback was shared with panel members and the questionnaire consolidated all responses to the second questionnaire into 26 statements—again sent to panel members via survey monkey (Appendix B). This time panel members were asked for their views of the relative importance of each statement. Feedback was also sought on the content, format and the suitability of this draft survey planned for New Zealand Universities in Phase 2 of my study.

Phase 2: Lecturer survey and interviews

Survey construction. This survey was derived from the round three Delphi questionnaire. In addition to the 26 statements on the characteristics of quality teaching emerging from that questionnaire, three open text questions were added to discern lecturers' views on other factors they considered important for quality teaching, how students learn science, and the impact their teaching had on students' learning (Appendix B).

Participants. In the process of obtaining permission from universities to access academic staff (see ethics section above) I received very thoughtful and constructive feedback from one senior manager that prompted me to reconsider the original definition of science and who should be included in this study. Ultimately I chose to use the term 'natural sciences' to differentiate the disciplines from the formal sciences (mathematics and philosophy) and human sciences (humanities and arts disciplines) in recognition that the meaning of science varies from any logical enquiry to a specific empirical methodological approach. Within natural sciences I included all disciplines with a hands-on practical experience, for example, experiment- or computer-based activities or field trips.

Survey implementation. I invited all lecturers and other teaching staff in the natural sciences at the seven New Zealand universities that had given permission to access staff to participate in the study (see ethical considerations above). Administrative staff of the relevant departments circulated my invitations in all but two cases; I circulated

the invitations directly to individual staff in these cases. Because of the organisation of some university colleges/schools/institutes/departments the invitation was inevitably sent to some staff who may not be considered to belong to the natural sciences, for example, engineering or statistics. Where responses were received from such staff, I included them in the study on the basis that these lecturers had chosen to participate (self-selected); they were excluded only from analyses of specific disciplines. My invitations to participate, with a link to the survey on Survey Monkey and a project information sheet, were sent to lecturers between May and September 2015.

Interviewee selection. I selected the first 20 survey respondents that fulfilled the criteria of >2 years teaching experience, from at least 3 different universities (with no more than six from any one university), from a range of disciplines and who had expressed their willingness to be interviewed, as potential interviewees. I selected the next five such survey respondents as 'reserve' potential interviewees in case any of the initial 20 were unable to participate.

Interview process. I conducted eleven interviews face-to-face at a place chosen by the interviewee; on-site in their office at their university in six cases. Interviews of five staff in one institution where I was known were conducted in a quiet room away from their offices and mine, for privacy. I used Skype with audio recording (Amolto) for seven interviews where I was unable to travel to the interviewee's university. Professional secretarial staff who signed confidentiality agreements transcribed all recordings. Transcripts were returned to interviewees for approval, editing and further comments if desired. I received seven transcripts with minor revisions. One interviewee also sent further documents illustrating examples that we had discussed in our interview.

3.3.3 Data analysis

Phase 1: Delphi study

For the Delphi study, I analysed the first questionnaire qualitatively using lenses 1-5 to discover emergent views about how students learn science (question 1), quality teaching in science (question 2), how current methods of teaching science prepare students for using science (question 3), and the main influences on panel members'

development as a teacher (question 4). Illustrative statements from the first questionnaire formed the basis for items on the second questionnaire under three broad headings: (i) how students learn science; (ii) characteristics of quality teaching in science; and (iii) how current methods of teaching science prepare students for working in science. I analysed the second questionnaire qualitatively and quantitatively. A thematic analysis using lenses 1-5 as predefined categories captured emergent ideas for each of the broad headings. A statement strongly supported by the panel with all responses on the Likert-type scale of agree (4) or strongly agree (5) was considered to show strong consensus. A statement including 'neither agree nor disagree', in the absence of any 'disagree' responses, was considered to show a lesser consensus. A statement with some differences of opinion with responses that included strongly disagree (1) or disagree (2) was considered to show little (or lack of) consensus. I scrutinised open text boxes for comments that would lead to clarifications of the 27 statements. Cross comparison between items under the three broad headings showed considerable overlap. Therefore, together with panel members' comments, this led me to clarify and rephrase some statements to focus the third questionnaire on quality teaching in science.

The third questionnaire was also analysed qualitatively and quantitatively. Responses to the final 26 statements emergent from the third questionnaire were rated according to the importance assigned to each statement. An attempt was made to capture all views and identify the extent of consensus on the importance of the characteristics the panel associated with quality teaching using a similar method to questionnaire two. A statement with all responses of 'extremely important' and 'very important' was considered to show strong consensus. A statement including 'important', in the absence of any 'not at all important' responses' was considered to show a lesser consensus. A statement receiving responses that included 'not at all important' was considered to show little (or lack of) consensus. I used descriptive statistics, in particular, frequency distributions, to analyse the quantitative data from the third questionnaire and categorise the importance of characteristics of quality teaching in undergraduate science with the aim of producing a preliminary quality teaching

framework. IBM SPSS Statistics 23 was used for all statistical analyses. Delphi response data was exported directly from Survey Monkey in SPSS format for this.

Phase 2: Lecturer survey and interviews

Statistical analyses. I used descriptive statistics, in particular, relative frequency distributions, to analyse the quantitative data from the lecturer survey. I used exploratory factor analysis to explore the possibility of latent factors (underlying variables) in this data. The number of factors to retain was determined by visual examination of scree plots. Factors were extracted by the maximum likelihood method and an oblique rotation (varimax) used as factors were considered likely to be correlated (Field, 2013, pp. 665-719; Yong & Pearce, 2013). Factors were retained as Anderson-Rubin scores for further analysis. Differences between factor groups were confirmed by analysis of variance (ANOVA) with post-hoc Tukey tests (Field, 2013, pp. 429-475). All analyses were conducted with IBM SPSS statistics version 23. Graphs were prepared in MS excel 2013/2016 as these gave clearer presentations.

Coding. I analysed all open text data from survey questions 11, 12 and 13 (Appendix B) with theoretical thematic coding using lenses 1-5 in Table 2 as predefined categories. For the interview data, I coded all data with the lenses as above and then coded data within each lens category inductively using template analysis (Brooks, McCluskey, Turley, & King, 2015). This was necessary because there was a large volume of data and I wanted to code all the data; initial attempts at coding revealed much of the data had not been coded. I used template analysis with NVivo10 software to help organise the data, initially coding a few interview transcripts with lenses 1 to 5 as the main hierarchical codes and inductively assigning codes hierarchically within these as necessary, and then coding a few more interview transcripts, adding extra codes as required. This provided a convenient way of managing the large volumes of interview transcript data and ensured that the whole dataset was coded. The addition of inductive thematic analysis to coding with the sensitising lenses highlighted the open nature of the study to emergent findings, in keeping with complexity thinking.

3.3.4 Methods summary

In this part of the chapter, I described the principles and processes undertaken to address the research questions and presented the measures taken to address the ethical concerns inherent in the research. I have outlined the data collection and analysis methods employed for the three rounds of the Delphi study in Phase 1, and the lecturer survey and interviews in Phase 2. The use of exploratory factor analysis and template coding highlighted the open nature of the study to new techniques and emergent findings, in keeping with the overarching theoretical framework based on complexity thinking.

I next present the findings from Phase 1, the dissensus Delphi study.

CHAPTER 4: DELPHI STUDY FINDINGS

4.1 Introduction

In the first part of the chapter, I address research question 1: What do national award-winning tertiary teachers consider to be quality teaching and learning in undergraduate science? I do this by describing my findings from Phase 1—the Delphi study—that analysed the variety of views on quality teaching and learning from a panel of tertiary teaching excellence award (TTEA) winners with lenses based on complexity and wickedness. I present the findings of each of the three surveys (rounds) in this exploratory sequential mixed method study culminating with the third round forming (1) a draft of the proposed national lecturer survey for Phase 2 of this study and (2) the basis of a conceptual framework for quality teaching and learning in undergraduate science.

I start with panel members' views on the open-ended questions from Round 1 on: how students learn science, the meaning of quality teaching in science, and preparation for working in science viewed with each of the three lenses—problem definition, openness and social complexity (Chapter 3, Table 2). Next, I report the findings from Round 2 where I sought panel members' extent of agreement with statements derived from Round 1, and their reasons for any disagreement. Following this, I present the findings from Round 3 on the relative importance of statements describing quality teaching in science (derived from Rounds 1 and 2) and propose a conceptual framework for quality teaching and learning in undergraduate science based on these findings.

In the second part of the chapter, I address research question 3: 'What are the main influences on lecturers' views on quality teaching?' by analysing the panel members' responses to questions in Round 1 asking about the most important positive and negative influences on their development as a university/tertiary teacher with the nonlinearity and multicausality lenses (Chapter 3, Table 2).

4.2 What do national award-winning tertiary teachers consider to be quality teaching and learning in undergraduate science?

4.2.1 Round 1: panel members' views on quality teaching, learning and preparation for working in science

Round 1 used open-ended survey questions (Chapter 3 and Appendix B) to ask the panel members for their views of how students learn science, the characteristics of quality teaching in science and how current methods of teaching science prepare students for working in science. I analysed their responses to each main question with the sensitizing concepts (lenses) to get a sense of the themes that may contribute to conditions for the emergence of quality teaching and learning in science. I present my findings from each of the lenses—problem definition, openness and social complexity (Chapter 3, Table 2)—below.

The problem with defining quality teaching in undergraduate science

The problem definition lens considers the reasons for difficulties with defining quality teaching and learning in undergraduate science and highlighted the panel's awareness that individual students have different expectations of teaching and learning. Some prefer teaching that focuses on required facts while others focus on scientific process. Such learning and teaching preferences demonstrate the complexity of teaching science and influence how students and lecturers define quality teaching in science. For example, panel members reported:

Different students learn equally effectively through very different methods. So, while one student might require hands-on experimentation in a wet lab, another might make similar progress through private study, using online simulations, or in a classroom where an enthusiastic lecturer challenges the preconceptions students bring with them. (Panel member 2)

And

They [students] try and learn science by memorising facts . . . but they actually learn by UNDERSTANDING the scientific process and how to

formulate hypotheses, design experiments to test the hypotheses, interpret experimental data, revise their hypotheses etc etc. (Emphasis in the original. Panel member 1)

This lens also highlighted different views on the form of quality laboratory experiences. Although panel members agreed that practical laboratory experience is essential for quality learning and teaching in science, views on the forms this should take differed. Some preferred prescriptive labs for learning specific skills in year 1 whilst others advocated project-based labs for learning scientific thinking skills at all year levels. For example, one panel member summarised the issue with traditional laboratory classes as follows:

Undergraduate laboratories are traditionally run via ‘recipes’ – students are asked to perform particular tasks in a particular order, and can complete the lab without understanding the experimental design. A better way is to ask them to design their own experiment, then carry it out themselves and critique the strengths and weaknesses of their experimental design, as well as the results and conclusions. (Panel member 1)

Similarly, there were different views on the nature of quality classroom teaching. There were differences about what methods challenge, stimulate, motivate and inspire students. But whether in a traditional lecture environment or an alternative classroom format, panel members described the importance of engaging students:

One of my colleagues’ first year Physics lectures revolve around performing amazing in-class demonstrations. His introductions to them and body language are crafted to give the impression that they might be disastrous failures, or if they did work, they might well cause mayhem and possibly explosions on the front bench. As a result, students sit forward on their seats, entranced, waiting to see if the gallant lecturer will be disabled or possibly incinerated. Many students bring their friends from other courses to experience them. But all are carefully crafted to work, often with an unexpected twist, and are cleverly designed to reinforce some aspect of the course material in a vivid and memorable way. (Panel member 4)

The best example I have ever seen was a foundation biology class at the University of . . . The course uses the flipped classroom model, wherein content is learned by students in their own time from online resources. The daytime instruction uses enquiry based learning in digitally-enhanced active classrooms. Students work in teams to solve real problems using the information they learned by themselves. (Panel member 2)

The *students'* ability to recognise when learning had occurred in non-traditional classes was raised by another:

my own experience . . . indicates that students often fail to recognise the nature and quality of their learning when it occurs gradually over the space of the course. (Panel member 3)

Quality as openness

The openness lens highlights interactions with new information or experiences and suggested that panel members were challenged to help students connect to prior learning, other courses of study, current research in the discipline, industry and future careers. They recognized the importance of connecting science and other aspects of student life such as social clubs and cultural contexts. For example, panel members reported:

In addition to appreciating the knowledge a student brings to the class room, wherever possible I choose teaching materials and activities that relate to the students' needs and future goals to illustrate how their attained knowledge will help them with their further learning. As adults they want to know why they need to learn something and how it will benefit them. Students tell me that encouraging them to talk about their knowledge and experience and allowing them to apply it to their learning improves their understanding of the new concepts and also leads to more discussion after class. (Emphasis in the original. Panel member 6)

And

Because content dominates teaching at the undergraduate level, the opportunities for acquiring the intellectual culture of science are limited, and students may struggle to learn content in the absence of clear connections to their other content knowledge and to life outside the university. The teaching of content rather than ideas can make it difficult for students to extract meaning from what they are being taught. In these circumstances, students must be enabled to make connections between their prior learning, their current content learning in lectures and labs . . . They must also be given signposts to their future studies so that they can see what they are learning at present will lead them forward into particular areas of study that should extend their interest and lead them into promising futures. (Panel member 7)

Quality as relationship

The social complexity lens considers the interactions between people and how these are promoted to produce change. Panellists thought positive social interaction between lecturers and students and between students, such as in scientific inquiry and flipped classrooms, is vital. Here quality is in relationships between science lecturers and others. For example, panel members reported:

Some (particularly the few Polynesians) studied best in groups, and we organised special tutorials where they could do this together. (Panel member 4)

As a teacher I interpret teaching as involving any interactions with students, whether the discussion be academic or pastoral in nature. (Panel member 7)

Construction of Round 2 questionnaire

I used the findings above and the problem resolution lens to reveal emergent ideas about quality teaching in the sciences. These focused on how students learn, characteristics of quality in teaching and preparation of students for working in science. The problem resolution lens enabled a series of preliminary statements for testing in the second round. I selected illustrative statements for each of the main themes identified from the panel members' responses to Round 1 questions, to form the second round survey, and further explore views on how students learn, characteristics of quality in teaching and preparation of students for working in science (Appendix B: Round 2 questionnaire).

4.2.2 Round 2: discerning the extent of consensus on characteristics associated with quality teaching

I analysed the 27 statements from Round 2 for the extent of support they received from panel members. A statement strongly supported by the panel with all responses of 4 (agree) or 5 (strongly agree) was considered to show strong consensus. Statements showing lesser consensus included 'neither agree nor disagree' responses, in the absence of any disagreement. A statement receiving a difference of opinion, including 1 (strongly disagree) or 2 (disagree), was considered to show little (or lack of)

consensus. Most statements about quality teaching in science, and how students learn science, met the criteria for strong consensus. A few showed lesser consensus and one showed little (or lack of) consensus. Statements are ordered below according to the strength of responses.

How students learn science

Under the heading 'How students learn science', five statements were supported by a strong consensus, and one further statement received a lesser consensus. A lack of consensus was found for one item: using prescribed laboratory experiments that are guaranteed to work. Table 7 summarises these statements and their strength of support by panel members. The frequencies of panel members' responses for these statements are shown in Figure 8 in relative order of agreement (with the most strongly supported statements on the left of the graph).

Table 7. Delphi study Round 2 statements and strength of panel members' responses to 'Students learn science by . . .'

Strength of support	Statement following the stem 'Students learn science by . . .'
Strong consensus	(i) adding connections to their prior knowledge, knowledge in other subjects, and life outside the University
	(ii) understanding the scientific process and how to formulate hypotheses, design experiments to test these, interpret experimental data and revise hypotheses
	(iii) being motivated and wanting to learn for intrinsic or extrinsic reasons
	(iv) completing exercises, assignments and solving problems
	(v) seeing and hearing the evidence of science from authorities ranging from parents to lecturers and from other forms of authority such as television and Wikipedia ^a
Lesser consensus	(vi) a variety of different methods, reflecting differences in their educational background, culture and personality
Lack of Consensus	(a) doing prescribed laboratory experiments that are guaranteed to work.

^aThis statement received all 'Agree' responses so fulfils the criteria for strong consensus, however, as it was the only statement to receive no 'Strongly agree' responses it appears on the right of Figure 8 as priority for data is based on the frequencies of 'Strongly agree' then 'Agree'.

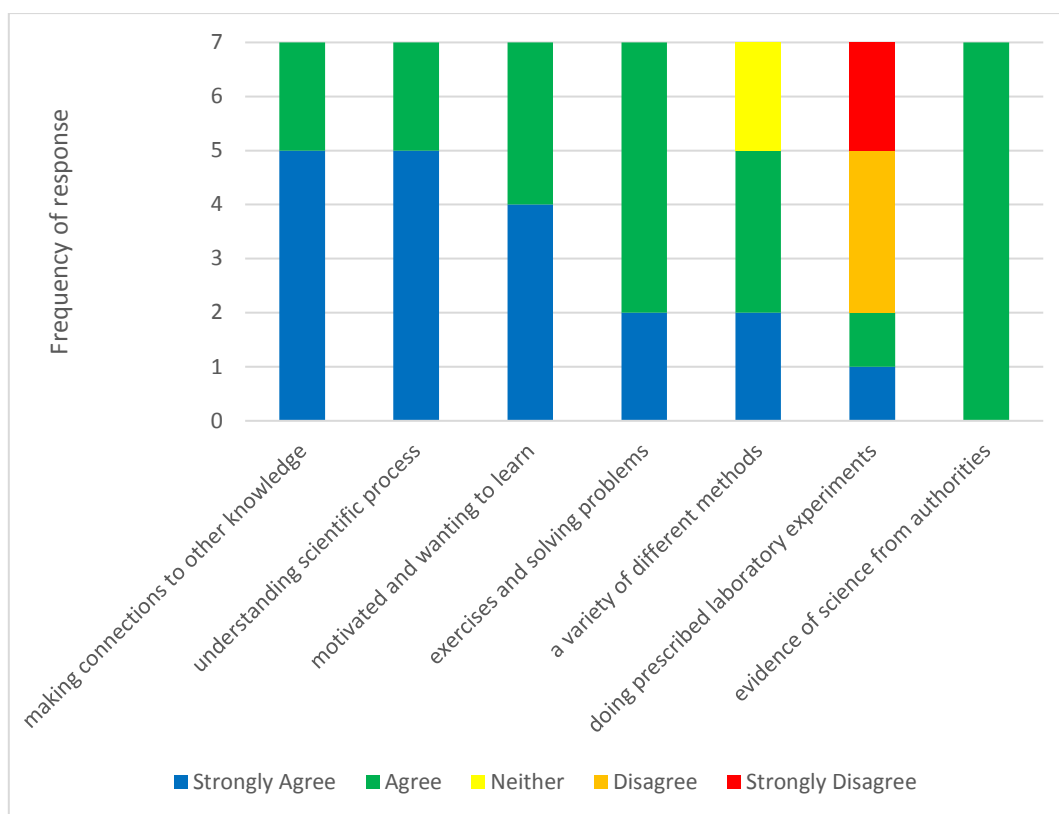


Figure 8. Delphi study Round 2 responses to the question ‘Students learn science by . . .’. Bar colours indicate frequency of the responses ‘strongly agree’, ‘agree’, ‘neither’, ‘disagree’ and ‘strongly disagree’ as shown in the legend on the Figure. Statements follow ‘students learn science by . . .’ and are shown in abbreviated form with full versions given in Table 7. Note: The presence of any ‘disagree’ or ‘strongly disagree’ responses indicates lack of consensus; the presence of any ‘neither’ responses, in the absence of any disagreement indicates a lesser consensus; all responses of ‘agree’ and ‘strongly agree’ indicate strong consensus. The priority for data is based on the frequencies of ‘Strongly agree’ then ‘Agree’.

Characteristics of quality teaching in science

Nine statements under the heading ‘Characteristics of quality teaching in science’ were supported by a strong consensus with three further statements receiving a lesser consensus. There was a lack of consensus on one statement: using lectures with demonstrations and activities at intervals to refocus the class. Table 8 summarises these statements and their strength of support by panel members. The frequencies of panel members’ responses for these statements are shown in Figure 9 in relative order of agreement (the most strongly supported the statements are on the left of the graph).

Table 8. Delphi study Round 2 statements and strength of panel members' responses to 'Quality teaching in science at university means . . .'

Strength of support	Statements following the stem 'Quality teaching in science at university means . . .'
Strong consensus	<p>(ii) providing authentic scientific experiences by connecting students with current research</p> <p>(i) providing opportunities for students to explore and discover</p> <p>(iii) using inquiry based learning (or guided inquiry)</p> <p>(viii) helping students to learn to become independent in the laboratory by asking students to design their own experiment, then carry it out themselves and critique the strengths and weaknesses of their experimental design, as well as the results and conclusions</p> <p>(vii) providing opportunities for students to be more critical of information than they may have been previously</p> <p>(vi) providing opportunities for students to reflect on their learning</p> <p>(v) being interactive and breaking down the barriers between lecturer and student to create a relaxed atmosphere in which the student can learn</p> <p>(iv) providing opportunities for students to apply knowledge from one area to another</p> <p>(ix) encouraging students to discuss their own experiences of the topic</p>
Lesser consensus	<p>(x) interacting with students, including provision of pastoral care</p> <p>(xi) engaging with Māori (indigenous people of New Zealand) and Pasifika (people originating in the Pacific Islands) students and helping these students to make connections to their own lives</p> <p>(xii) students learning about the history of New Zealand and the impacts of humans on the environment, and being encouraged to consider current issues at a philosophical level</p>
Lack of consensus	<p>(a) using lectures with demonstrations and activities at intervals to refocus the class.</p>

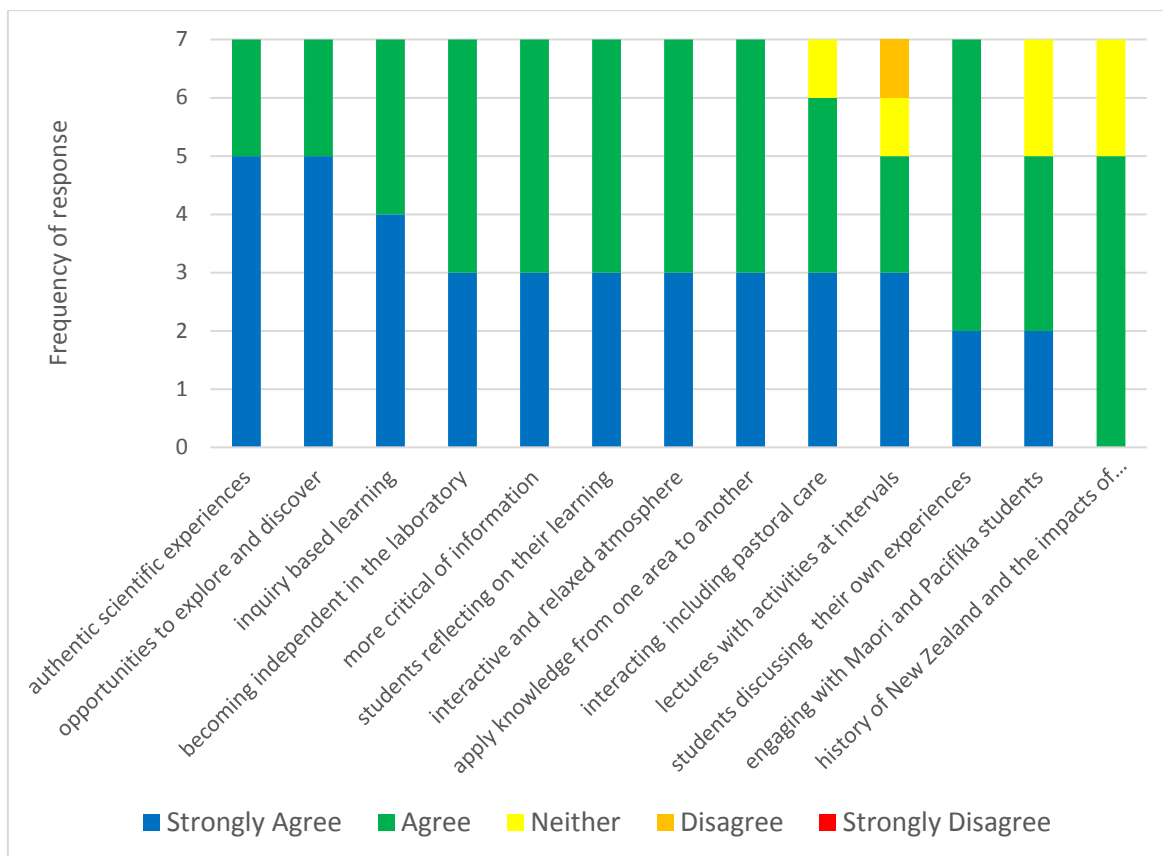


Figure 9. Delphi study Round 2 responses to the question ‘Quality teaching in science at university means . . .’ Bar colours indicate frequency of the responses ‘strongly agree’, ‘agree’, ‘neither’, ‘disagree’ and ‘strongly disagree’ as shown in the legend on the Figure. Statements are shown in abbreviated form with full versions given in Table 8. Note: The presence of any ‘disagree’ or ‘strongly disagree’ responses indicates lack of consensus; the presence of any ‘neither’ responses, in the absence of any disagreement indicates a lesser consensus; all responses of ‘agree’ and ‘strongly agree’ indicate strong consensus.

Preparation for working in science

The greatest disagreement about statements is found under the heading ‘Preparation for working in science’ with one statement receiving strong consensus, two statements with a lesser consensus and four with a lack of consensus. Table 9 summarises these statements and their strength of support from panel members.

Table 9. Delphi study Round 2 statements and strength of panel members' responses to views on preparation for working in science

Strength of support	Statement following the stem 'Current methods of teaching science prepare students <i>WELL/POORLY</i> * for the wider world of using science/working in the science field because . . .'
Strong consensus	(i) students often work in silence . . . The labs may deliver some useful skill sets, but they do nothing to capture the excitement of real science
Lesser consensus	<p>(ii) there is too little authentic science, for example, independent project work, internships, 'scenario' assessments</p> <p><i>(iii) ongoing mutually-supportive relationships between universities/Institutions and stakeholder industries ensure that programme content and delivery is developed so it is relevant to students, up to date and responsive to industry needs</i></p>
Lack of consensus	<p>(a) inquiry-based learning strategies require sophisticated teaching and skilful teachers and are often the province of expert teachers which beginning academics are usually not</p> <p><i>(b) authentic tasks are being used, for example, internships, 'scenario' assessments and independent project work where experiments may not work and original thought is required to overcome obstacles</i></p> <p>(c) content is over-emphasised and the development of lasting mastery of the discipline is questionable</p> <p>(d) a 'traditional' lecture . . . does little to challenge enquiring minds, or to improve the creative and critical thinking skills</p>

*text in *italics* indicates statements related to the stem 'Current methods of teaching science prepare students *WELL* for the wider world of using science/working in the science field because . . .'. Normal text indicates statements related to the stem 'Current methods of teaching science prepare students *POORLY* for the wider world of using science/working in the science field because . . .'

Given that supported statements (i) and (ii) are couched negatively, and statements with a lack of consensus show some discomfort with both traditional and more active learning methods, it seems that panellists are not overly convinced that current teaching methods prepare undergraduate students very well for working in science. The frequencies of these responses are shown in Figure 10 in relative order of agreement (the most strongly supported statements are on the left of the graph). The presence of 'Disagree' (orange) on this Figure represents statements with a lack of consensus.

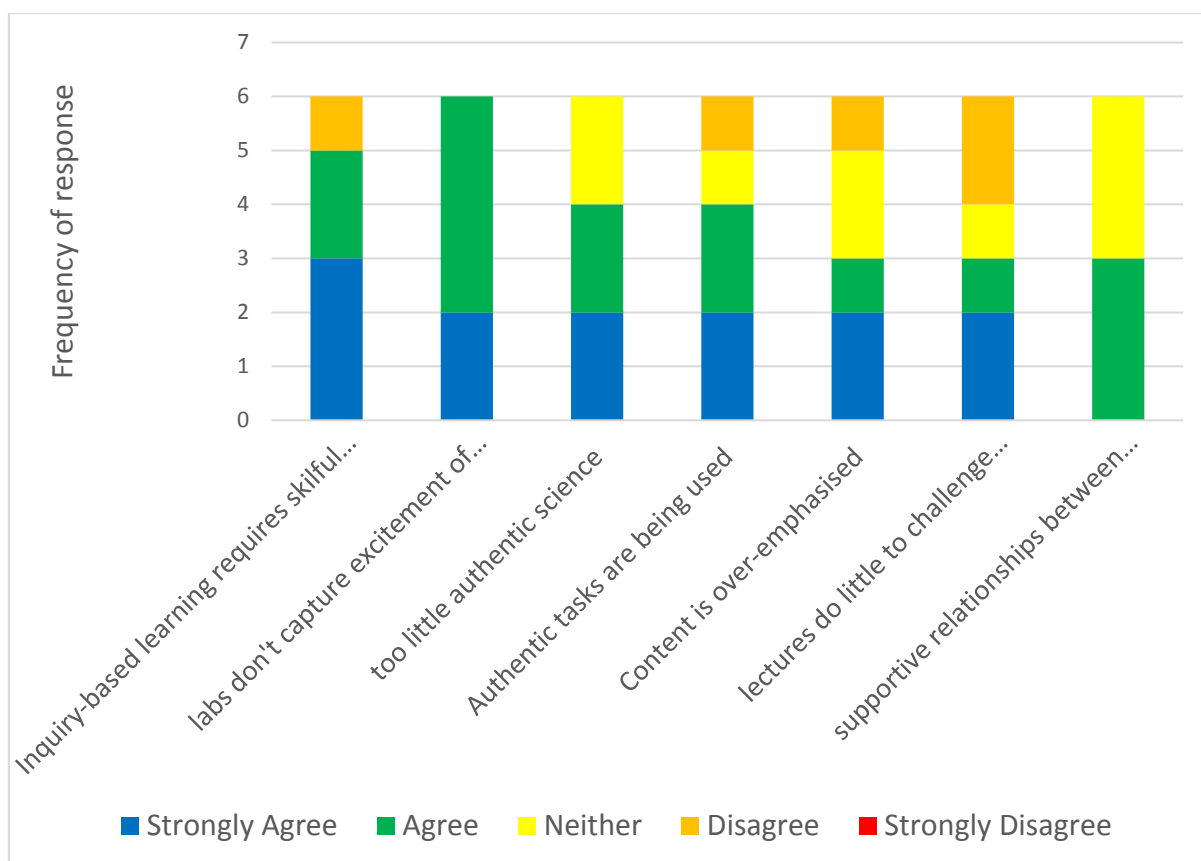


Figure 10. Delphi study Round 2 responses to the question 'Current methods of teaching science prepare students WELL/POORLY for the wider world of using science/working in the science field because . . .' Bar colours indicate frequency of the responses 'strongly agree', 'agree', 'neither', 'disagree' and 'strongly disagree' as shown in the legend on the Figure. Statements are shown in abbreviated form with full versions given in Table 9. Note: one panel member did not respond to this question on the survey.

Lecturers' justifications for responses

The comments section in the second questionnaire provided space for panel members' to support their views or give reasons for disagreement. These comments helped to modify statements for the Round 3 questionnaire which was expected to yield (1) a draft version of the proposed national lecturer survey for Phase 2 and (2) the framework for understanding quality teaching and learning in undergraduate science. For example, there was a lack of consensus about the statement 'content is over-emphasised and the development of lasting mastery of the discipline is questionable':

Usually the trap of the beginning teacher and required to produce grades at entry level classes- e.g. into medicine but less of an issue at advanced degree levels 300 and post graduate. (Panel member 5)

This helped to modify the original statement to ‘focusing more on understanding concepts and not over-emphasising content’. Similarly, there was a lack of consensus about the statement that inquiry-based learning strategies require skilful and often expert teachers:

Frequently new staff have been taught and succeeded in a traditional context - it takes time and confidence for them to believe they can use alternative methods. (Panel member 5)

This led to the statement being modified to recognize that alternative methods to lectures can take time and confidence to plan and implement.

Also, there was a lack of consensus about the statement ‘doing prescribed laboratory experiments that are guaranteed to work’ as illustrated in the following three quotes:

they do these as the basis to learn techniques at entry level degree teaching (Panel member 5)

When a prescribed laboratory is guaranteed to work, learning is likely to be lower in other experiments in which the outcome is often uncertain. A series of perfect experiments over the course of labs may develop knowledge of content being taught but will not necessarily generate learning about the scientific process . . . (Panel member 7)

This is the least good way for students learning from experiments. Many students escape learning. (Panel member 3)

This led to the statement being modified to have two statements: this at entry-level to learn techniques (new statement) and a separate statement for scientific process to cover techniques and process.

I collated panel members’ open text feedback to Round 2 describing their reasons for disagreeing with survey statements, and rephrased or split some statements to clarify meaning in response to this feedback. I also carefully rephrased, without changing the meaning, some responses from questions on how students learn science and how well current teaching methods prepare students for working in science, to focus on quality teaching. Hence, Round 2 and the panel’s feedback on Round 2 provided the basis for the final statements for the Round 3 questionnaire.

4.2.3 Round 3: refining statements on quality teaching

The third questionnaire emerged from the analyses of Rounds 1 and 2. It was designed to review, with the panel, how well the statements in the third questionnaire would serve as (1) the survey of science lecturers at New Zealand universities planned for Phase 2 and (2) the framework for understanding quality teaching and learning in undergraduate science. Participants were asked to rate the importance of each statement on a 5 point Likert-type scale where 1 represents the most important and 5 the least important (Appendix B). I analysed the statements from Round 3 for the extent of support they received from panel members. A statement strongly supported by the panel with responses entirely of extremely important (1), very important (2) or important (3) was considered to show strong consensus. A statement receiving any 'somewhat important' responses, in the absence of any 'not at all important' responses, showed a lesser consensus. A statement receiving any 'not at all important' (5) responses, was considered to show a lack of consensus. Although 6 panel members responded to round three, one returned a partial response so the data below represents responses from five panel members.

The frequencies of responses are shown in Figure 11 in relative order of importance (the most strongly supported statements are on the left of the graph).

Based on these findings I made a provisional conceptual framework for understanding quality teaching and learning in undergraduate science, shown in Table 10, to which findings from the lecturer survey in Phase 2 of the study would be added. This provisional framework shows three broad groups of findings: strong consensus, strongly supported characteristics associated quality teaching; lesser consensus, less strongly supported characteristics associated with quality teaching; and characteristics with a lack of consensus about which there are a variety of views.

Table 10. A provisional conceptual framework for understanding quality teaching and learning in science.

Quality teaching in science at university means . . .
Strong consensus statements
helping students to learn the scientific process (method) including how to formulate hypotheses, design experiments to test these, interpret experimental data and revise hypotheses.
providing opportunities for students to explore and discover to capture the excitement of real science, for example, in laboratory-based projects or field trips.
providing opportunities for students to be more critical of information than they may have been previously.
using lectures that present ideas well and challenge, stimulate, motivate and inspire students.
making connections to students' prior knowledge, other subject knowledge, and life outside the university.
providing opportunities for students to reflect on their learning.
providing opportunities for students to apply knowledge from one area to another.
motivating students by highlighting why and how things work.
using a variety of teaching approaches, rather than a 'one size fits all', because of the diverse characteristics and backgrounds of students.
using approaches to promote students' active learning, for example, exercises, assignments, problem-solving.
focusing on understanding concepts and not over-emphasising content.
using alternative methods to lectures that can take time and confidence to plan and implement.

helping students to learn to become independent in the laboratory by providing opportunities where experiments may not work and original thought is required to overcome obstacles.

providing authentic scientific experiences by connecting students with current research.

motivating students by highlighting the relevance to their future, including their careers.

having ongoing mutually-supportive relationships between universities and stakeholder industries to ensure that programme content and delivery is developed so it is relevant to students, up to date and responsive to industry needs.

Lesser consensus statements

creating a social environment for learning, for example by being interactive and breaking down the barriers between lecturer and student to create a relaxed atmosphere.

engaging with Māori and Pasifika students and helping these students to make connections to their own lives.

using inquiry based learning (or guided inquiry).

interacting with students, including provision of pastoral care.

providing opportunities for students to learn to evaluate evidence from various sources ranging from parents to lecturers etc. and from other forms of 'authority' such as television.

encouraging students to consider current issues at a philosophical level.

encouraging students to learn about the history of New Zealand and the impacts of humans on the environment.

Statements with a lack of consensus

encouraging students to discuss their own experiences of the topic.

using authentic tasks, for example, internships, 'scenario' assessments.

Statements with all responses of 'extremely important', 'very important' or 'important', in the absence of any 'not at all important' responses, were understood to indicate a strong consensus about the relative importance of the statement. Sixteen statements achieved strong consensus by this criterion with another seven receiving a lesser consensus (Table 10).

In addition to learning the scientific process, teaching methods involving connecting to other experiences, critical thinking and stimulating lectures were judged to be among the most important, with strong consensus from the panel. Reflection, application of knowledge, variety in teaching approaches, active learning, relevance and concept development also received strong support.

Relationships between teachers and students were also important, but received a lesser consensus. These included constructive involvement with diverse cultures, creating a relaxed learning environment and positive personal relationships between students and teachers. This group also included engagement beyond science such as philosophy and history of New Zealand.

Three statements had responses that included 'not at all important' indicating a lack of consensus. Two of these statements were considered of lesser importance in the framework but were nevertheless included as they were 'very important' in the views of most expert panel members and therefore worthy of inclusion. There was little support for prescriptive labs (no 'very important' or 'extremely important' responses) and therefore this item was not included in the framework.

Panel members agreed that the content and format was ready for use in the lecturer survey. All statements were retained for the lecturer survey (Appendix 3).

4.3 What are the main influences on lecturers' teaching and learning?

4.3.1 Quality as change

This lens looks at lecturers changing their teaching through multiple non-linear local interactions such as self-reflection and feedback on teaching. Panel members reported making changes in their teaching because of student feedback:

Modifying my presentation in responses to feedback from students. I assess the class reaction to every course I give . . . Reading critical comments can be very humbling, but acting on them works. (Panel member 4)

Panel member 6 highlighted the use of reflective practice, and how she developed this with the help of professional development opportunities, as well as using student feedback to develop his/her teaching practice:

I have continued to take full advantage of professional development opportunities that would help me to improve my reflective practice as I strive to support students along their journey of becoming independent, responsible, lifelong learners. The other crucial aspect of my teaching practice development has been around the area of student feedback. I work hard to collect both formal and informal feedback from students on methods I use that work for them and those that I could improve on. Most of my teaching practice has evolved out of my student feedback (Panel member 6)

4.3.2 Quality as influence

In Round 1, I also asked panel members about the influences on their development as a university/tertiary teacher⁴. The multiple ‘causality’ lens considers quality as influence and showed quality teaching emerged from multiple sources. Important positive influences included mentors, supportive colleagues, observing inspirational lecturers, student feedback, passion for the subject, professional development and institutional recognition and encouragement. For example, panel member 2 valued having a mentor as well as recognition of the importance of teaching at her institution:

As a young lecturer at . . . I was very fortunate to have a mentor who challenged me to think about new ways of delivering challenges to students. At . . . University I am very fortunate to work in a School that recognises the importance of good quality education, and has given me almost free reign to develop and promote contemporary pedagogies. (Panel member 2)

⁴The focus of this sub-question changed during the study. Here in Phase 1, the focus was initially on development as a teacher. In response to survey findings in Phase 2, and because I didn’t want to ask interviewees a leading question about educational development, this was expanded to explore broader influences on teaching. Therefore, I subsequently modified the question to ‘What are the main influences on lecturers’ quality teaching’.

Panel member 6 enjoyed teaching and was influenced by his/her students:

I was delighted to discover that I enjoyed working with the students as I had never considered teaching as a career. Over the years I have been teaching that has not changed, the main positive influence for me has been from the students themselves. (Panel member 6)

In contrast, negative influences included workload, having to balance teaching, research and administrative roles, the role of research assessment exercises, lack of time to develop teaching resources, and the lack of promotion for quality teaching. Panel member 5 suggested quality teaching is not a main aim of institutions:

The need to balance teaching, research and administration in a financially stretched University. Quality undergraduate teaching is not necessarily the main aim of institutions or way to advance an academic career. (Panel member 5)

The adverse effect of the Performance-Based Research Fund (PBRF) on teaching was highlighted by several panel members, as panel member 2 illustrated:

The PBRF environment immediately comes to mind. For a while it stifled any innovative approaches to teaching. This was especially true at . . . and . . . Universities, where the drive was for quality research at any cost. (Panel member 2)

4.4 Chapter summary

In this chapter, I showed that tertiary teaching excellence award (TTEA) winners in science held consensus views on many characteristics they associated with quality teaching and learning in science. In addition to helping students learn the scientific process, strongly supported characteristics included critical thinking, making connections to other aspects of students' lives and using a variety of active learning strategies. Still important, but less so, were social interactions, and engaging with Māori and Pasifika students. However, there was little support (with 'not at all important' responses) relating to encouraging students to discuss their own experiences of the topic. Similarly, there was little support on how well authentic tasks were being used to prepare students for the world of working in science. There was very little support from the panel for prescriptive laboratory classes. Overall, the panellists saw science teaching as focused on process and an academic discipline rather

than preparation for employment or providing a general education. These findings formed the basis of the framework for understanding quality teaching and learning in undergraduate science and the national survey for Phase 2 of this study.

CHAPTER 5: LECTURER SURVEY FINDINGS

5.1 Introduction

In this chapter, I describe my findings from the lecturer survey where I extended the survey derived in the Delphi study to the larger sample of science lecturers at New Zealand universities. I begin with a description of the participants—including university and discipline distributions, length of time teaching and ethnicity. Next, I address the research question ‘What do a larger sample of university science lecturers consider to be quality teaching and learning in undergraduate science?’ using statistical analyses of lecturers’ views on the statements derived from the Delphi study. I use descriptive statistics to show the relative importance of survey statements, frequency of implementation and the relationship between the two. This is followed by an exploratory factor analysis that identifies underlying factors. Then I address the above research question through an analysis of the open text survey comments with the problem definition, openness and social complexity lenses. Finally, I address the research question ‘What are the main influences on lecturers’ quality teaching?’⁵ with the non-linearity and multi-causality lenses.

5.2 Survey participants’ demographics

5.2.1 Response rate

I received 130 responses from approximately 990 invitations sent to lecturers at the seven participating universities, estimated from departmental staff lists on University websites and administrators, suggesting a response rate of about 13%. This is a low response rate and I

⁵ The focus of this sub-question changed during the study. In Phase 1, the focus was initially on development as a teacher. In response to survey findings in Phase 2, and because I didn’t want to ask interviewees a leading question about educational development, this was expanded to explore broader influences on teaching. Therefore, I subsequently modified the question to ‘What are the main influences on lecturers’ quality teaching’.

acknowledge that the sample is likely to consist of science lecturers who are particularly interested in teaching. I excluded one response as the lecturer was not from a university on the list of universities included in the study (and therefore did not have ethical approval for inclusion) leaving 129 valid responses for analysis. Some respondents did not answer all the questions, however, the responses to the open questions were greater in number and richer in content than I had anticipated.

5.2.2 Demographics

Most responses (74% percent) were received from lecturers affiliated with three universities, with less than 10% from each of the remaining four universities (Figure 12). To explore and analyse disciplines, I amalgamated these into three groups: life sciences (biology related disciplines), physical sciences (physics, chemistry) and earth sciences (geology, geography). This showed that 43%, 26% and 20% of the respondents were from the life sciences, earth sciences and the physical sciences, respectively, with 11% from other science, technology, engineering and mathematics (STEM) disciplines (Figure 13) and 2% did not state a discipline. There were more responses from university A and from the life sciences, with life sciences overrepresented at university A, compared with the other disciplines and universities (Figure 14).

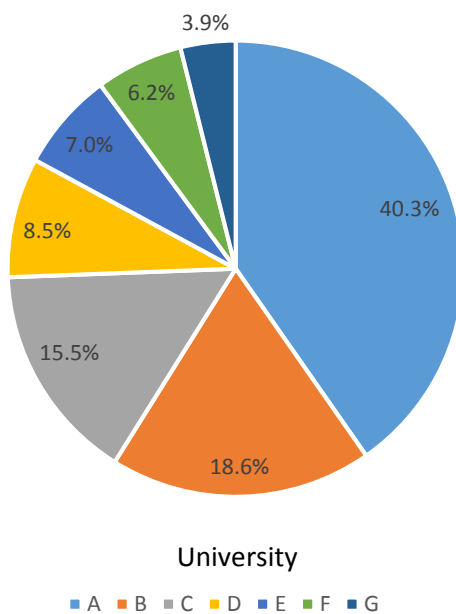


Figure 12. Frequency of lecturer survey responses by university. Universities represented by colours as shown on the Figure.

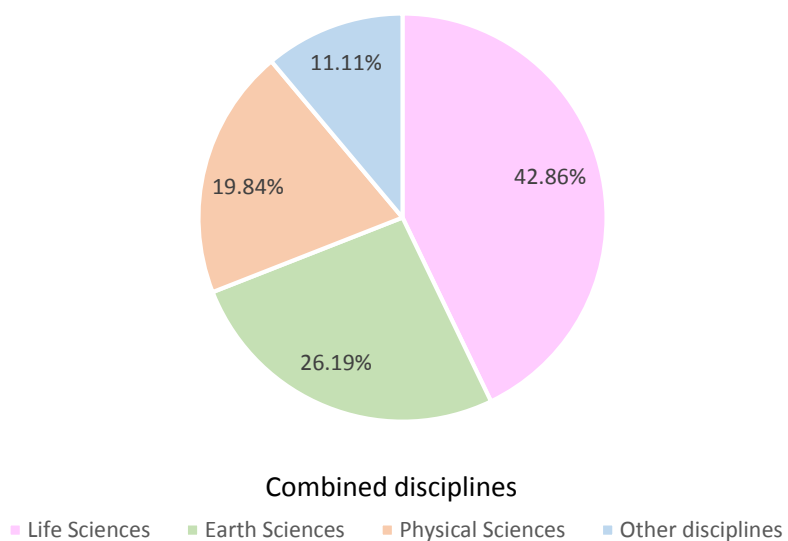


Figure 13. Lecturer survey responses by discipline. Combined disciplines represented by pale colours as shown on the Figure.

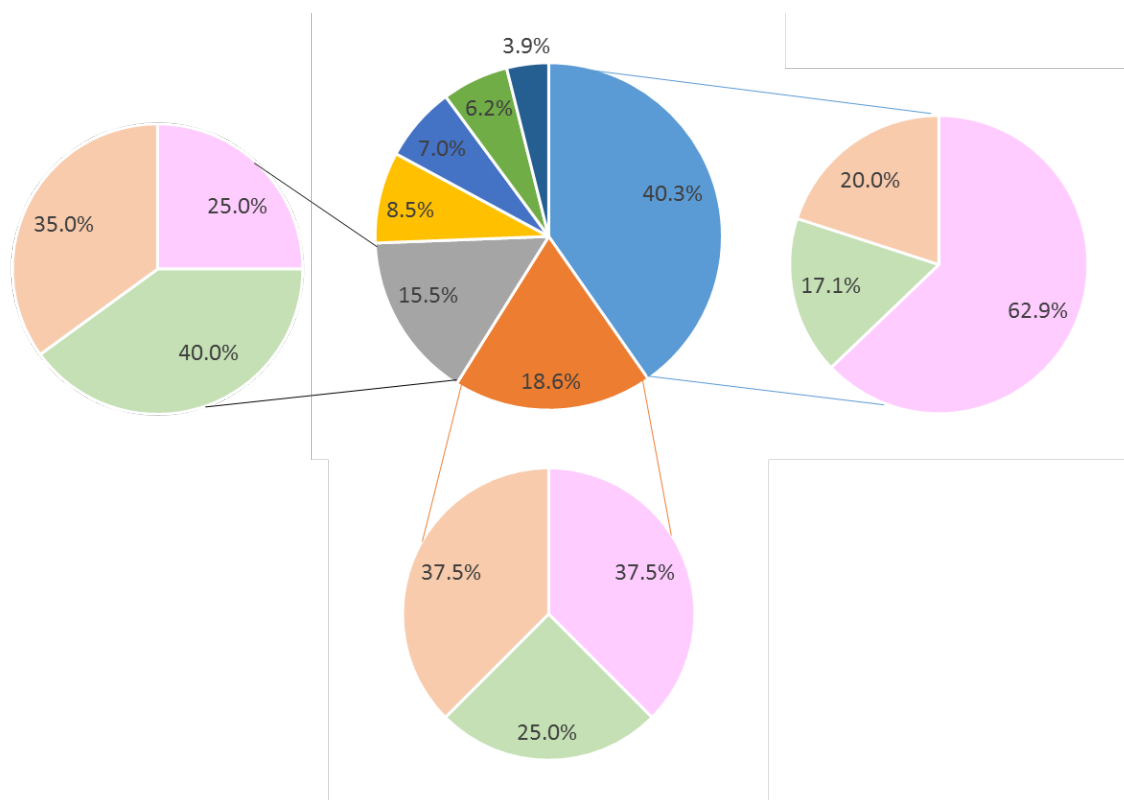


Figure 14. Distribution of responses by university and grouped discipline for universities with a minimum of 20 participants. Colours in the centre chart represent different universities as in Figure 12. The smaller charts represent the responses by grouped disciplines of life sciences, earth sciences or physical sciences at each university (as in Figure 13).

Most participants (95%) had been teaching for at least two years with 82% having at least five years' teaching experience and 57% had more than 10 years' experience. (Figure 15), indicating that the majority of participants were relatively experienced university teachers.

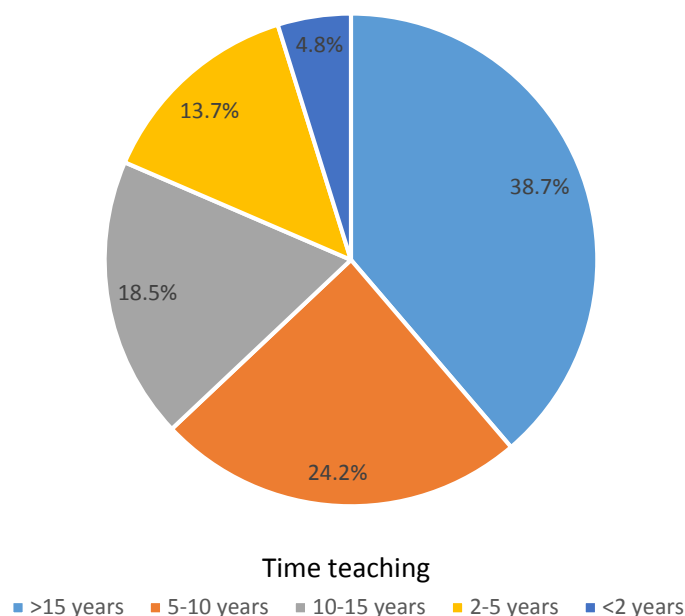


Figure 15. The university teaching experience of participants.

The majority of participants did not have any formal teaching qualifications and had not received any teaching awards (80% and 73% of participants respectively) with 5% not answering the question in both cases. This showed that the majority of participants had received no formal recognition for their teaching. Two-thirds of participants who declared an ethnicity identified as New Zealand European; 9% did not answer and 5% expressed a preference not to answer this question⁶. Figure 16 (left) highlights the very low numbers of participants who identified as Māori, Pacific peoples or Asian (less than 4%). The ethnicities with which people identified within the 16% of the 'Other' category were predominantly

⁶ 'Prefer not to answer' was an option for this question

European (including Belgian, British, German, Italian and unspecified), Australian and North American (Figure 16 right). This highlights that the participants were not representative of the New Zealand population as a whole for Māori, Pacific peoples or Asian people who were recorded at 15%, 7% and 12% respectively by Statistics New Zealand in the 2013 census (Statistics New Zealand, 2014).

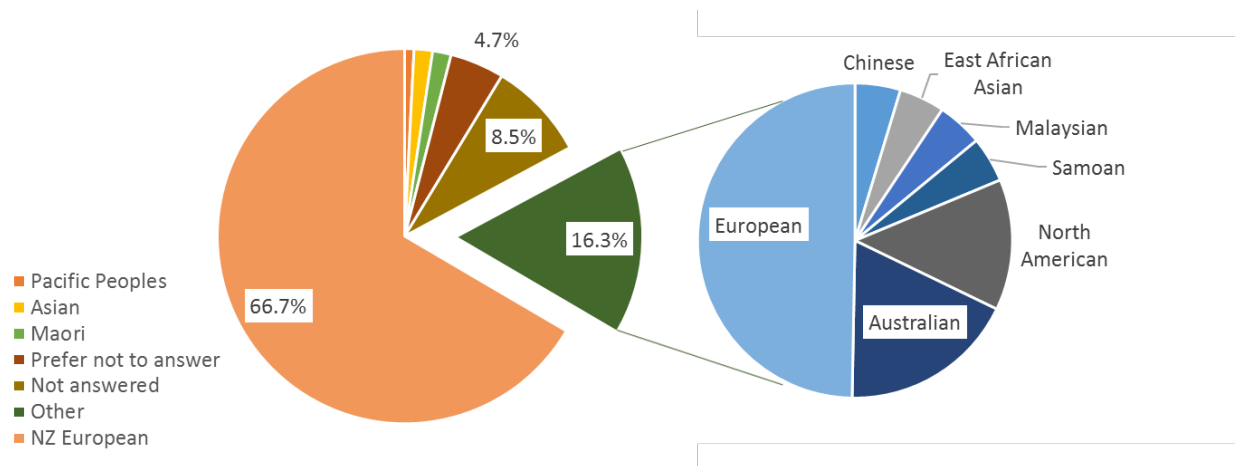


Figure 16. The preassigned ethnic groups with which participants identified on the survey (left). The ethnicities identified by participants within the survey category 'Other' (right).

5.3 What do a larger sample of university science lecturers consider to be quality teaching and learning in undergraduate science?

5.3.1 Statistical analyses of quantitative survey data

The relative importance of the survey statements

To determine how important a larger sample of lecturers perceived the 26 statements relating to quality teaching in science elicited in the Delphi study (Phase 1), I asked participants to rate their importance on a Likert-type scale of 1 to 5 where 1 corresponded to 'extremely important' and 5 to 'not at all important'. The larger number and variety of responses in this survey, compared with the Delphi study, necessitated different criteria for the classifications of consensus to reflect the greater breadth of lecturers' views. This sample of lecturers perceived all items as important but the strength of support varied (Figure 17).

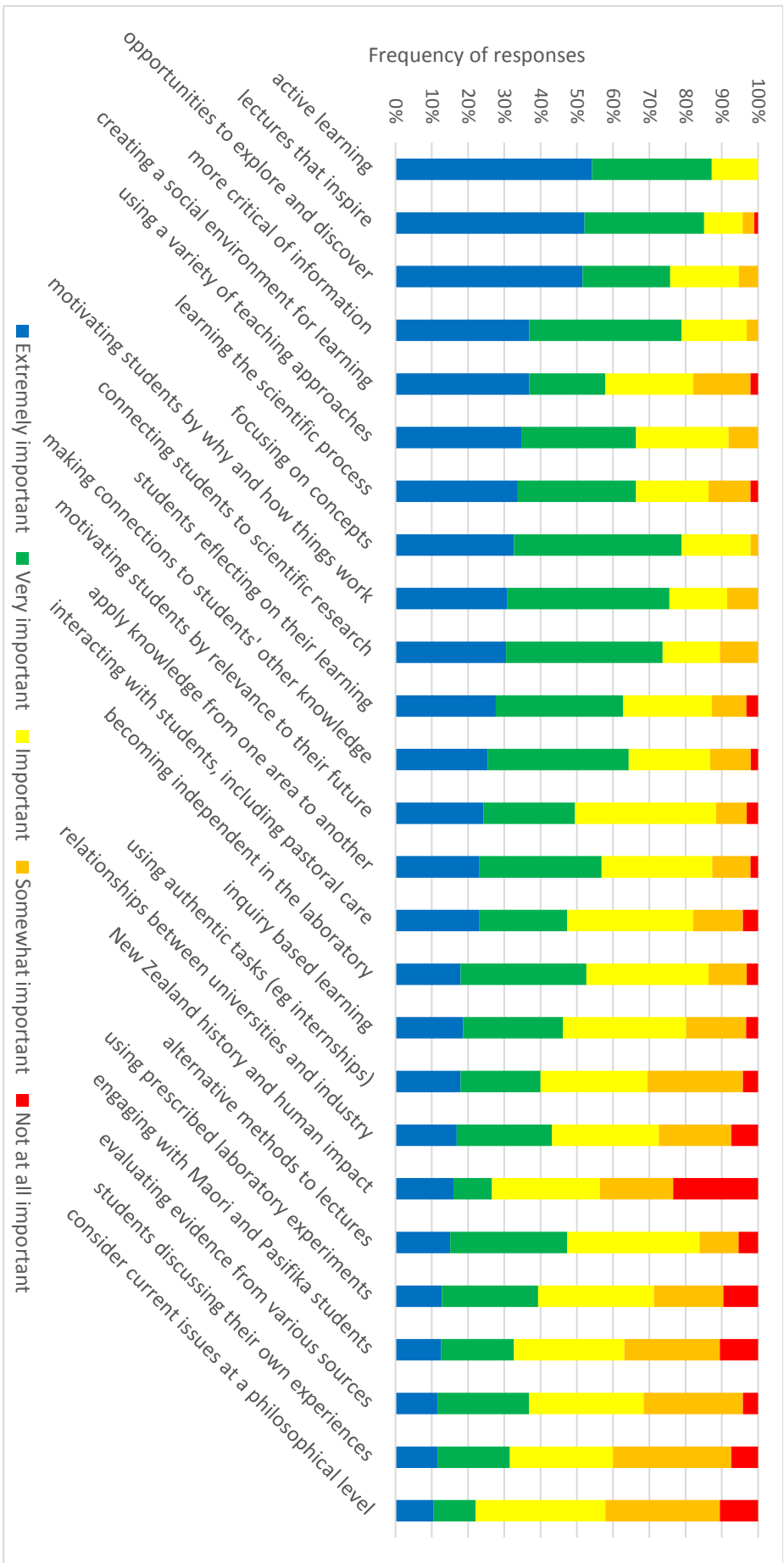


Figure 17. The relative frequency of responses to the lecturer survey on quality teaching in science. The importance lecturers' ascribed to the survey statements is indicated by the colours on the Figure. The items are sorted in order of importance with priority in the order of extremely important, very important, important, somewhat important, not at all important. The most important characteristics are on the left.

To aid interpretation of the results, I combined responses of 'extremely important', 'very important' and 'important' into one category of 'Important'. I combined the responses of 'somewhat important' and 'not at all important' into one category of 'Unimportant' on the basis that these are the two least positive responses of the five available (Figure 18).

Based on the relative frequencies of these combined responses, I classified statements as showing a greater consensus, strong consensus, lesser consensus or a lack of consensus. I used groupings suggested on this graph to assign all categories. I looked for groups with similar percentage results, and assigned the cutoffs between these. I was also mindful that a common cutoff for consensus in Delphi studies, used to determine when to stop multiple rounds, is 70% agreement. Figure 18 suggested that 25% or more combined 'Unimportant' responses formed a group that lacked consensus, and included eight statements. I classified statements with more than 90% combined Important responses as showing greater consensus (seven statements). Statements with less than 90%, but at least 85% combined Important responses showed strong consensus (seven statements), and statements with less than 85%, but more than 75%, showed a lesser consensus (four statements).

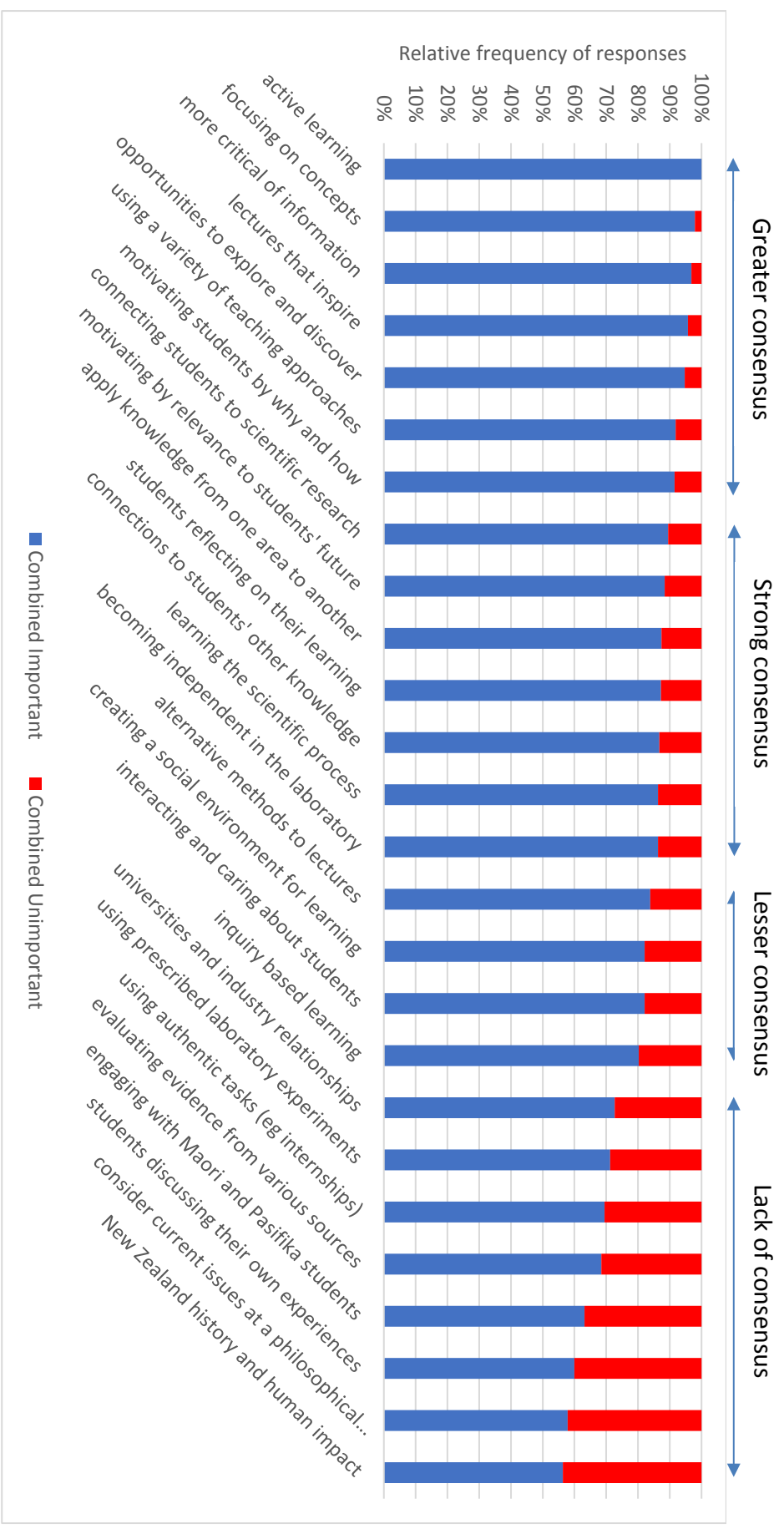


Figure 18. The relative frequency of combined Important responses to statements on the lecturer survey on quality teaching in science. Statements receiving the most combined Important responses are on the left. Consensus classifications are based on the relative frequencies of each of these combined responses. Statements with more consensus are on the left and statements with less consensus are on the right.

The frequency of implementation

I wanted to know if the characteristics of quality that lecturers viewed as most important in the survey were the ones they used most in their teaching. To ascertain this, I asked participants to indicate the relative frequency with which they implemented survey items into their teaching practice using a Likert-type scale of 1 to 5, where 1 corresponded to 'always' and 5 to 'never' (Figure 19). The graph shows the relative frequencies with which lecturers implemented the characteristics into their teaching practice.

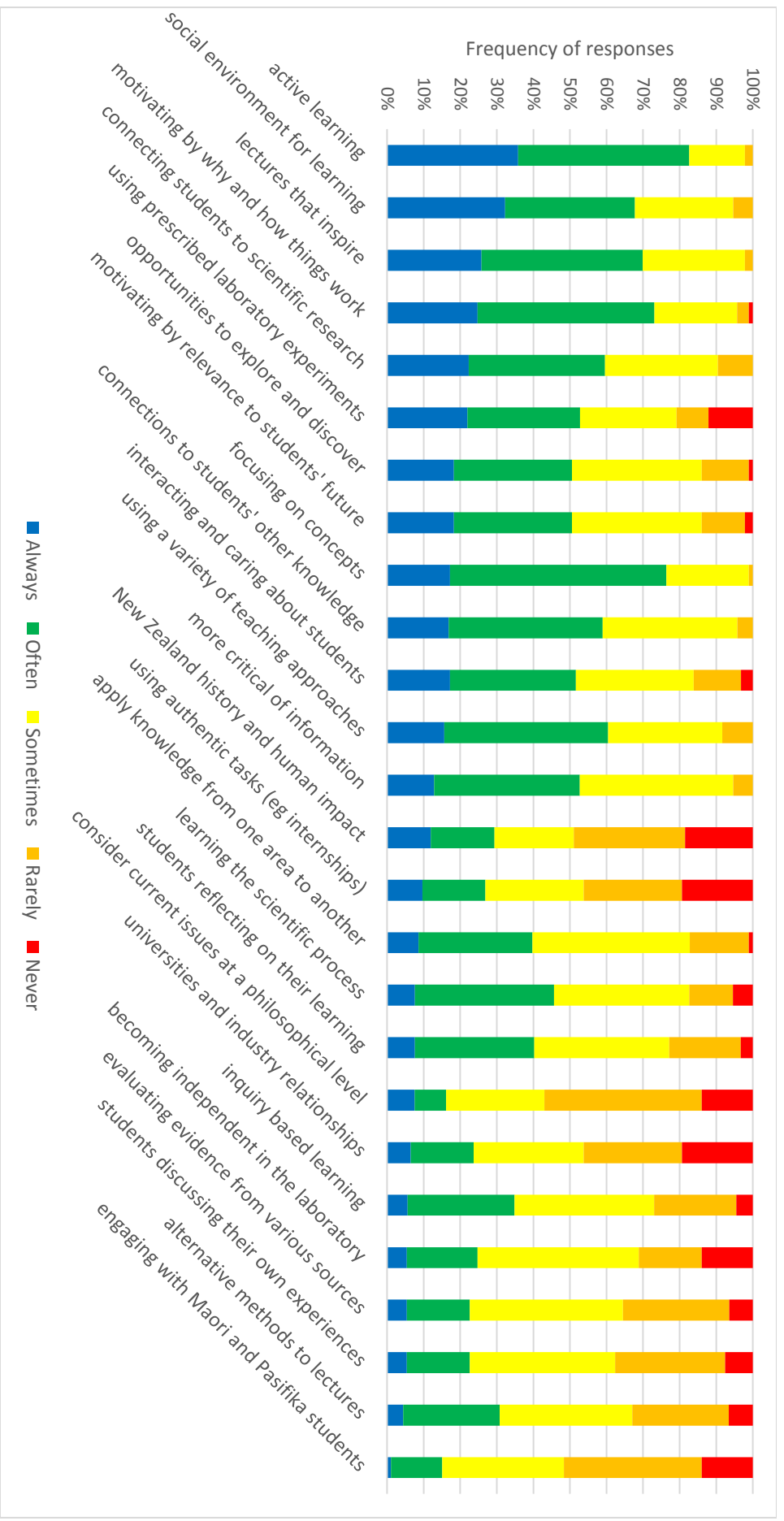


Figure 19. The relative frequencies with which lecturers implemented the characteristics they associated with quality teaching in science. The items are sorted in order of frequency of implementation with priority in the order of always, often, sometimes, rarely, never. The most frequently implemented characteristics are on the left.

I used the difference between individuals' frequency of implementation and importance responses to determine if participants had implemented survey items more frequently or less frequently than expected. The difference for each participant was calculated as the importance score minus the frequency of implementation score. I classified a difference of -1, 0 or 1 as no different to that expected based on the importance score. A difference of -2 or less indicated less frequent implementation than expected, and differences of 2 or more suggested more frequent implementation than expected (Figure 20).

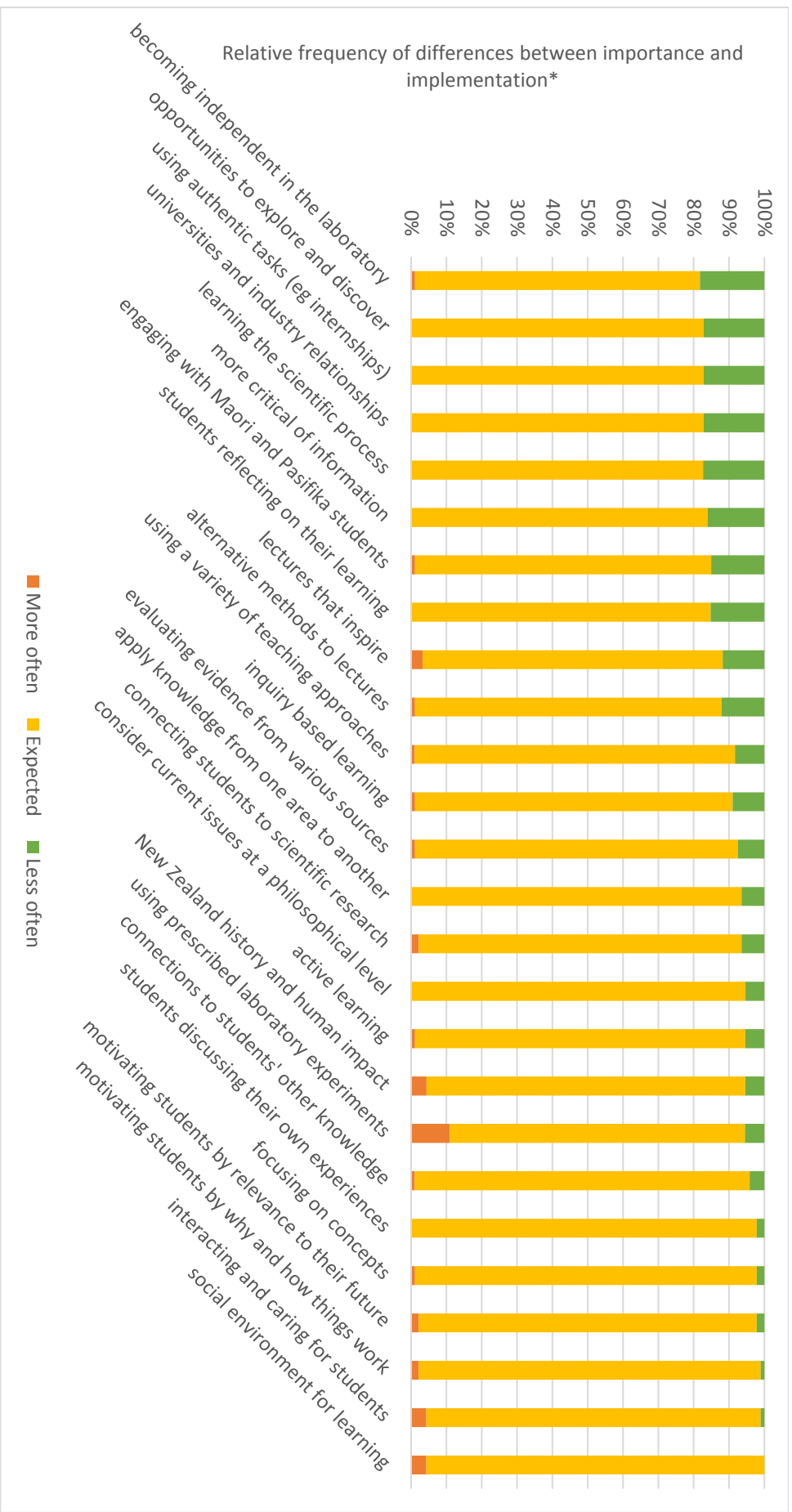


Figure 20. The relative frequencies of grouped differences between frequency of implementation and importance to statements on the lecturer survey on quality teaching in science. The items are sorted in order of the differences with priority in the order of less often, as expected, more often. Characteristics implemented by lecturers less often than expected are on the left. * Combined scores (see text).

Figure 20 shows that at least 15% of lecturers are implementing characteristics directly related to science—explore and discover, learning the scientific process, using authentic tasks and independence in the laboratory—less often than would be expected based on the importance ascribed to them. Relationships with industry and being critical of information are also in this category. Lecturers (14%) also implemented student-related items concerning students reflecting on their learning and engaging with Māori and Pasifika students less frequently than suggested by their relative importance (Figure 20). Conversely, 10% of lecturers use prescribed laboratories more frequently than would be expected based on the importance they had ascribed to them. These results highlight an issue with lecturers not implementing characteristics that they themselves deem important for quality teaching and learning in undergraduate science.

To determine whether the characteristics identified in the Delphi study and used in the lecturer survey were related to each other and manifestations of underlying factors, I next conducted an exploratory factor analysis.

Exploratory factor analysis of survey responses

To explore the possibility of ‘latent’ variables (factors) underlying the 26 statements relating to the importance of a variety of characteristics associated with quality teaching in the lecturer survey, I applied exploratory factor analysis to the survey responses. I ultimately selected three factors to extract, based on a scree plot of eigenvalues that showed a point of inflexion at this point and screening of data obtained from extraction of 2, 3, 4 and 5 factors (Field, 2013). Extraction of 2, 3, 4 and 5 factors indicated that 4 factors gave a good fit but as one of these factors had only two items, and another 8 items had loadings less than 0.4, these items were removed and a 3 factor analysis was repeated on the remaining items. I conducted a maximum likelihood analysis on the remaining 17 items with oblique rotation (promax with Kaiser normalisation), excluded cases listwise and saved the factors as Anderson-Rubin score variables (DiStefano, Zhu, & Mindrila, 2009) for further analyses.

The sampling adequacy was good as determined by the Kaiser-Meyer-Olkin measure of 0.82 with most individual communalities above 0.5 and therefore acceptable (Field, 2013). In

combination, the three factors accounted for 56.5% of the variance. The factor loadings (also called the pattern matrix) are shown in Table 11. Based on the items that aggregate around the same factor, I suggest Factor 1 represents student-centred pedagogy (teaching practice), Factor 2 represents culture and context and Factor 3 represents ways of thinking and practising in science.

Table 11. Summary of exploratory factor analysis results for the lecturer survey questions on quality teaching

Quality teaching survey item	Factor 1	Factor 2	Factor 3
10w. using authentic tasks (eg internships)	.756		-.466
10b. making connections to students' other knowledge	.733		
10x. relationships between universities and stakeholder industries	.727		
10k. motivating students by relevance to students' future	.670		
10s. students discussing their own experiences	.649		
10n. students reflecting on their learning	.617		
10o. creating a social environment for learning	.593		
10r. using inquiry based learning	.584		
10z. using alternative methods to lectures	.537		
10t. apply knowledge from one area to another	.529		
10i. promote students' active learning	.433		
10u. New Zealand history and human impact on the environment		.847	
10v. consider current issues at a philosophical level		.680	
10h. engaging with Māori and Pasifika students		.524	
10c. connecting students to scientific research			.613
10l. motivating students by highlighting why and how things work	.555		.585
10e. scientific process			.455

Note. Extraction method: maximum likelihood. Rotation method: promax with Kaiser normalisation. Rotation converged in 8 iterations. Values < 0.3 are not shown in the Table. Items 10w and 10l cross load onto Factors 3 and 1, respectively, with 10w indicating a negative relationship with Factor 3 (i.e. anti-Factor 3).

Analysis of the extracted factors

To explore whether there were any differences in the responses to the three factors between universities or disciplines, I compared the means (and confidence intervals for these) graphically and then by ANOVA with post-hoc Tukey's test (and Hochberg's for unequal sample sizes) (Field, 2013). Factors 1 and 3 showed very little difference between

the groups (See Appendix C for graphs, Appendix D for Tables with descriptive statistics and Appendix E for ANOVA tables).

In contrast, Factor 2—culture and context—varied between universities and between disciplines. The statistical analysis indicated there was a significant difference ($p < 0.05$) between inferred responses to Factor 2 between University A and University B, with University A associated with significantly higher scores than University B (Figure 21, Tables 12 and 13, mean values in Appendix D).

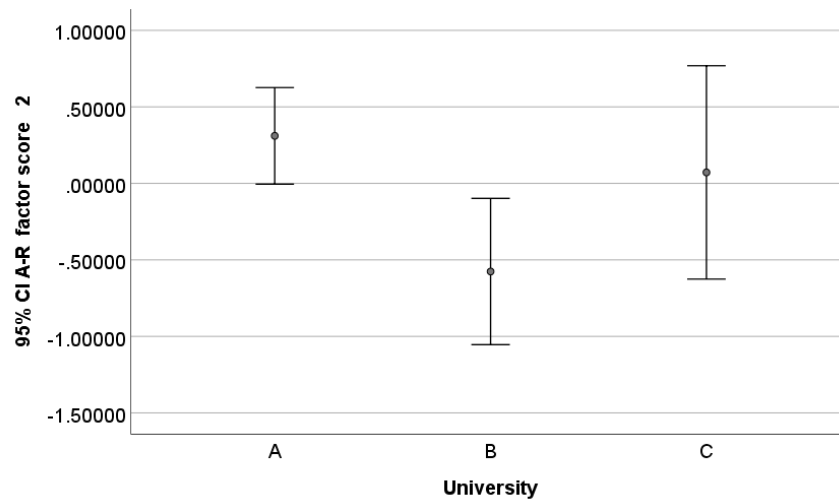


Figure 21. Means and 95% confidence intervals for Factor 2 (culture and context) for universities. Note: Factor scores represented as Anderson-Rubin variables for comparison.

Table 12. Oneway ANOVA for Factor 2 between the Universities A, B and C.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.507	2	3.754	4.255	.019
Within Groups	51.168	58	.882		
Total	58.675	60			

Note. The F-value has a probability of 0.019 indicating there is a significant difference between the groups at $p=0.05$ level

Table 13. Between-university comparisons for Factor 2: post-hoc tests (Tukey) for the oneway ANOVA.

(I) Uni	(J) Uni	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A	B	.887*	.304	.014	.156	1.618
	C	.239	.313	.727	-.514	.992
B	A	-.887*	.304	.014	-1.618	-.155
	C	-.648	.376	.205	-1.552	.257
C	A	-.239	.313	.727	-.992	.514
	B	.648	.376	.205	-.257	1.552

*. The mean difference between Universities A and B (highlighted) is significant at the 0.05 level.

Again for Factor 2, there was a trend for the disciplines of life sciences and earth sciences to respond differently to the physical sciences; the difference was statistically significant between life sciences and physical sciences ($p < 0.05$) with higher scores in the physical sciences (Figure 22, Tables 14 and 15, mean values in Appendix D).

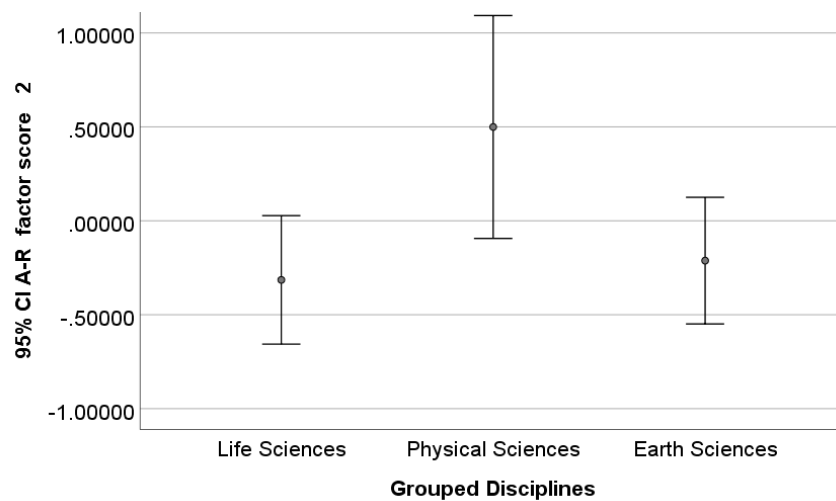


Figure 22. Means and 95% confidence intervals for Factor 2 (culture and context) for grouped disciplines. Note: Factor scores represented as Anderson-Rubin variables for comparison.

Table 14. Oneway ANOVA for Factor 2 between the grouped disciplines.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6.959	2	3.480	3.805	.027
Within Groups	64.927	71	.914		
Total	71.887	73			

Note. The F-value has a probability of 0.027 indicating there is a significant difference between the groups at $p=0.05$ level

Table 15. Between discipline comparisons for Factor 2: post-hoc tests (Tukey) for the one-way ANOVA.

(I) Grouped Disciplines	(J) Grouped Disciplines	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Life Sciences	Physical Sciences	-.814*	.300	.023	-1.532	-.096
	Earth Sciences	-.103	.254	.914	-.710	.505
Physical Sciences	Life Sciences	.814*	.300	.023	.095	1.532
	Earth Sciences	.711	.324	.079	-.065	1.487
Earth Sciences	Life Sciences	.103	.254	.914	-.505	.710
	Physical Sciences	-.711	.324	.079	-1.487	.065

* The mean difference between Life Sciences and Physical Sciences (highlighted) is significant at the 0.05 level.

Overall, exploratory factor analysis identified three underlying factors in the survey data that I called student-centred pedagogy (Factor 1), culture and context (Factor 2), and ways of thinking and practicing in science (Factor 3). University and discipline had no significant effect on lecturers' views on characteristics of quality teaching associated with student-centred pedagogy or ways of thinking and practising in science. However, the findings showed that University A, and the Physical sciences, are associated with significantly higher scores for Factor 2—culture and context—than Universities B and C, or the life science or

earth science disciplines, respectively. Institutions and specific disciplines within the sciences therefore affect lecturers' views on quality.

5.3.2 Analyses of qualitative survey comments with the lenses

I was pleasantly surprised at the number and complex nature of open text comments received in the survey. The three statements: 'Please . . . add anything else that you consider important for quality teaching in the natural sciences at undergraduate level at university in New Zealand' (question 11); 'In the natural sciences, students learned by . . . ' (question 12) ; and ' . . . please describe the impact you think your teaching has on student learning' (question 13) received a total of 218 responses, representing 36%, 67% and 66% of all possible responses, respectively. The lower response rate for the statement inviting lecturers to add anything else they considered important for quality teaching probably reflected the teaching-focused nature of the preceding Likert-type scale statements in the survey. The large number of comments received overall confirmed that the survey respondents were very interested in teaching, and that the sample may be biased towards lecturers more interested in teaching than the general population of science lecturers. I analysed the open text comments using the lenses based on complexity and wickedness as predefined themes (Chapter 3). I present my findings for the three open text comments together, under the headings of each of the three lenses that address the research question exploring what lecturers consider quality teaching and learning in undergraduate science—problem definition, openness and social complexity.

The problem with defining quality teaching in undergraduate science

The problem definition lens focuses on difficulties with defining the issue, or problem, under investigation. This lens specifically aided interpretation of the majority of comments, with 63% of lecturers' responding to at least one of questions 11, 12 or 13 with a comment classified with this lens. I identified four main categories with this lens that each encompassed a variety of lecturers' views. In order of the frequency of lecturers' comments, the categories were: teaching and learning science (88% of lecturers with comments classified with the problem definition lens), student-related characteristics (40% of lecturers), definition of quality (16% of lecturers), and the purpose of university education

(10% of lecturers). A variety of lecturers' views within these categories would lead to difficulties defining quality teaching and learning in undergraduate science. I next present a selection of illustrative comments demonstrating the variety of views within these categories. In this section, I refer to 'many', 'most', 'some' and 'a few' lecturers. These represent more than 50% (most), 33% to 50% (many), 20% to 32% (some) and 19% or fewer lecturers (a few).

Teaching and learning science. Most lecturers' (59%) with comments in the teaching and learning category focused on doing practical labs or field trips. This comment highlighted the general view:

doing. They need to understand the theory behind the idea but ultimately they need to experience it with relevant hands-on activities. (Survey ID 22, Engineering, University A)

Within this category, some lecturers thought that students needed more opportunities to experience real scientific research:

doing actual science. There are too few opportunities for undergraduate research in our curriculum, I think. (Survey ID 51, Life Sciences, University B)

Other lecturers highlighted the difficulty in providing these opportunities for large first-year classes:

experience more than anything. By having chances to discover for themselves. This is very, very difficult to provide in huge first year classes but gets a little easier at 2nd and 3rd year. (Survey ID 72, Physical Sciences, University B)

Many lecturers (30/81=37%) emphasised the need for a variety of teaching activities and active engagement for student learning. This lecturer highlighted the difference between student learning in a lecture and a more active environment:

If I lecture to the students in a standard lecture I believe that the majority of students do not learn very much from the class. If I explain a concept to the students in a short class and they have to research and/or apply this then my thought is that the students learn and retain the knowledge better. (Survey ID 124, Engineering, University A)

In contrast, some lecturers thought lectures had an important role as one of a variety of teaching strategies:

a combination of hands on field and lab experiences and chance to "get" the background info behind those experiences via formal teaching including lectures and small group tutorials. (Survey ID 69, Earth Sciences, University D)

Some lecturers (23/81=28%) expressed views on their role in teaching. These views reflected different perceptions that would lead to different definitions of quality teaching.

Some lecturers considered themselves facilitators of student learning:

I don't consider myself as a teacher. University lecturers are not teachers, but facilitators of education. (Survey ID 66, Physical Sciences, University D)

In contrast, other lecturers were focused on students remembering experiences and retaining skills:

My principal goal is to have a student remember his/her experiences and retain (some) skills, knowledge and attitudes which give confidence and competence to go forward to more complex learning and practice, whatever that may be. (Survey ID 14, Life Sciences, University A)

Student-related characteristics. The student-related characteristics category included study habits, interests, background, year level and different ways of learning. Many lecturers (32/81 = 40%) thought that these student-related characteristics influenced teaching and learning; hence these may affect the definition of quality in a particular context. Several of these lecturers expressed the importance of providing opportunities for students' self-directed learning:

they learn best by a mix of classroom based enquiry learning . . . and opportunities for self-directed learning. (Survey ID 64, Life Sciences, University D)

This lecturer illustrated the role of student motivation and interest in student learning held by several lecturers, in combination with the lecturer's role to guide, or scaffold, student learning:

being motivated and excited about the subject, and also being guided and scaffolded well as they learn increasingly complex concepts. (Survey ID 34, Life Sciences, University A)

Some lecturers highlighted that their intent for teaching didn't change but how they achieved this with students at different levels did:

It would have been easier (and likely more reflective) if I could have responded to the above for each year (eg, how I teach at first year is very different at third year - the intent is always the same - to inspire students who can think and write critically in a changing world - but how I seek to achieve it is very different due to class sizes, prior knowledge, etc). (Survey ID 43, Life Sciences, University B)

Although some lecturers recognised student background as an important influence on learning, with analysis of the quantitative data identifying this as an area that lacked consensus (Figure 18), and exploratory factor analysis showing significant differences between universities and disciplines for culture and context (Factor 2), there were very few specific comments on this. However, a couple of lecturers did not consider any special treatment was warranted for Māori and Pasifika students in 'hard physical science'. The following comment illustrates this view:

To go on in hard physical science, Māori and Pacifica students must become proficient in the necessary skills, as anyone must. Every group of students has a different background that provides them with strengths to draw on, and weaknesses to overcome or find work-arounds for. I prefer not to emphasize preconceptions based on racial background or skin colour. I prefer to focus on the individuals, helping them to define their goals, and bring those goals to fruition. (Survey ID 95, Earth Sciences, University F)

Some lecturers' comments identified that individual students may learn differently highlighting that defining quality may be dependent on the learning preferences of students:

many different techniques! some students love the imaginative putting together of ideas, some love proving something controversial, some need to touch something, others need to hear something or see something. The academic environment rewards abstract learning but . . . is a very tactile subject so I think its important to implement as much variety as possible. (Survey ID 70, Earth Sciences, University B)

Definition of quality. The definition of quality category included comments where a few lecturers (13/81 = 16%) indicated they did not know how to assess the impact of their teaching on student learning. This highlighted the lack of clarity in defining quality teaching and learning, a key issue in viewing quality as a complex issue, rather than a wicked problem, and hence amenable to proposing conditions for emergence (Chapter 3)(Rittel & Webber, 1973). This lecturer illustrated a common response when asked about the impact of their teaching on student learning:

I have no idea. Relative to what? Relative to nothing, probably significant. Relative to what someone else could do, I have no idea and no way to assess. (Survey ID 105, Life Sciences, University A)

Purpose of university education. A few lecturers (8/81 = 10%) highlighted the difference that preparing students for employment or research would make to their teaching, indicating that different purposes of education influence the definition of quality teaching and learning. This lecturer illustrated the problem of not knowing what careers students pursue when they leave university:

depend on what careers we are preparing the students for. If I thought I was preparing students mainly to become researchers, I would have answered many questions differently. Problem is I have very little idea what will actually become of most of my students. If I only knew, I could be a much better teacher. (Survey ID 3, Life Sciences, University A)

Although several lecturers highlighted preparing students for employment in industry or an academic career, this lecturer suggested a focus on students learning about themselves:

A separate question is the degree to which students learn about themselves (as opposed to the subject) through this process. Maybe we would be better focusing more on student education at the expense of student learning? . . . (Survey ID 50, Physical Sciences, University B)

Quality as openness

The openness lens concentrates on interactions with new experiences or information. This lens classified a majority of all lecturers' comments. I identified four main categories within this lens: making connections, research and enquiry, generic skills and application. I next

present a selection of illustrative comments demonstrating the lecturers' views within these categories.

Making connections. Most lecturers considered helping students make connections between courses within the university and connecting students to the 'real world' outside the university to contribute to quality teaching and learning.

This lecturer highlighted the process throughout an undergraduate degree that builds towards students being able to undertake discipline research and the importance of time spent in the laboratory, field and library:

gaining a fundamental understanding of the discipline (often through lectures and readings). This should be followed by allowing the student to apply their new knowledge (say in second year), through application of the scientific method, trial and error, deductive reasoning, solving real world problems, etc. After this, the student should have the understanding and skills to begin questioning basic assumptions and carry out their own research. This requires abundant time in the laboratory, field, library, etc . . . students learn by doing. (Survey ID 97, Earth Sciences, University F)

A common view considered it important to connect students to the 'real world' outside the university using examples:

I try to include pertinent current events/real-life examples . . . to give a "real-world" grounding/foundation to the scientific theories being explored, allowing students to use their own experiences to connect over-arching themes together and begin to question these, fostering a deeper level of learning. (Survey ID 19, Life Sciences, University A)

Other lecturers felt it was valuable to connect students to their own discipline research:

Bringing actual examples from ones own research and experience into the teaching I think is v. important. One can bring a certain passion to the subject which is harder for material where one doesn't have an actual direct connection. (Survey ID 25, Life Sciences, University C)

Some lecturers felt science students needed to be able to connect to the broader social context:

I think it is important for science students to understand a bit about how society, economy and politics work so they know that the provision of facts is not enough for widespread change. (Survey ID 46, Earth Sciences, University B)

Research and enquiry. Many lecturers regarded the inclusion of some form of research and enquiry, problem-solving, or case-based learning as important for quality teaching and learning in undergraduate science. This lecturer described the use of problem solving for increasingly complex learning:

problem solving i.e. applying a small set of fundamental concepts to simple model systems to become familiar with the concepts then extending the problems to more complex models that require new application of the concepts, and then finally to real systems that might require the student to either use new concepts or ideas and practices learnt in other settings. (Survey ID 106, Physical Sciences, University A)

Generic skills. Many lecturers with comments classified with the openness lens noted the importance of students learning generic skills. These skills included the ability to think critically, communicate, work independently, and how to learn. Lecturers viewed questioning and thinking critically as the most important generic skills for students to learn, as this lecturer highlighted:

I like to think that I have been able to excite students about science, which will hopefully lead them to ask questions about what they are seeing or reading in the future, and be able to think critically and be inspired about the world around them. (Survey ID 71, Life Sciences, University A)

Application. Many lecturers considered application of knowledge, skills and attitudes important for quality teaching and learning. Lecturers considered application integral to teaching and learning:

I hope they see knowledge and its application as being an integral part of their experience. That they can take this knowledge and make informed decisions. (Survey ID 75, Physical Sciences, University G)

Quality as relationship

The social complexity lens focuses on promoting interactions between lecturers and students and between students. Lecturers considered social interaction important for quality teaching and learning and many lecturers valued student-to-teacher interactions for monitoring student learning, as this lecturer illustrated:

personal contact between student and lecturer is important so that you can figure out exactly how previous knowledge is affecting the student's learning and what aspect is poorly understood. to see the student's eyes light up with understanding. This is what keeps my job enjoyable and I would never want to give this up. (Survey ID 70, Earth Sciences, University B)

The role of practical sessions in facilitating interactions was highlighted:

Some of them have come back to me and thanked me for the belief and encouragement they took away from my teaching, largely through interactions in the field trips and laboratory practicals. That's where the real teaching happens, connections are made and students discover what they enjoy, where their passion may lie. (Survey ID 101, Earth Sciences, University F)

Many lecturers also viewed student-to-student interactions as important:

Some of the main learning in my 100-level classes is when students are discussing the answers to clicker questions. Most of the main learning in my 200-level classes is during the interactive tutorial style sections of the 'lecture'. (Survey ID 107, Life Sciences, University A)

A few lecturers also valued external interactions and included industry or community partners in student teaching and learning.

5.4 What are the main influences on lecturers' teaching and learning?

5.4.1 Quality as change

Some lecturers indicated changes in their teaching resulted from student-feedback or self-reflection and the impact this had on their teaching and students' learning. The majority of

these lecturers referred to feedback, and most of these to student feedback, as typified by this example:

I am working on improving the lectures and use constructive student feedback on my courses in order to achieve this. Therefore, I think my teaching has a positive impact on student learning. (Survey ID 23, Earth Sciences, University A)

Some lecturers were concerned about the validity of student evaluations and the lack of responses in many instances:

Student evaluations give us the main, though not the only, feedback, and they are biased because the students are more likely to make positive statements than critical ones. So I am pleased when I get good scores in course evaluations, but these are seldom returned by more than half the class, and I always wonder what the rest thought. (Survey ID 112, Life Sciences, University D)

Only one comment mentioned the value of feedback from colleagues:

I have been very fortunate to work with some great colleagues in developing our teaching approaches including colleagues whose research is in higher education. I have substantially gained as a result in terms of the depth of my thinking about my teaching (Survey ID 109, Life Sciences, University E)

Surprisingly, only one comment referred to self-reflection, although it could be considered that the whole survey, especially the open text comments, was an exercise in self-reflection.

5.4.2 Quality as influence

The multiple 'causality' lens focuses on the influences on the groups involved and classified comments from about one-fifth of lecturers. I classified comments with this lens as concerns.

Concerns

I categorised the lecturers' concerns as institutional, student-related characteristics or external factors (schools or government).

Institutional factors. Lecturers highlighted the prime importance of laboratory and fieldwork, and time to develop teaching. Many lecturers felt the need for more institutional

and managerial support for these. In particular, some lecturers felt that laboratory and fieldwork in the natural sciences were undervalued by institutional management:

Although students learn a greater range of things in a lab, the university does not value lab teaching highly. We should place greater importance on the time given by staff to labs and field work. (Survey ID 13, Life Sciences, University A)

Many lecturers agreed there was insufficient time to focus on teaching and were concerned that workload adversely affected quality teaching. Lecturers prioritised research in response to their universities' expectations:

As you can see there is a large gap between what I think is important and what I actually do. The reason? In prioritizing my time, the message from the powers-that-be is research outputs must come first. There is not enough time left over for many undergraduate teaching innovations so I just do what I can. Unfortunately I can't see this changing anytime soon. (Survey ID 34, Life Sciences, University A)

Student-related characteristics. Some lecturers expressed concern at the central role that assessment plays in student learning:

paying very little attention to our teaching but cramming for the vast multitude of bitsy assessments we provide. (Survey ID 3, Life Sciences, University A)

5.5 Chapter summary

In this chapter I showed that the larger sample of university lecturers generally viewed all the survey statements on quality teaching and learning derived from Phase 1 as important. However, the extent of consensus varied, and lecturers implemented many characteristics that they deemed important for quality teaching, less frequently than expected, for example, many characteristics associated with learning the scientific process. Exploratory factor analysis identified three underlying factors responsible for 56.5% of the variation that I called student-centred pedagogy (Factor 1), cultural context (Factor 2), and ways of thinking and practising in science (Factor 3). University and discipline had no significant effect on lecturers' views on Factor 1 or Factor 3. There were significant differences between lecturers' responses to Factor 2 (culture and context) at universities A and B, and

between physical sciences and life sciences, with significantly higher scores for university A and for the physical sciences.

The sensitising lenses based on complexity and wickedity, showed that defining quality teaching and learning in undergraduate science was challenging as lecturers saw their role in different ways, often as facilitators of learning but sometimes as conveyors of discipline information. This was further complicated by varying views on the purpose of university education—research, employment or personal development—and student diversity. Quality teaching and learning in practice was generally viewed as learning discipline specific skills by doing enquiry-driven laboratory or fieldwork, and active learning in the classroom involving research and enquiry while also learning generic skills including critical thinking and communication skills. Lecturers considered social relationships such as student-to-student and lecturer-to-student interactions as essential to quality teaching and learning.

Interactions with teaching colleagues and partners outside the university also contributed to enhancing teaching. The main factor that contributed to changing teaching was student feedback although some lecturers were unsure of how to measure the impact of their teaching. There was a general view of quality teaching as complex, practical, enquiry-driven and social. Lecturers' main concern was lack of institutional support for practical science and time to develop teaching. Lecturers were also concerned about students' focus on assessment.

Next, I present the findings from exploring the views of a sample of the survey participants in interviews.

CHAPTER 6: LECTURER INTERVIEW FINDINGS

6.1 Introduction

In this chapter I describe my findings from the lecturer interviews that aimed both to add to the findings of the Delphi study and explore some of the findings from the lecturer survey in more depth. The aim was to construct a framework for understanding quality teaching and learning in undergraduate science. I start the chapter with a brief description of the interviewees. In the next part of the chapter, I address the research question: 'What do a larger sample of university science lecturers consider to be quality teaching and learning in undergraduate science?' by analysing lecturers' interview responses to questions related to quality teaching and learning with the problem definition, openness and social complexity lenses based on complexity and wickedity. In the last part of the chapter, I address the research question: 'What are the main influences on lecturers' quality teaching?' by analysing interview responses with the non-linearity and multiple causality lenses. I used the lenses deductively as predefined themes and assigned these as the first level categories. Then I used template analysis to identify levels of categories (themes, subthemes) inductively within these (Brooks et al., 2015). I based the initial template on a preliminary analysis of six interview transcripts and subsequently refined this. Further themes were added as they emerged (Brooks et al., 2015). In accordance with the complexity thinking concepts of openness, diversity and inclusiveness, I defined categories, themes and subthemes based on references from at least two interviewees. Ideas occurring only once were collectively categorised as 'other' and are not considered further here.

6.2 Interviewee demographics

Interviewees were survey respondents who indicated on the survey their willingness to participate in interviews. I selected 20 potential interviewees (with five additional reserves) in chronological order of their survey responses who fulfilled the criteria of at least two years teaching experience at a tertiary institution, a range of universities (with no more than six from any one university), and a breadth of disciplines (Chapter 3). Because of the relatively large numbers of volunteers from the life sciences and small number of volunteers

from the physical sciences, I used the reserve list to increase the number of interviewees from the physical sciences. Ultimately, I interviewed 18 lecturers as two of the final 20 were unavailable and I considered that data were saturated (Saumure & Given, 2008) and little would be gained from organising two further interviews. I conducted 11 interviews face-to-face and seven using Skype with audio recording. These 18 were from six universities (with between one and six participants from each university); eight were from life sciences, seven from earth sciences and three from physical sciences (Table 16). The majority of interviewees (11/18) had more than 15 years teaching experience and only three had five years or less. Six of the interviewees had been recognised by their universities for teaching excellence; three of these were TTEA⁷ winners. One had a tertiary teaching qualification and two were qualified secondary school teachers. Thirteen of the 18 interviewees identified as New Zealand European and the remaining five identified with other ethnic groups. The interviewee demographics are summarised in Table 16.

⁷ Tertiary Teaching Excellence Award (Ako Aotearoa)

Table 16. Interviewee demographics.

Interviewee pseudonym	University	Discipline group	Ethnic group	No. of years teaching experience	Teaching awards	Teaching qualifications
Andrew	A	2	New Zealand European	>15 yrs	Student award	no
Barry	A	1	New Zealand European	2-5 yrs	no	no
Connor	A	1	European	>15 yrs	VC Teaching Excellence Award 2015	Postgraduate Certificate in University Teaching & Learning
David	C	3	Asian - Chinese	2-5 yrs	no	no
Edward	A	2	New Zealand European	>15 yrs	no	no
Frank	A	2	New Zealand European	>15 yrs	TTEA 2003, DEANZ Award 2008	no
Gary	E	2	New Zealand European	10-15 yrs	no	no
Hannah	B	2	Canadian	10-15 yrs	University Teaching Award, 2010	no
Isabel	B	1	New Zealand European	5-10 yrs	no	no

John	B	3	New Zealand European	>15 yrs	University Teaching Award; University Teaching Medal	no
Keith	B	2	New Zealand European	5-10 yrs	no	no
Lisa	C	1	New Zealand European	>15 yrs	no	no
Mark	B	1	New Zealand European	>15 yrs	University teaching award 2008, TTEA 2009, University teaching medal 2013	no
Naomi	D	1	New Zealand European	>15 yrs	no	no
Olivia	D	2	New Zealand European	>15 yrs	2 University Teaching Excellence awards, TTEA 2010	Trained Teachers Certificate NZ secondary schools
Patricia	B	1	American	>15 yrs	no	no
Quentin	G	3	New Zealand European	>15 yrs	no	Part of MEd
Rose	G	2	English European	2-5 yrs	no	NZ-trained secondary school science (Biology major)

Note. 1, earth sciences; 2, life sciences; 3, physical sciences.

6.3 What do a larger sample of university science lecturers consider to be quality teaching and learning in undergraduate science?

6.3.1 The problem with defining quality teaching in undergraduate science

The problem definition lens considers the reasons for difficulties with defining quality teaching and learning in undergraduate science. With this lens, I identified five main categories that may contribute to the difficulty of defining quality in teaching and learning in undergraduate science. These categories, in order of number of interviewees referring to that category were: teaching and learning science (or how to teach science) (17/18), student-related characteristics (11/18), the definition of science (9/18), the purpose of university education (8/18), and the definition of quality (7/18).

I next present the five categories above and some of the themes identified within these. In this section I refer to ‘many’, ‘most’, ‘some’ and ‘a few’ lecturers. These represent more than nine (most), at least six but not more than eight (many), four or five (some) and two or three lecturers (a few).

Teaching and learning science (or how to teach science)

Lecturers’ views on how undergraduate science should be taught for quality teaching and learning focused on active learning and engagement, and teaching science as process or ‘doing science’, rather than teaching science as content or ‘facts’ to be memorised as seen in traditional undergraduate science teaching. Nearly all lecturers (16/18) stated the importance of active learning and engagement and the role of, for example, enthusiasm, relevance, questioning and quizzes, as well as challenging students and encouraging curiosity. Some lecturers (5/18) specifically identified a role for problem-solving or other type of investigation to actively involve students in their own learning. Two thirds of lecturers (12/18) highlighted the vital role of practical experiences—doing science—for learning the scientific process. Overall, lecturers viewed teaching and learning science as a

participative process with a strong practical focus. Keith summarised this neatly by differentiating between students learning science, and learning facts resulting from science:

Quality teaching . . . would be a way in which . . . a student goes into a science class and, at the end, understands the scientific processes that have given rise to the . . . knowledge that has been generated in that field . . . One example would obviously be a course in which students will be doing science themselves . . . [or] try to see if they can understand science a little bit at a deeper level than just the little facts that are the result of scientific process. (Keith, University B, life sciences)

Student-related characteristics

Most lecturers (10/18) viewed student characteristics, including background (academic, socioeconomic and cultural) and ability, as important influences on quality teaching. Some lecturers (4/18) considered the variety of ways in which students learn as significant influences and felt it was important to ‘reach across all of these different ways’ (Lisa) rather than use a ‘one size fits all’ approach. Because of these student-related characteristics, lecturers may define quality teaching differently for different groups of students, contributing to the problem of defining quality teaching in undergraduate science.

Interestingly, Hannah described using the academic diversity in her large first-year class as a difference to celebrate and to engage students:

And also at first year we have a real spectrum of students. We have our mature students who haven't looked at a biology text book ever, they are in their 30s, 40s or 50s and they have come back to university to learn. And then we have our over-achievers that have come straight out of NCEA and feel like they know it all. So one of the things that I do is to engage the class to recognise that we have a lot of diversity in the room and that diversity is a good thing, but it is challenging . . . (Hannah, University B, life sciences)

The definition of science

Half of the interviewees (9/18) sought clarification on the meaning of ‘science’ highlighting the lack of a universally agreed definition. Some lecturers (3 or 4/18 for each theme) emphasised a relatively broad definition of science, science as enquiry, or that science cannot be completely objective and is influenced by background. That undergraduate

science was the Western model of science and a meritocracy, was highlighted by two lecturers. The absence of a universally agreed definition of science contributes to the problem of defining quality teaching in science as it is unclear what is (or should be) included in undergraduate science courses.

Frank considered that science included a very broad range of research with a formal methodology:

. . . science is huge and it does range from, quantum physics to even, you could argue, some of the social sciences. I would still put that into science. Wherever you're applying a methodology of research I suppose, there's exploration there, and where there's some sort of hypothesis that needs testing and you employ formal methodologies to test that. I mean, to me that's sort of the foundation of science isn't it. (Frank, University A, life sciences)

Patricia drew attention to the interpretive nature of science and the influence of background:

My definition of science is that you are open to many interpretations . . . always acknowledging that it is not possible to be purely objective . . . and you are making the interpretations based on your background and your data collected . . . I try and make my students aware of how their background and their way of viewing things is colouring what they do . . . and so just making them aware of that lets them also start to become aware of how maybe other things in their lives are going to also affect how they view their science. (Patricia, University B, earth sciences)

The definition of quality

Many lecturers (8/18) referred to specific types of quality when discussing quality teaching, giving different definitions, highlighting the problem definition issue with quality in higher education. The definitions included quality as meeting predefined outcomes (expectations, standards), excellence or something 'extra', a whole institutional framework (or holistic concept), and personal development (or transformation). For standard-based definitions, the utility of a single standard at lower levels was combined with setting different goals related to a student's entry level for more advanced courses. Quality as excellence encompassed 'that human element to it, to personalise it' (Rose) and the need for caring,

professional, motivated teachers to enable this. Lecturers also noted the difference between students', universities' and lecturers' perceptions of quality teaching, especially when quality was viewed as 'meeting the customer's expectations' (Andrew). Lecturers' different conceptions of quality contribute to the problem of defining quality teaching in undergraduate science and, importantly for this study, this needs to be clarified to enable resolution (Chapter 3).

Quentin illustrated the difference between a common student perception where quality teaching meant everything provided for them, and an holistic view of quality as equipping students for life:

Students' perception of [quality teaching] can actually be interesting because a lot of students like, what they call good and quality teaching, is where everything is laid out for them in a well-defined very coherent set of instructions or patterns so they can sit an exam and they can do well in the exam. But I believe that good teaching actually has a much longer timeframe and a much more unexpected timeframe . . . Quality teaching I think is equipping students with tools to deal with their environment, present and future and, to some extent, past. So you can interpret how you have got to that point. (Quentin, University G, physical sciences)

John differentiated teaching and education and suggested that measuring the value of education as personal development (or transformation) may be more complex than measuring final outcomes:

. . . the ultimate measure of quality of teaching is actually how well it does its job . . . The value of education is a lot less definable than a lot of the things we'd like to put measurements on. Whether they're looking at 'Is this person qualified for a job, can they go out and do this, this and this'. . . There's a lot more to it than that, it's less definable in that sort of way, it's less valued now, the kinds of things that people learned about themselves when doing a BA, were really quite valuable and I think that's been lost . . . (John, University B, physical sciences)

The purpose of university education

There were different understandings of the purpose of university education with many lecturers (7/18) associating this with qualifications or employment, and a couple (2/18) with personal development and citizenship. Edward's comment illustrated a popular view: 'we

should be preparing students for the real world and for getting jobs not just teaching them degrees'. In contrast, John considered students' personal development and citizenship to be the primary purpose of university education:

Not enough thought is going into how the students are going to be educated, what they're going to learn about themselves as a result of going through this process, what they're going to be able to contribute to society as a result of this kind of process. I'm actually quite concerned that . . . some of the stuff that we want people in our courses to get, you know the sheer joy of discovery, the stuff that's tied to the process of how they do it, and what they learn about themselves as they go through that, some of that's far more important . . . (John, University B, physical sciences)

Lecturers' different goals for university education may contribute to the problem of defining quality teaching by influencing their underlying teaching philosophy and focus, which in turn will influence their teaching approach.

The categories, themes and subthemes identified with the problem definition lens, together with the number of lecturers referring to each of these (in order of number of lecturers) are summarised in Table 17. This table also shows the total frequency count of each category, theme and subtheme.

Table 17. The categories, themes and subthemes identified with the problem definition lens as contributing to the problem of defining quality teaching and learning in undergraduate science.

Category, theme and subtheme*	No. of sources (interviewees) referring to category/theme/subtheme*	Total frequency count of category/theme/subtheme*
Learning and teaching science	17	73
Active learning and engagement	16	27
Problem-based learning	5	6
Science as process or 'doing science'	12	21
Importance of planning	4	5
Student-related characteristics	11	27
Student characteristics	10	20
Interests (or natural curiosity)	7	9
Background	5	6
Ability	3	3
Expectations	2	2
Learn in different ways	4	7
Definition of science	9	18
Broad definition of science	4	9
Influenced by background	3	3
Science as enquiry	3	3
Western model of science (meritocracy)	2	3
Purpose of university education	8	19
Qualification and or employment	7	12
Personal development & citizenship	2	7
Definition of quality	7	9
Meets pre-defined outcome	5	5
Excellence or something 'extra'	2	2
Whole institutional framework or holistic	2	2

Note. *Categories are inclusive of themes (indented) which are inclusive of subthemes (indented within themes).

6.3.2 Quality as openness

The openness lens highlights interactions with new information or experiences and how these are promoted. I identified six categories that contributed to providing interactions with new experiences or information in teaching and learning in undergraduate science with this lens. All interviewees valued context-based science (18/18), especially practical and

field classes, for the opportunities they provide for student learning in the physical, cognitive and emotional domains. This category also included embedding generic life skills (14/18), in addition to learning science specific skills. Nearly all lecturers considered that an understanding of other worldviews (17/18), especially Māori culture, was important, as was connecting teaching and learning to other aspects of students' lives (13/13). Interestingly, one-third of lecturers highlighted the need for students to learn about change and uncertainty in science (6/18). The creative nature of science was also noted by a few lecturers (3/18).

I next present the six categories that contributed to providing interactions with new experiences or information in teaching and learning in undergraduate science and some of the themes identified within these.

Context-based science

All interviewees (18/18) viewed context-based teaching and learning as essential in undergraduate science. Half of the lecturers (9/18) within this category considered that applying knowledge to new questions or problems was key to quality teaching and learning. These lecturers highlighted the importance of application to different situations, and that this is necessary to avoid students learning by memorisation. Students learning to apply knowledge by making their own decisions was considered fundamental to this, as summarised by Edward's comment 'they need to have situations where they are using that information and making decisions about that information on their own'. Many lecturers (7/18) viewed collecting and interpreting real data or conducting real science research projects (5/18 lecturers) part of quality teaching. This included students collecting data as part of a larger research project where, as Barry succinctly noted 'They see that this is actual real research that they're doing'. Some lecturers (5/18 for each theme) highlighted the role of discipline research and enquiry skills; discipline content, background or technical skills; and scientific literacy (laboratory reports, data interpretation). Olivia summarised the need for these skills in her comment, 'a lot of [the information] is going to be out of date five years down the track. They need to know how to find the information and how to assess the information'.

Therefore, lecturers valued context-rich opportunities for students to interact with new experiences and information and had clear ideas on the nature of these. Lecturers also made suggestions for enhancing these, for example, Gary considered practical research projects so valuable that they should be an 'immersive' experience. He suggested undergraduate research experiences should be over a whole week, rather than split into short timetabled classes, and encompass the whole research process including formulating a research question:

. . . idea of immersive teaching where you are replicating in some way the way that research takes place so . . . [Students] are in small research groups, facilitated or supervised in order to undertake research projects of their own design. So they're having to think about the whole research process, "what's an interesting question?" . . . "what sort of information would allow you to answer that question?" "can you get that information?" "how can you manage it?" "what did you conclude from that?" . . . I think they get so much more out of it, they see how all the different pieces fit together. (Gary, University E, life sciences)

Science and worldviews

Nearly all lecturers (17/18) considered that an understanding of worldviews, especially students' cultural backgrounds, was important or even essential for quality teaching and learning. Half of the lecturers (9/18) recognised a special place for Māori in the New Zealand context, and some lecturers (4/18) expressed a desire for greater acceptance by students of multicultural differences and actively encouraged valuing cultural diversity among students. Although some lecturers appreciated the contribution of a Māori perspective to teaching science, for example, on river systems, an increasing recognition of the need to consider different worldviews was noted, in particular the importance of Māori and Pasifika cultural values.

A suggestion to enhance interactions with these worldviews was to increase the number of Māori students in science. Edward felt that more Māori students in science would help other students value Māori culture more and consider Māori views when they entered the 'real world', as well as encourage more Māori involvement in resource management:

Actually, it would be really nice to have a lot more Māori science students. We need far more Māori to be involved in the management of our fresh waters

because they have that strong whakapapa with many awa⁸ and rivers, and their feelings and appreciation of water is . . . much more advanced than a lot of [Pakeha]. Pakeha, just sort of see them as things flowing by that are not important at all. (Edward, University A, life sciences)

Embedding generic skills

Embedding generic skills in undergraduate science classes was part of quality teaching and learning for most lecturers (14/18). The most frequently mentioned generic skill in this category was communication skills (8/18), especially writing and literacy skills. Lecturers also valued presentation skills for helping students learn because, as Gary summarised, ‘the ability to collate information and present it to others also reinforces your own understanding.’ Some lecturers (5/18) highlighted the importance of critical thinking beyond its application in the discipline, as illustrated by Isabel’s comment ‘part of the preparation for the wider world is getting them to practise thinking critically and being able to . . . not take things at face value but try to get the processes and the politics . . . behind what happens.’ A few lecturers (3/18) viewed resilience, persistence and general problem-solving as important generic skills to foster. Quentin highlighted how problem-solving in experimental laboratory work related to problem-solving adverse situations in life in general ‘A lot of things just plain don’t work . . . but you should always be actively trying to figure out a way to improve it or fix it, or understand what went wrong’.

Although most lecturers agreed that providing opportunities for students to interact with new experiences and information in the form of generic skills by embedding these in science courses was important, Olivia noted that soft skills can get ignored because some lecturers don’t necessarily consider them their responsibility:

I think the competencies, the capabilities, the things people would view as these soft skills kind of get ignored. You know “somebody else should be teaching that” “somebody else should be teaching them how to write an essay, I haven’t got

⁸ Awa means river or stream in Māori

time to teach them how to do that and mark up the essay.” . . . Whereas you want them to learn something, that’s fine, give them formative assessments before they get their final mark and they are more likely to internalise it and I don’t think we do that very well . . . I don’t think it probably happens much in science. (Olivia, University D, life sciences)

Making connections

Most lecturers (10/18) viewed making connections between science and outside university (the 'real world' and students' own lives) significant for quality teaching and learning. Some lecturers (5/18) also considered it important to make connections explicit within and between courses, and to provide depth in a qualification by ensuring that each year builds on the preceding one.

John explained the value of relating science to life outside the University in helping students 'normalise' concepts to aid learning and to provide a mechanism for students to communicate their science to others:

. . . you can talk about nightclubs and dance floors, and how ordered or disordered they are and that sort of stuff . . . you can use those sorts of things as ways to normalise the material we're dealing with, because chemistry is . . . regarded as hard and esoteric . . . But if you can find ways where you can link chemical concepts to every day events, then you provide them with a mechanism by which they can communicate about their science, to non-scientists, you provide them with a mechanism by which they can be reminded about their science. (John, University B, physical sciences)

Uncertainty and creativity in science

A third of the lecturers (6/18) considered that the inclusion of the notion of change and uncertainty in science was an important aspect of quality teaching and learning. A few lecturers (3/18) noted the creative nature of science, for example, creating new hypotheses, new methods and new scenarios, and suggested that this was often absent in traditional science teaching. When talking about prospective students wanting to take science, Olivia asked the pertinent question 'why on earth do you want to take the joy and creativity out of it by making it sound as if you can't be creative?'

Olivia also highlighted the need to move students away from the idea that knowledge in science is fixed:

That is one of the things about science isn't it, so science is always changing, you get new data, you refine your interpretation, you move on. There is no one absolute expert. I think we do students a real disservice if we teach only from the text book and we give them the impression that it is all a fixed body of knowledge that isn't going to change with experience. (Olivia, University D, life sciences)

Hannah illustrated the temporal nature of scientific knowledge and the need to help students become comfortable with 'the grey area':

The media doesn't like uncertainty, there are lots of people who don't like uncertainty, but as scientists we should be comfortable with uncertainty, but yet still make certain decisions, or decisions where we are making the best decision at the time based on the available data. And I think if we can push students to explore that grey area then we are readying them for a career in science because it is all about the grey. (Hannah , University B, life sciences)

The categories, themes and subthemes identified with the openness lens, together with the number of lecturers referring to each of these (in order of number of lecturers) are summarised in Table 18. This table also shows the total frequency count of each category, theme and subtheme.

Table 18. Quality as openness: the categories, themes and subthemes related to interacting or encountering new information or experiences identified with the openness lens.

Category, theme and subtheme*	No. of sources (interviewees) referring to category/theme /subtheme*	Total frequency count of category/theme/subtheme*
Context-based science	18	56
Applying knowledge to new questions or problems	9	12
Collecting real data	7	10
Discipline research and enquiry skills	5	8
Real research projects	5	8
Discipline content, background or technical skills	5	7
Realistic assessments	5	5
Scientific literacy	4	6
Science and worldviews	17	63
Other worldviews	15	39
Cultural	12	20
Religious worldviews	10	19
New Zealand context	9	18
Open-minded	4	6
Embedding generic life skills	14	41
Communication skills	8	13
Writing and literacy skills	6	7
Oral presentation skills	4	6
Thinking critically	5	8
Work readiness (punctuality etc)	4	4
Dealing with adversity	3	6
Numeracy	3	4
Teamwork	2	3
Lifelong learning	2	3
Making connections	13	34
Outside university	10	25
Within courses	5	6
Between courses	3	3
Uncertainty in science	6	9
Science as creativity	3	4

Note. *Categories are inclusive of themes (indented) which are inclusive of subthemes (indented within themes).

6.3.3 Quality as relationship

The social complexity lens considers the interactions between people and how these are promoted to produce change. I identified five categories of interactions with this lens. Three of these focused on lecturers collaborating with other lecturers (9/18), other non-university staff (2/18) or external partners (9/18). The remaining two categories involved lecturers interacting personally with students (8/18), and lecturers promoting student learning through student-to-student interactions in small groups (8/18).

Next, I present the five main categories of social interactions.

Lecturers collaborating with teaching colleagues

Half of the lecturers (9/18) considered interactions with colleagues to be significant for quality teaching. This included collaborating with a range of colleagues, for example, technical staff, postdoctoral fellows and PhD students, to provide sufficient advisers for undergraduate students' research projects. Some lecturers described being members of a teaching team where many or all aspects of a course were negotiated. Barry emphasised the joint decision-making of his teaching group:

*I say "we" because I can't separate what I do from the rest of my teaching group . . . because we all make these decisions together . . . We often have discussions about what it is we're going to cut out and what we are going to focus on.
(Barry, University A, earth sciences)*

Lecturers teaching with external partners

Half of the lecturers (9/18) highlighted the value of involving community organisations or experts external to the University as partners in teaching. Mark described community-based projects where groups of students undertake projects with various community partners:

. . . we call community-based learning and it operates in the city with research groups of five students generally who negotiate a topic in a broad problem area that I pre-negotiated with a community partner . . . (Mark, University B, earth sciences)

Quentin highlighted the value perceived by students of having practising professionals involved in their teaching and learning:

This is a course which is done entirely with external lecturers, they come from the legal profession, they come from government, they come from industry . . . and it is actually a huge amount of information . . . The [students] love it. The reason they like it I think is that they get this feeling that everybody who is in front of them, that's what they do. (Quentin, University G, physical sciences)

Student-student interactions

Many lecturers (8/18) viewed student-to-student interactions to be essential to quality teaching in science and students working in small groups was an integral part of their teaching and learning in laboratory classes, field work, and other classes. Lecturers varied from encouraging students to work together to implementing a structured team-based learning approach where teams of students are formed for the duration of the course. Naomi summarised the value of students learning from each other in small groups in her comment 'because they learn from each other, they gain confidence . . . the best way to learn anything, to reinforce it and get it clear in your own mind, is to have to explain it to someone else.'

Olivia highlighted the value of social learning for Māori students:

The embarrassment of being in front of the class and getting stuff wrong or being singled out . . . remains kind of a barrier I think from talking to some of our Māori students and talking to our Kaitiaki⁹ . . . There is also a much stronger . . . a much more valued place for social learning and learning in groups. (Olivia, University D, life sciences)

⁹ Kaitiaki means guardian, trustee, steward or caregiver in Māori

Lecturer interacting personally with students

Many lecturers (8/18) viewed interacting with students on an individual basis as key to quality teaching. Keith described the benefits of building personal relationships with students early on in terms of student learning and success and the need for lecturers to have the communication skills to enable this:

I've put much more emphasis on building a personal relationship with students. I more strongly feel that we can only do that quality teaching if we first work on our communication. We need to make sure that students are . . . comfortable with trusting a person, so that if there's issues and things are not going so well with their studies, they feel free to come in for a chat and to ask for advice . . . and of course that mostly happens in the 100 level because if you get it down there, then you can benefit from it later on. (Keith, University B, life sciences)

Olivia raised the point that the nature of the lecturer-student relationship needed to be friendly yet professional:

To me, the relationships you build with your students are very, very important . . . the relationship students build with their teachers are a big influence on their success . . . And I have to explain to them periodically that I am not going to be their friend on facebook and they say, "But you are friendly", and I say, "Yes, but there is a big difference between friendliness and being someone's friend, I am never your friend but I like having a friendly open relationship with you." (Olivia, University D, life sciences)

Lecturers interacting with other university staff

A couple of lecturers (2/18) viewed their interactions with other members of the university community as vital to quality teaching; for example, online learning support and Kaitiaki. Hannah highlighted the variety of help that was available when she started asking for it:

. . . and I also work with the Flexible Learning Team and . . . so to me it is all about the power of the collaboration and I found a lot of collaborators within the school and within the University and also internationally as well. And I think it is as soon as you start asking the questions, people pop out of the woodwork, they really do. (Hannah, University B, life sciences)

The categories identified with the social complexity lens, together with the number of lecturers referring to these (in order of number of lecturers) are summarised in Table 19. This table also shows the total frequency count of each category.

Table 19. Quality as relationship: the categories related to social interactions identified with the social complexity lens.

Category	No. of sources (interviewees) referring to category	Total frequency count of category
Lecturers collaborating with colleagues	9	23
Lecturers teaching with external stakeholders	9	17
Student-student interactions	8	17
Lecturer interacting personally with students	8	14
Lecturers and other university staff	2	3

6.4 What are the main influences on lecturers' teaching and learning?

6.4.1 Quality as change

The nonlinearity lens looks at agents changing through multiple local interactions. I identified two categories of local (i.e. lecturer-based) interactions with this lens. Most lecturers viewed feedback on teaching (11/18) and self-reflection (10/18) as significant for changing their teaching.

Next, I present illustrative examples of lecturers' views on feedback and self-reflection that describe how these changed their teaching in undergraduate science.

Feedback on teaching for change

Most lecturers (11/18) viewed student feedback as a major influence for changing their teaching and used formal and informal feedback mechanisms for this. Most of these lecturers (10/18) stated that their teaching had changed in response to students' feedback but did not specify how; time constraints prevented further exploration in these cases. Only one lecturer reported changing their teaching in response to collegial feedback.

Barry noted the powerful nature of student feedback when he changed his teaching following feedback from informal discussions with students in a practical class:

I remember talking to students last year in this practical . . . and asking them what they thought about the paper and I learnt that a lot of them resented having to do the paper as a pre-requisite for their . . . agricultural degrees . . . So this year . . . I gave some examples of why agricultural students need to . . . know something about soil development, erosion and so on . . . and why it's useful . . . [they said] "Oh it's really useful. I can really see how it's useful to agriscience" . . . having their feedback is really quite powerful. (Barry, University A, earth sciences)

Barry also gave an example of the value of providing time for students to consider questions in enhancing the quality of feedback:

Actually, something that we did this year . . . in the van on the way back from the field trip [was] we asked everyone what they thought and . . . the whole van was silent for 10 minutes and . . . then one person opened their mouths and they said, "Well, actually, I think this." And then there was about 15 minutes of feedback coming to us . . . But it made me realise, I think often with those [online surveys] they do them in a hurry and they don't put sufficient time into actually thinking about constructive feedback. (Barry, University A, earth sciences)

Self-reflection for change

Most lecturers (10/18) viewed self-reflection on their teaching as significant for changing their teaching and enhancing quality in teaching and learning. Lisa illustrated how self-reflection led to his/her reducing material and being very selective by refocusing on what was important:

I thought, "well, they don't need to know every single phylum, how to identify these things . . . they need to learn the key ones, the most important ones, for example, the ones that they might encounter the most or have the most relevance . . ." And so I found that then instead of trying to rush through an entire, maybe two year curriculum in a semester of all the palaeontology you can learn, we're very selective, but the idea is they can then go anywhere and apply this and they've really used different tools. (Lisa, University C, earth sciences)

Hannah highlighted how the process of self-reflection on an online activity, together with the confidence to try something new, transformed a large lecture class:

I think something happened . . . I was just reflecting on the fact that there had been a question that was posted on our student forum . . . no-one had answered it. . .[and] that you telling someone they have a misconception and telling them what the right answer is not a way for them to unlearn the misconception. They need to discover the misconception on their own . . . and [the lecture] turned into a 30 minute tutorial with 200 students, and I had probably about 8-10 different questions from 8-10 different students throughout the entire lecture theatre. For me it was amazing . . . and I think it was just my having the confidence to go in and see where this goes. (Hannah, University B, life sciences)

The categories and themes identified with the non-linearity lens, together with the number of lecturers referring to each of these (in order of number of lecturers) are summarised in Table 20. This table also shows the total frequency count of each category and theme.

Table 20. Quality as change: the categories and themes related to agents changing through local interactions identified with the nonlinearity lens.

Category and theme*	No. of sources (interviewees) referring to category/theme*	Total frequency count of category/theme*
Feedback on teaching for change	11	17
Student	11	16
Peer (colleague)	1	1
Self-reflection for change	10	18

Note. *Categories are inclusive of themes (indented).

6.4.2 Quality as influence: supporting influences

The multiple causality lens considers quality as influence. This lens highlighted the positive influence of local support (15/18 lecturers) and external support (15/18 lecturers). I present lecturers' views on these positive influences next.

Local support

Most lecturers (13/18) viewed support from their host university as key to quality teaching. Many of these lecturers (8/18) considered recognition and reward for quality teaching by the University as important, and some lecturers (5/18) valued the freedom that enabled them to be innovative in their teaching. Half of the lecturers (9/18) highlighted the

importance of support at the departmental level, especially from the Head of Department (HoD). Hannah illustrated the support for teaching at her university in the form of a dedicated 'teaching week' and how this leads to staff wanting to raise the bar in teaching:

We now have something called Teaching Week so . . . whoever receives teaching awards receives them at an event during Teaching Week . . . there are a series of sessions that . . . tackle different topics in teaching . . . when you are in those sessions presenting then you get to see what everybody else is up to and there is a real sense to want to elevate the bar when it comes to teaching. (Hannah, University B, life sciences)

External support

Many lecturers (8/18) viewed educational development opportunities (formal courses and less formal gatherings) important positive influences for the quality of their teaching and learning practice. Isabel précised the specific value of educational research in a formal course to boost her confidence in teaching 'looking at the research around feedback . . . for me that was a really big change moment that boosted my confidence.' Many lecturers (8/18) also highlighted the value of individual mentors or role models, especially early on in their academic careers. Mentoring circles ('teaching and learning circles') were valued for motivation and sharing ideas with colleagues from other disciplines. Lecturers greatly appreciated colleagues sharing resources for new teaching strategies. For example, a colleague from abroad enabled Hannah to implement team-based learning in her classes 'she sent me material from her own courses, she was very, very open and willing to share. And that completely influenced a lot of what I've done.' (Hannah).

Isabel noted how her postgraduate supervisor had encouraged and provided her with teaching opportunities early on in her career:

. . . my [Master's] supervisor was [Name 1] whom I know has won a few teaching awards since then, and she really encouraged me to develop teaching . . . she gave me some tutorials, gave me marking . . . and I did a few weeks of [Name 2's] third year course. And so I kind of had good role models I think to start off with, so I had quite high expectations of what I should be doing. And then I really wanted to teach. (Isabel, University B, earth sciences)

Connor highlighted the significant impact of a formal teaching course early on in his academic career:

I think the whole, my whole philosophy, my whole teaching philosophy has been formed by a course that I took at the outset of my academic career at [a UK university] and [Name] who was leading that course at the time. (Connor, University A, earth sciences)

The categories, themes and subthemes identified as supportive of teaching with the multiple causality lens, together with the number of lecturers referring to each of these (in order of number of lecturers) are summarised in Table 21. This table also shows the total frequency count of each category, theme and subtheme.

Table 21. The influences that lecturers viewed as supporting their teaching.

Category, theme and subtheme*	No. of sources (interviewees) referring to category/theme/subtheme *	Total frequency count of category/theme/subtheme*
Local support	15	43
University	13	25
Recognition reward (incl financial support & valuing teaching)	8	9
Freedom	5	7
Facilities	3	6
Personnel	2	3
Department (HoDs)	9	10
Colleagues	5	6
Self	2	2
External support (positive influences)	15	41
Educational development (informal or formal)	8	15
Mentors, role models or external	8	12
Discipline community of practice	2	3
Discipline heroes	2	2
Technology	2	2
Science education evidence base	2	2
Own undergraduate experience ^c	2	2
Other ^a	3	

Note. *Categories are inclusive of themes (indented) which are inclusive of subthemes (indented within themes). ^aOther theme includes: group annual review, an encouraging environment (including peer review), and love of discipline. ^cThis included one Oxbridge tutorial system and one description of lecturing with passion and enthusiasm.

6.4.3 Quality as influence: concerns

The multiple causality lens revealed lecturers' concerns for three main categories of influences that had the potential to negatively affect the quality of their teaching and hence student learning. These three categories were institutional (17/18), student-related (10/18) and political (or societal) influences (8/18).

Institutionally-related concerns

Nearly all lecturers (17/18) had institutionally-related concerns. Most of these concerns (11/18) revolved around increased workload or lack of time, with many lecturers (6/18) expressing concerns about the priority given to research and the performance based research fund (PBRF) exercise summarised in phrases such as 'promotions are mainly around your research' (Lisa) and 'there is always this emphasis on research outputs' (Rose). Some lecturers (4/18) were concerned about the lack of support for quality teaching and learning from their colleagues.

Isabel illustrated the lack of collegial support experienced when colleagues didn't take peer review of teaching seriously:

We do peer reviews of teaching . . . I have asked [my peer review group] for a review of my course outline, one of them gave feedback that . . . wasn't very useful . . . We haven't managed to get a time where we have actually done a peer review of teaching. So the feeling I get is that they are not really interested . . . (Isabel, University B, earth sciences)

Student-related concerns

Most lecturers (10/18) had student-related concerns with some (4/18) worried about student attendance. Other lecturers (4/18) were concerned about student workload and learner fatigue, and suggested that care was needed not to overwhelm students with numerous new learning techniques. Concerns about reduced student attendance at lectures centred around video-recording of lectures. There was concern that the demand for videoed lectures encourages passive information gathering without using it and the suggestion that flexible learning, for example, videoed lectures, may disengage students as it has to

compete with other distractions. Olivia highlighted the need to make classes engaging for students so that students want to attend:

we record [lectures] and we noticed an increasing tendency for students on campus not to come to class. And some of my colleagues take this quite personally . . . it has led to some interesting discussions on students, "Well why do you want them to be there?" . . . "What do you do in class that makes them want to be there?" And that is where this whole flipping thing comes in to it really . . . So I do stuff that gives them a reason to come. Because while they can watch that on the video I guess it is a lot more fun actually being there. (Olivia, University D, life sciences)

In contrast, David had concerns about students not attending lectures for different reasons; he focused on what lecturers could discern from students attending lectures:

I think [a recording is] different to what . . . you get from when you are actually sitting there with the human interactions. You look at [students] to see whether they understand or not . . . you can't ask questions . . . simple things like if you're . . . explaining a slide that is quite complicated . . . you ask them at the end . . . "do you understand, do you want me to talk through it once more?" During the class people would say "yes" or "no" or . . . look away or they look at you . . . it's subtle . . . I think you can feel what a class is . . . that is engaged with what you're talking about and a class that isn't interested. (David, University C, physical sciences)

Schools system concerns

Many lecturers (8/18) expressed concerns about the schools system with a perceived lack of enthusiasm for science among primary school teachers. A few lecturers were concerned about the preparation of university entrants from high schools, in particular, their literacy skills, and there was a perception that students from the NCEA system seem to be less able to think for themselves than previous cohorts. Keith expressed his frustration with the poor writing skills of new students:

One thing I'd like is a better education system at the high school level, I'd like to get some better students coming in . . . because especially writing, what am I going to do with that? All these students, we want them to write essays . . . I spend so much time providing feedback on them, 99% probably don't even look at it, [and the] horrible [hand]writing (Keith, University B, life sciences)

The categories and themes identified with the multiple causality lens as lecturers' concerns adversely affecting quality teaching, together with the number of lecturers referring to each of these (in order of number of lecturers) are summarised in Table 22. This table also shows the total frequency count of each category and theme.

Table 22. The influences that lecturers viewed as negatively affecting their teaching.

Category and theme*	No. of sources (interviewees) referring to category/theme*	Total frequency count of category/theme*
Concerns	17	100
Institutional	17	72
Workload or lack of time	11	20
Research priority or PBRF or lack of commitment to teaching	6	8
Lack of colleague support	4	6
University bureaucracy	3	9
Student evaluations	3	3
Other institutional concerns ^a	13	26
Student-related	10	14
Student attendance	4	5
Student workload	4	4
Student expectations	2	2
Student understanding or retention of knowledge	2	3
Political or societal	8	12
School system	8	11
Other concerns	3	4

Note. *Categories are inclusive of themes (indented). ^aOther institutional concerns includes: academic freedom (as a bad thing), large class sizes, lack of contact time, exam system, insecurity of a minority field, lack of uptake of Maori scholarships, lack of commitment to teaching, and degree structure too flexible. ^bOther concerns include: internships, engaging with the public, student access to university.

6.5 Chapter summary

In this chapter, I reported the findings from 18 semi-structured interviews analysed with the lenses based on complexity and wickedity. The lecturers highlighted several issues that contribute to the problem of defining quality teaching in undergraduate science including a variety of views on how to teach science, the purpose of university education and the

definitions of science and quality. Lecturers also considered that student-related characteristics such as year level and learning preferences influenced the definition of quality teaching. All lecturers valued opportunities that enabled students to encounter new information or experiences (openness). In addition to providing context-based science learning, most lecturers considered embedding generic life skills their responsibility. Most lecturers considered making connections to other aspects of students' lives, and including Māori values, essential to quality teaching and learning. About half the lecturers viewed relationships (social complexity lens) as contributing to quality teaching and learning with collaboration with colleagues, external partners and interacting personally with students important. Lecturers also considered providing opportunities for students to learn with each other in small groups important.

Most lecturers changed their teaching in response to non-linear local interactions that focused on self-reflection and student feedback. Major positive influences on lecturers' teaching included the support of their Head of Department and departmental colleagues. Lecturers valued institutional recognition and reward as well as the freedom to implement teaching innovation. External support was also valued, with many lecturers benefiting from formal and informal educational development and mentors, especially early on in their academic careers. Lecturers' main concern was lack of institutional support. Lecturers were also concerned about student attendance and workload, and high school preparation for university.

In the next chapter, I integrate the findings from the Delphi study, lecturer survey and interviews to synthesize a view of the research as a 'whole'.

CHAPTER 7: INTEGRATION OF FINDINGS

7.1 Introduction

In chapters 4, 5 and 6, I presented the findings of each component of the multistage mixed methods research. In this chapter, I integrate the findings from Phase 1—the Delphi study—and Phase 2—the lecturer survey and interviews, providing the point of integration for the research and enabling a view of the findings as a ‘whole’ (Schoonenboom & Johnson, 2017). As in previous chapters, this chapter is organised around the main findings that emerged in response to the research questions. I start by reporting the key findings that emerged from analysis with the problem definition, openness and social complexity lenses and statistical tools when I addressed research questions 1 and 2 asking what national award-winning tertiary teachers and the larger sample of university science lecturers considered to be quality teaching and learning in undergraduate science. Then I report on the influences resulting in lecturers changing their teaching practice, followed by the broader influences on lecturers’ teaching, revealed with the nonlinearity and multiple causality lens, respectively, addressing research question 3 asking what influences lecturers’ quality teaching.

7.2 What do science lecturers consider to be quality teaching and learning in undergraduate science?

7.2.1 The problem with defining quality teaching in undergraduate science

The problem definition lens considers the reasons for difficulties with defining problems and issues and I used this lens to explore the difficulties with defining quality teaching and learning in undergraduate science. The aim was to aid resolution by constructing a transformational framework for understanding quality teaching and learning in undergraduate science based on lecturers’ views (Chapter 3) and, from this, a conceptual framework for its emergence. Findings from round one of the Delphi study in Phase 1, and the lecturer survey open text comments and lecturer interviews in Phase 2, revealed a wide range of lecturers’ views on how to teach science, in particular, on quality practical laboratory experiences. Phase 2 also highlighted the variety of views lecturers held

regarding the role of lecturers, the purpose of university education and the definitions of quality and science. These different views may lead to lecturers holding a variety of definitions of quality teaching and learning in undergraduate science. For example, lecturers agreed that practical experiences—‘doing science’—are essential for quality learning and teaching in science but views on the forms this should take differed. Some prefer prescriptive laboratory classes (labs) for learning specific skills whilst others advocate project-based labs or fieldwork (‘real science’) for learning scientific thinking skills at all year levels. Lecturers recognised a range of student-related characteristics that influenced student learning and acknowledged this range required a variety of teaching strategies rather than a traditional ‘one size fits all’ approach of lectures, tutorials and laboratory classes. Lecturers reported changing what they did in their teaching according to the academic background, learning stage or year level of students, indicating that their definition of quality teaching and learning was dependent on these student-related characteristics. Also, lecturers were aware of the general understanding in educational research that individual students have different expectations of, and preferences for, teaching and learning. Diversity in student learning preferences or expectations of teaching can also lead to differences in student definitions of quality teaching and learning. Lecturers and students may therefore have definitions that differ not only within their groups but also from each other. Lecturers also held differing views about the purpose of university education with a focus on employment, discipline research or personal development. Some lecturers had strong feelings on this subject (this was especially clear in interviews) whilst others passively accepted a prevailing climate of preparing ‘work ready’ graduates and others wanted to know what students intended doing after university so they could tailor their teaching accordingly. This suggests that the purpose of university education, from students’ and lecturers’ perspectives, affects teaching and learning and the definition of quality teaching and learning.

Interestingly, some lecturers in the interviews raised questions about the definition of science. These lecturers highlighted the need to discuss the nature of science with students. This included not only the scientific method of enquiry, but also that this is the Western model, and that observation on which scientific evidence is based is inherently subjective.

The importance of including these perspectives in teaching and learning was summed up by Mark as ‘science isn’t merely a set of tools . . . but it is something that you work with and create.’ Other lecturers held more traditional views of science as positivist and objective. These different views on the fundamental nature of science, part of lecturers’ worldviews, will influence teaching and learning and the definition of quality teaching and learning in science.

Lecturers may therefore hold different views on what constitutes quality teaching and learning depending on their context, for example, background of students, year level and course purpose, as well as their fundamental beliefs about the purpose of university education, their role in teaching and definitions of quality and science. These different views demonstrate the wicked and complex nature of teaching science and highlight the need to clarify and understand lecturers’ views of quality teaching in science. From problem clarification, conditions for the emergence of quality from a complex system may then be proposed (Chapter 3, Table 2).

7.2.2 Variation in extent of consensus

The dissensus Delphi technique provided an exploratory tool to collect views on quality teaching and learning in science from a panel of Tertiary Teaching Excellence Award (TTEA) winners in science. I used the findings from this to construct the survey to collect the views of the larger sample of science lecturers at New Zealand universities in Phase 2. Combining the responses from the science lecturers in Phase 1 and Phase 2 of this study showed a very wide range of views on many characteristics associated with quality teaching and learning in undergraduate science (Figure 23 and Appendix C). Based on the relative frequency of extremely important/very important/important responses (combined into a single category of ‘Important’ responses), I classified these statements as showing a greater consensus, strong consensus, lesser consensus and a lack of consensus (Table 23). In this context, statements with 30% or more responses of ‘somewhat important’ and ‘not at all important’ responses, combined into a single category of ‘Unimportant’ responses, were considered to show a lack of consensus.

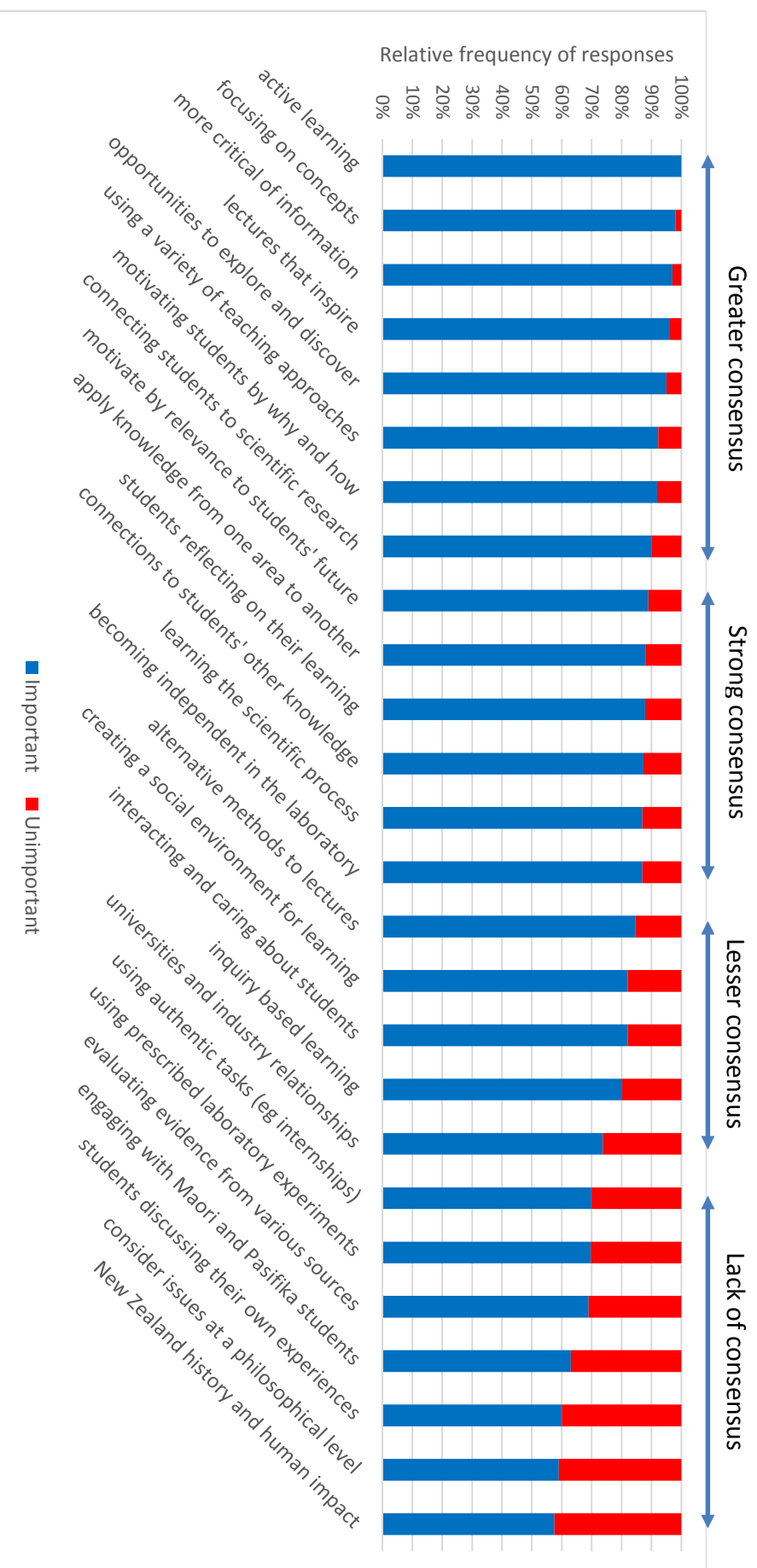


Figure 23. The relative frequency of combined responses from Phase 1 and Phase 2 to the lecturer survey on quality teaching in science. The importance ascribed to the survey statements by lecturers is indicated by the colours on the figure with responses combined as 'Important' ('extremely important', 'very important' and 'important' responses), or 'Unimportant' ('somewhat important' and 'not at all important' responses). The items are sorted in order of importance with the most important on the left.

Table 23. Categories of survey statements based on combined findings from the lecturer survey and Delphi panel

Item no.	Survey statement following the stem 'Quality teaching in science at university means...'	Lens group ^b	Factor ^c
Statements with a greater consensus ^a			
10i	using approaches to promote students' active learning, for example, exercises, assignments, problem-solving.	PD	1
10y	focusing on understanding concepts and not over-emphasising content.	PD	
10m	providing opportunities for students to be more critical of information than they may have been previously.	O	
10q	using lectures that present ideas well and challenge, stimulate, motivate and inspire students.	PD	
10f	providing opportunities for students to explore and discover to capture the excitement of real science, for example, in laboratory-based projects or field trips.	O/PD	
10a	using a variety of teaching approaches, rather than a 'one size fits all', because of the diverse characteristics and backgrounds of students.	PD	
10l	motivating students by highlighting why and how things work.	O/PD	3 1 ^d
10c	providing authentic scientific experiences by connecting students with current research.	O/PD	3
Statements with a strong consensus ^a			
10k	motivating students by highlighting the relevance to their future, including their careers.	O/PD	1
10t	providing opportunities for students to apply knowledge from one area to another.	O	1
10n	providing opportunities for students to reflect on their learning.	PD/NL	1
10b	making connections to students' prior knowledge, other subject knowledge, and life outside the university.	O	1
10e	helping students to learn the scientific process (method) including how to formulate hypotheses, design experiments to test these, interpret experimental data and revise hypotheses.	PD	3
10g	helping students to learn to become independent in the laboratory by providing opportunities where experiments may not work and original thought is required to overcome obstacles.	O/PD	

Statements with a lesser consensus ^a

10z	using alternative methods to lectures that can take time and confidence to plan and implement.	PD	1
10o	creating a social environment for learning, for example by being interactive and breaking down the barriers between lecturer and student to create a relaxed atmosphere.	S	1
10p	interacting with students, including provision of pastoral care.	S	
10r	using inquiry based learning (or guided inquiry).	O/PD	1
10x	having ongoing mutually-supportive relationships between universities and stakeholder industries to ensure that programme content and delivery is developed so it is relevant to students, up to date and responsive to industry needs.	S	1

Statements lacking consensus^a

10w	using authentic tasks, for example, internships, 'scenario' assessments.	O/PD	1
10d	using prescribed laboratory experiments that are guaranteed to work for entry level students to learn techniques.	PD	
10j	providing opportunities for students to learn to evaluate evidence from various sources ranging from parents to lecturers etc. and from other forms of 'authority' such as television.	O	
10h	engaging with Māori and Pasifika students and helping these students to make connections to their own lives.	S	2
10s	encouraging students to discuss their own experiences of the topic.	S	1
10v	encouraging students to consider current issues at a philosophical level.	O	2
10u	encouraging students to learn about the history of New Zealand and the impacts of humans on the environment. ^e	O	2

^a Statements with a greater consensus received $\geq 90\%$ of responses in the combined Important category; this was visually a 'cut-off' point on the relative frequency distribution (Figure 22). Statements with a strong consensus received $< 90\%$ but $\geq 85\%$ of responses in the combined Important category. Statements with a lesser consensus received $< 85\%$ and $> 70\%$ responses in the combined Important category. Statements receiving $\leq 70\%$ in the Important category, i.e., $> 30\%$ of responses in the combined Unimportant category, lacked consensus.

^b O, openness lens; PD, problem definition lens; S, social complexity lens; NL, nonlinearity lens

^c Factor from exploratory factor analysis

^d this item cross-loaded onto factor 1

^e this item received the most 'not at all important' responses (22%).

All survey statements received a majority of extremely important/very important/important responses (combined into a single category of 'Important' (Figure 23) indicating that every item was considered to be a contributing factor to quality teaching. However, the extent of consensus varied. Items with a greater or strong consensus included those associated with general principles of good teaching practice, for example, active learning, variety of approaches, motivation, and connecting to students' other knowledge. Items associated with scientific ways of thinking and practising including learning scientific process, authentic practical experiences and becoming independent in the lab, were also in the greater or strong consensus categories. Views lacking consensus were associated mostly with characteristics that varied with different contexts, as highlighted by exploratory factor analysis where Factor 2 (culture and context) showed a significant difference between institutions and disciplines, suggesting that these characteristics were more important in some contexts than others.

7.2.3 Quality as openness and relationships

Table 23 (and Figure 23) show that the support for items associated with openness or relationships varied. There was strong support for many items associated with openness—providing opportunities for new experiences—related both to generic principles of good teaching and scientific thinking. However, there was a lack of consensus about whether teaching science should include diverse worldviews to enable cultural minorities to connect science with their cultural frameworks or include learning from other disciplines such as history and philosophy, in particular about the New Zealand context. The openness lens revealed the most variable views about learning about the history of New Zealand and considering current issues at a philosophical level (Table 23).

Table 23 and the social complexity lens in Phase 1 and Phase 2 revealed a wide variety of views on the five items involving relationships with lesser or lack of consensus on all items associated with relationships. A lack of consensus was expressed for engaging with Māori and Pasifika students and encouraging students to discuss their own experiences. Hence the least important items, showing a lack of consensus, are associated with the openness and social complexity lenses and include all three items characterised by exploratory factor

analysis as belonging to Factor 2—culture and context (Table 23). Of particular note, engaging with Māori and Pasifika students was included in Factor 2 and in this category. There were significant differences between the responses from lecturers in different disciplines, and at different universities, to Factor 2, suggesting a role for institutional and other factors in attitudes to cultural engagement and building social relationships.

Many lecturers used some of the teaching characteristics in their teaching more often than relative importance suggested, for example, prescriptive labs (Chapter 5, Figure 20) and others less often, in particular, several items related to scientific ways of thinking and critical thinking. This indicated some discordance between what lecturers practised in their teaching and what they considered important, consistent with my personal observations that originally led to this research. The application of the nonlinearity and multicausality lenses, presented next, were intended to help understand some of the influences on lecturers that may contribute to this discordance.

7.3 What are the influences on lecturers' quality teaching?

7.3.1 Quality as change

I used the nonlinearity lens, which looks at agents changing through multiple non-linear local interactions, to reveal the local factors that led lecturers to make changes to their teaching practice. Members of the Delphi panel (Phase 1) reported that student feedback and reflective practice were the main drivers leading to improved teaching practice.

Lecturers in Phase 2 added to these findings with feedback from colleagues also leading to change. Often these colleagues were from outside the lecturer's own discipline department with expertise in higher education, online learning or cultural practices, for example, tikanga¹⁰ Māori. Interviewees in Phase 2 also expanded on the value of reflective practice

¹⁰ Tikanga means correct procedure, custom or manner and Tikanga Māori describes the customary system of values and practices in Māori culture

noting that it gave them the confidence to try new things and to be selective by refocusing on what matters. Lecturers in Phase 1 and Phase 2 indicated changes in their teaching resulted from constructive student feedback although there was concern about the validity of student evaluations associated with low response rates and a bias towards positive comments. Student feedback was the major factor resulting in changes in teaching practice described by the interviewees who reported gaining valuable informal feedback through casual in-class discussions, often in laboratory classes or field trips rather than through formal institutional quality evaluation surveys.

The combined findings from Phase 1 and Phase 2 demonstrate that lecturers' reflective practice that included student feedback is the main driver of teaching change. It is the interrelationship of these that is important, as illustrated by Edward's comment:

I don't think I've really been influenced by anybody other than myself . . . I have taken the teaching component quite seriously and I always try to improve it and I've done that by trying to get feedback from the students about how to do things better and by experimenting. (Edward, University A, life sciences)

7.3.2 Quality as influence

To help understand other, external influences on lecturers' teaching, I also explored the positive and negative influences on lecturers' teaching. I specifically asked the Delphi panel and interviewees about the positive and negative influences on their teaching. Although I did not ask lecturer survey participants directly, some referred to concerns (negative influences) when describing the impact of their teaching.

Concerns of the members of the Delphi panel in Phase 1 and the larger sample of lecturers in Phase 2 revolved mainly around high workloads with a lack of time to develop teaching resources and the difficulties of balancing teaching, research and administrative roles. The role of the Performance Based Research Fund (PBRF) exercise in institutions prioritising research, and the lack of institutional recognition of quality teaching for promotion, contributed to the low priority that lecturers gave to developing teaching because of the perceived need to obtain a high PBRF score. Lecturers in the survey in Phase 2 also indicated

an institutional undervaluing of practical experiences (laboratory and fieldwork) that led to reductions in these times for students and lecturers.

Lecturers in Phase 2 also expressed concern regarding a lack of collegiality about teaching, for example, peer review of teaching wasn't always taken seriously. Lecturers were also concerned about student factors including a focus on assessment rather than learning. Lecturers considered this partly due to traditional views of some colleagues reflecting how they were assessed as students, but also to institutional cultures that revolved around formal assessments, final exams and the bureaucracy often involved in changing assessment items.

Lecturers in Phase 2 also expressed concerns about student attendance in response to the availability of recorded lectures, early scheduling of lectures and the travelling times for some students. Whilst some lecturers thought recorded lectures might encourage passive information gathering, others highlighted the need to make live lectures sufficiently active and engaging for students to consider them worth attending. Another student-related concern revolved around learner fatigue if lecturers overwhelm students with too many different teaching and learning approaches.

Lecturers' in Phase 2 also raised concerns about other external factors such as high school preparation for university study and government priorities for funding. The mechanism of funding universities and the role of government priorities in this concerned lecturers. For example, the focus on research outputs adversely affected the time available for developing teaching discussed above, and the current focus on employment benefits applied courses with links to industry over 'pure' sciences. Concerns about schools revolved around lecturers' perceptions of a lack of enthusiasm and knowledge of science amongst primary teachers, and poor preparation of university entrants by high schools. In particular, lecturers perceived students from the current NCEA system to lack important literacy skills and to be unable to transfer skills to novel situations. Some lecturers thought the modular approach to assessment in high schools encouraged short-term memorisation and enabled schools to select topics, avoiding more challenging ones, leaving gaps in students' discipline knowledge.

The important positive influences on teaching for members of the Delphi panel in Phase 1 included mentors, supportive colleagues, observing inspirational lecturers, student feedback, professional development and institutional recognition of the importance of teaching. Phase 2 of the study confirmed and added to these findings with interviewees considering support from their host university as key to quality teaching. In addition to the importance of institutional recognition and reward for quality teaching in the form of promotional criteria, overt institutional support for enhancing teaching was viewed as vital, for example, in the form of a 'teaching week'. These lecturers also highlighted the value of the freedom to be innovative in their teaching. Several lecturers highlighted cases where such freedom at the institutional level had led to not only enhancing student learning but also to publications and local, national and international recognition. Many lecturers also highlighted the importance of support for teaching innovation at the departmental level, especially from their heads of departments, although collegial support was also valued. Peer (or group) mentoring circles (Darwin & Palmer, 2009; Kroll, 2016) were valuable for sharing ideas about teaching and learning especially with colleagues from disciplines outside science.

Many interviewees viewed educational development opportunities (formal courses and less formal meetings) as highly significant positive influences on the quality of their teaching and learning practice with several considering them underpinning their teaching philosophy. Interestingly, one very experienced professor expressed a wish for more opportunities for people at his stage to learn more about teaching and many interviewees expressed a strong desire for better access to educational resources, for example, websites with links to discipline specific teaching resources, to help them improve their teaching.

7.4 Chapter summary

Taken together, the findings highlight the range of views that lead to a lack of clarity on what constitutes quality teaching and learning within science. Without problem clarity, quality in undergraduate science remains a wicked problem where solutions that are effective on one day in one context may not work the next. In contrast, given problem clarity, quality in undergraduate science can be treated as a complex problem for which

conditions for its emergence can be proposed. The combined findings provide an integration of lecturers' views from which clarity in the form of a framework for understanding quality teaching and learning in undergraduate science can potentially be synthesised. From this, it should be possible to propose conditions for the emergence of quality. These are the topics of the main discussion chapter.

The findings also highlighted the discordance between the importance with which lecturers held some characteristics and how often they implemented these in their teaching. Findings from the nonlinearity and multiple causality lenses suggested the main drivers for change are mostly student feedback and reflective practice. Positive influences on lecturers' quality teaching included mentors, educational development and institutional support especially in the form of institutional recognition and reward. Lecturers' quality teaching was negatively influenced by perceived priorities, with teaching often perceived as a lesser priority than research. Lecturers also raised the importance of confidence to try new things, and access to educational resources. I develop these points as part of the proposals for the emergence of quality in the main discussion chapter.

CHAPTER 8: DISCUSSION

8.1 Introduction

In this chapter, I use the problem resolution and emergence of quality lens to look at the findings about quality and propose strategies for the groups involved to engage with the problem of quality. To do this, I start by discussing the findings on university science lecturers' views of quality teaching and learning in undergraduate science from Phase 1—the Delphi study—and Phase 2—the lecturer survey and interviews. From this, I propose a framework for understanding quality teaching and learning in undergraduate science as a starting point to provide some clarity on the problem. Then, I combine this with a synthesis of the influences on lecturers' teaching to propose conditions for the emergence of quality teaching and learning in undergraduate science.

The chapter is organised around the main findings about quality that emerged in response to the main research question: What do university science lecturers in New Zealand consider to be quality teaching and learning in undergraduate science? This question was explored by the research specifically addressing the sub-questions:

1. What do national award-winning tertiary teachers consider to be quality teaching and learning in undergraduate science?
2. What do a larger sample of university science lecturers consider to be quality teaching and learning in undergraduate science?
3. What are the main influences on lecturers' quality teaching?
4. What implications do these findings have for university science lecturer educational development programmes?
5. What other proposals for action arise from this?

8.2 Quality is viewed in multiple ways

Lecturers' ideas on quality explored in the interviews suggested individual lecturers held some definitions that accorded with quality in the higher education literature, for example, quality meeting predefined standards or excellence (Harvey & Green, 1993). Some lecturers

applied different standards to suit the range of students, indicating an awareness of the need to take account of student diversity. Where quality was seen as excellence, this was viewed as the personalisation and relationship brought by the lecturer and that could not be provided by any textbook, even the best interactive textbook. Some lecturers viewed quality in terms of equipping students for life; this has some similarities to quality as transformation (Harvey & Knight, 1996). None of the science lecturers in this study used the phrase 'fit for purpose' although this is a term used by Australian lecturers to describe the current situation in higher education, although their ideal is quality as transformation (Kalayci et al., 2012). The findings from this study and the Australian study suggest that university lecturers in New Zealand and Australia may not view higher education as a commodity, to which 'fit-for-purpose' generally relates, despite the marketization of higher education. It would be interesting to explore and compare the views on quality of other stakeholders, for example, managers (leaders) from these countries. The holding of different views on quality by different stakeholder groups, for example, quality as excellence or transformation, by lecturers as suggested in this study, and quality as fit for purpose by management, would have negative implications for quality enhancement as lecturers and management would have different purposes for quality. For these to align, all groups involved need to consider the purpose of quality and the purpose of education. I agree with Biesta (2009) that more consideration is given to the purpose of education. As outlined briefly in Chapter 1, I view the purpose of education as personally transformative and emancipatory for students; this accords with a transformative perspective of quality (Harvey & Knight, 1996).

8.3 The need for a transformative perspective of quality

8.3.1 Generic and science specific skills are essential for quality teaching and learning in science

The problem definition lens and lecturer survey findings suggested that a framework for understanding quality teaching and learning in undergraduate science would need to be broad because of the wide variety of views held within the science lecturer community. Lecturers considered all items in the survey to be important for quality teaching and

learning in undergraduate science although the extent of consensus varied. There was strong consensus regarding many characteristics associated with generic principles of good teaching (Biggs, 2011; Chickering & Gamson, 1987) and scientific ways of thinking and practising (Entwistle, 2005; McCune & Hounsell, 2005) but weaker consensus regarding social relationships. When compared to Chickering and Gamson's (1987) seven generic principles of good teaching science lecturers agreed with their principles three, four and seven: using active learning, giving feedback and respecting diverse talents and ways of learning. But there was a variety of views regarding aspects of principle one, encouraging contact between students and faculty. There was little mention of Chickering and Gamson's principles five and six – emphasising time on task and communicating high expectations.

Many of the lecturers' intentions for students' learning are encompassed by 'ways of thinking and practising' (WTP) in science (Entwistle, 2005, p. 67; McCune & Hounsell, 2005). These are broader than intended learning outcomes (or learning objectives) and describe what lecturers consider the essential nature of their discipline. The findings in this study agree with those from research exploring the development of biology students' WTP that showed the importance of students' engagement with experimental data, research literature and the written and oral conventions of the discipline (McCune & Hounsell, 2005). Since their first mention, there has been little further development of WTP although they offer a useful way of describing the knowledge, skills and attitudes encompassed in a discipline in all three learning domains—cognitive, psychomotor (physical) and affective domain (Seaman, 2011). Interestingly, threshold concepts, the knowledge that opens up a new way of thinking in a discipline, originally were suggested to be linked to WTP as learning to think like a member of the discipline could be considered a threshold concept (Meyer & Land, 2003). In practice however, the meaning of threshold concepts for scientists has tended to be associated with concepts in the cognitive domain. More recently, WTP have been advocated as a link between threshold concepts in a discipline and curriculum as an aid to 'bigger picture' thinking for disciplinary learning (Barradell & Kennedy-Jones, 2015). This view of curriculum and bigger picture thinking accords with the ideas of interactions and openness in complexity. Therefore, the specific findings from this study provide empirical support for the recent proposal to use WTP as a starting point to frame science

curriculum in higher education (Barradell, Barrie, & Peseta, 2018). These authors conceptualise a WTP approach on the basis that it provides an integrated view of curriculum, focuses learning on multiple knowledge forms, builds student agency by inducting them into disciplinary communities of practice and focuses on real-world needs. In this study, science lecturers identified many aspects of WTP for a science curriculum in higher education. However, the higher education curriculum is more than disciplinary learning and includes the multiple experiences that impact students' learning at, and for beyond the university. This highlights the importance of social skills and those that contribute to active citizenship.

Lecturers' weaker support for social relationships with and between students seen in this study suggests the value of these, long established in the educational literature (Astin, 1987; Tinto, 1997), may not be fully appreciated in the science community. Complexity thinking also highlights the value of social interactions in promoting conditions for emergence. Hence, the combination of research supporting the notion that social interactions are important for quality teaching and learning, and only weak support for these among science lecturers found in this study, indicates that these should be increased in undergraduate science to enhance student learning. It seems that quality teaching in science is most likely to emerge when generic principles of good practice are embedded in the ways of thinking and practising (WTP) in science, and social relationships are enhanced. The findings of this study show similarities to the pattern of higher education curricula based on knowing, acting and being, and dominated by knowing and acting with little integration of being, reported for science and technologies by Barnett et al (2005). However, a variety of views on other characteristics associated with quality teaching and learning in sciences found in this study indicate generic principles, WTP and social interactions are not enough and other factors have a role.

8.3.2 Quality in teaching and learning in science is context-dependent

The problem definition lens and the wide range of views in the survey showed a lack of consensus on some characteristics that contribute to quality teaching and learning in science. There was a lack of consensus among lecturers regarding characteristics associated

with the underlying factor 'culture and context', with significant differences between disciplines and institutions. This included characteristics related to Māori and Pasifika culture, history of New Zealand, philosophy of current issues and specific laboratory skills. This suggests the need for context-specific understandings of quality teaching and learning in addition to the longstanding generic understandings. The findings suggest there is a need for flexibility for lecturers to adapt to suit their specific cultural, historical and sub-discipline context.

The value interviewees in this study ascribed to worldviews, especially Māori culture, was particularly interesting as I took special care to refer to worldviews and not Māori culture directly. Interviewees highlighted river science as one of the areas in which Māori worldviews are included in undergraduate teaching and learning. Culture has been described as a critical variable in environmental decision-making where researchers have highlighted the need to integrate cultural knowledge, for example, river management in New Zealand and marine planning in western Canada (Satterfield, Gregory, Klain, Roberts, & Chan, 2013). Also, recent comparisons of how Māori knowledge and Western science are generated suggest there are some similarities between these (Hikuroa, 2017), and other authors have highlighted the blurred boundaries between Māori cultural knowledge and Western science (Clothier, 2014). Hence, research indicates local cultural knowledge can complement traditional (i.e. Western) science knowledge and contribute to managing complex societal problems supporting the views of the lecturers in this study that it needs to be included in quality in the New Zealand science context.

In addition to other cultural knowledge, history of a particular place and philosophy of current issues depend on national context; these are aspects that relate to active citizenship (Golubeva, Gómez Parra, & Espejo Mohedano, 2018). This was highlighted in a study of respondents' understanding of active citizenship and comparison with competencies for democratic culture (Golubeva et al., 2018). Students at one New Zealand university were shown to engage poorly with active citizenship and the need for lecturers to encourage this was highlighted (Leach, 2016). Research on active citizenship in schools in New Zealand identified specific pedagogies that supported citizenship learning and showed these included cognitive and affective engagement with societal issues (Wood, Taylor, Atkins, &

Johnston, 2018). Interestingly, interactive and role-playing activities were used to promote science students' understanding of complex socio-environmental issues, change attitudes and move from scientific literacy to sustainable literacy as an aspect of citizenship (Colucci-Gray, Camino, Barbiero, & Gray, 2006). The findings from this study suggest science lecturers focus on pedagogies in the cognitive and psychomotor domains, with affective domain learning largely limited to attitudes within the discipline as part of WTP in science. Hence, the importance of new experiences with other cultural knowledges, history and philosophy of current issues relevant to their time and place would enhance science students' understanding of, and empathy for, societal issues as part of building active citizenship.

Lecturers in this study expressed a lack of consensus regarding contextual factors associated with cultural and historical traditions specific to New Zealand. Barriers to Māori completion include relationships with academic staff, although factors outside university are also important (Theodore et al., 2017). The lack of consensus regarding lecturers engaging with Māori and Pasifika students in this study is of particular concern as these students are underrepresented in higher education and the Tertiary Education Commission (TEC) is committed to boosting achievement for Māori and Pasifika (<http://www.tec.govt.nz/news-and-consultations/parity-expectations/>). To help overcome this, some universities have specific strategies for Māori and Pasifika student admission and development (for example, see Richardson et al. (2014); Curtis et al. (2015)). Research on university entry scores in science for Māori and Pasifika students from one preferential admission scheme shows these scores are significantly below other students, indicating the need to address this issue in high schools (Curtis, Wikaire, Jiang, et al., 2015). In the present study, there were differences between institutions and disciplines in lecturers' views on culture and context in quality teaching suggesting these need to be further investigated and may need to be targeted for change in some cases, especially given the importance of the relationship between Maori students and academic staff (Theodore et al., 2017). Engaging with Maori and Pasifika students in this study was one of the characteristics that lecturers implemented less than suggested by the importance they ascribed to it (Figure 20), indicating the need for specific support to enhance these interactions as well as social interactions in general.

Characteristics on which there was a lack of consensus included traditional prescriptive laboratory experiments. Appropriate sub-discipline relevant practices for a given context may also include specific curriculum resources, or design approaches. For example, the need for a context-led approach in chemistry was highlighted to counteract the social perception of 'crazy chemists' (Smith, 2011). Also, the design of context-based curriculum resources based on authentic scientific modelling in schools suggests such approaches may be transferable to the higher education system (Prins, Bulte, & Pilot, 2018). The application of science sub-discipline context-based resources in these examples from the literature supports my proposal for a context-dependant framework for understanding quality teaching and learning in undergraduate science as prescriptive labs may be appropriate preparation in some specialised contexts.

The evidence of views with varying extents of consensus about quality teaching is not surprising. The quality teaching literature generally also shows sometimes conflicting perspectives. For example, the lists of quality teaching attributes listed by Ramsden and Callender (2014), Zepke and Leach (2010), Kuh (2009) and Kahu (2013) also show this diversity. Historically, North America has been associated with a focus on more behaviourist aspects of what students do whereas a more attitudinal stance prevailed in the U.K., Australia and New Zealand. More inclusive frameworks showing the importance of external factors and citizenship are offered by Zepke and Leach (2010) and Kahu (2013).

The findings from this study therefore suggest that lecturers need to consider what cultural, historical and specific discipline resources are relevant for their own context. They indicate the need for a transformative understanding of quality teaching and learning in undergraduate science that encompasses generic principles of good teaching, ways of thinking and practising in science, building good social relationships with variable context-dependent factors. This would be transformative for lecturers in being student-centred, and transformative for student learning in its inclusion of personal and social development.

A transformative framework for understanding quality teaching and learning in undergraduate science, based on the findings from this study is illustrated in Figure 24. Next, I discuss what makes this a complex system.

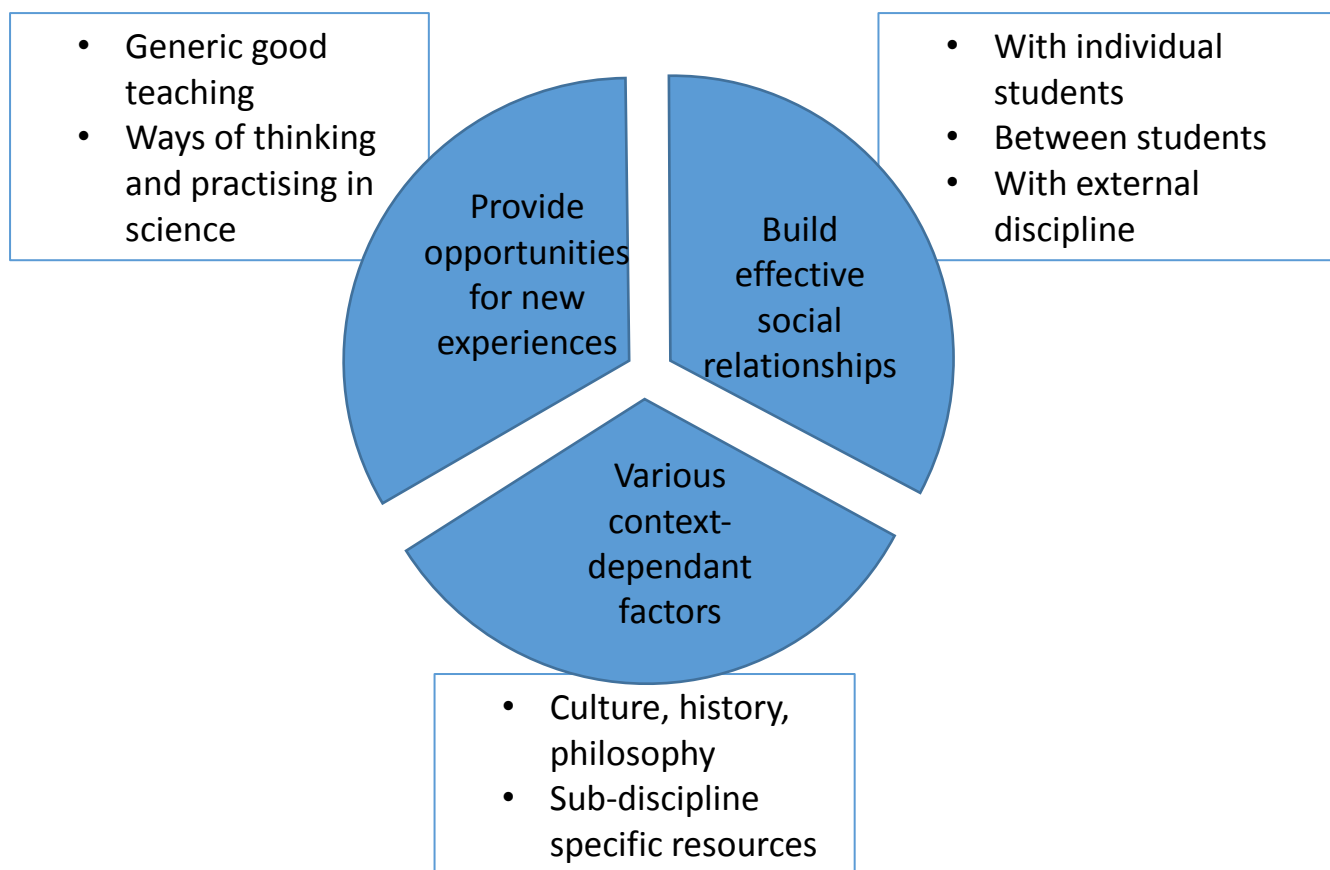


Figure 24. A transformative framework for understanding quality teaching and learning in undergraduate science. Each of the three sectors relates to characteristics described in Table 23. For example, the social relationships sector includes characteristics o, p, x, h and s. Context-dependant factors include characteristics that lack consensus, for example, w, d, v and u. The remaining characteristics relate to new experiences. For example, statements l, y, m, q, a, l, k, t, n, b, z, r, j relate largely to generic 'good' teaching practise whereas f, l, c, e, g relate to ways of thinking and practising in science. Various context-dependent factors allows flexibility for contexts to take account of cultural, historical and specific sub-discipline contexts depending on students, lecturer and institution.

8.4 Quality in science teaching and learning as a complex system

8.4.1 System components are interrelated

While each survey item is important for learning, complexity thinking focuses on interactive processes at all levels and proposes that the conditions for emergence are promoted at the

margins, when systems are far from equilibrium (Morrison, 2010; Richardson & Cilliers, 2001).

The lenses used to analyse the qualitative data in the study revealed 'a system that is comprised of a large number of entities that display a high level of nonlinear interactivity' (Richardson & Cilliers, 2001, p. 8). Features of quality identified through the problem definition, openness and social complexity lenses are both connected to each other and interdependent. For example, the problem definition and openness lenses revealed perspectives on quality featuring how to teach science, and opportunities for new experiences inside and outside the field of science, respectively. Lecturers displayed a lack of consensus around aspects of teaching practice, for example, some favoured traditional lectures whereas others preferred problem-solving approaches such as more experimental enquiry learning. Teaching preferences (beliefs or conceptions) are likely to influence lecturers' definition of quality teaching and learning and the extent of new experiences (openness) that lecturers provide for students. The support for inspiring lectures as one strategy in a variety of teaching approaches, agrees with suggestions that lectures are good for presenting current research (Svinicki & McKeachie, 2014). A variety of approaches was also supported in this study as reported elsewhere (Bosch et al., 2018). However, a meta-analysis of studies comparing student performance in STEM courses with lectures or active learning showed decreased failure rates with active learning and questioned the continued use of lectures, especially as a control for teaching research (Freeman et al., 2014; Wieman, 2014). It seems that the selective use of lectures that complement other teaching and learning activities, or specifically to illustrate seemingly counter intuitive concepts in some disciplines, as noted by one physics lecturer in this study, would disrupt the equilibrium and contribute to conditions for emergence. Indeed, diversity is necessary for emergence (Davis & Sumara, 2005), hence, the inclusion of the range of views is important for quality.

There were also tensions concerning quality laboratory experiences with a lack of consensus for prescriptive ('cookbook' style) labs. Again, this is likely to reflect interconnected features of quality, for example, this teaching preference for predictable lab results (seen in the problem definition category 'how to teach') is unlikely to promote openness in teaching practice, one of the preconditions for the emergence of quality. Lecturers' views that

prescriptive labs have a role in quality teaching in science contrasts with the literature (Brownell & Kloser, 2015; Lopatto et al., 2008) that indicates that traditional cookbook style labs are not part of quality science undergraduate teaching. This study suggests that both enquiry-based and prescriptive (competency-based) labs have a role in quality teaching and learning in undergraduate science. The need for very specialised skills in some subdisciplines within science suggests this is a context-dependent factor (in the psychomotor domain) rather than a WTP in the discipline of science. It has been my view that all skills can be learnt in context but I accept now that there may be specialist skills in some disciplines where hazards or delicate equipment may make competency based learning appropriate.

The lack of consensus shown by the relative frequencies of responses, and the nature of the diversity of views discerned from the qualitative data, shows quality teaching and learning in science is complex with many interacting factors. The least consensus was on factors associated with openness and relationships. Relationships are important for student engagement in learning (Leach, 2016). Enquiry and exploration are important aspects of WTP in science and are key aspects of openness (McCune & Hounsell, 2005; Mennin, 2010). Relationships, enquiry and exploration could also be considered aspects of 'activation and pleasure', the meaning recently assigned to student engagement by Balwant (2018) in his search for a definition with conceptual and operational clarity and alignment between educational and organisational disciplines.

Although the system components are interrelated, the interactions described above need to function for the system to behave as a complex system and for the emergence of quality. The question is, how can these interactions be promoted? This question is addressed in the rest of the discussion.

8.5 Multiple influences affect lecturers' teaching

8.5.1 Lecturers' reflective practice drives teaching change

The combined findings from Phase 1 and Phase 2 showed that lecturers' reflective practice that included student feedback is the main driver for changing teaching to enhance quality. Feedback from colleagues was also noted as contributing to this, from discipline teaching teams and from lecturers in other disciplines in group (peer) mentoring circles. Mentoring circles have been shown to be valuable for learning new skills and enhancing relationships (Darwin & Palmer, 2009; Kroll, 2016). These are examples of science lecturers learning from interacting with new information and experiences through openness and interacting with non-scientists in social relationships; key interactions in complex systems and preconditions for the emergence of quality (Mennin, 2010). These local interrelationships contribute to the iterative conditions necessary for adaptation and emergence in complexity thinking, similarly, reflective practice is also an iterative learning process (Dewey, 1910). These multiple interactions illustrate the complexity of the system at the level of the individual lecturer, as well as the system as a whole (self-similarity). The teaching change associated with reflective practice comes from within, or emerges from, the lecturer, and shows similarity with the emergence of quality from the whole complex system (Chapter 3, Figure 5); an example of self-similarity in complexity thinking similar to the relationship of leaflets (pinnae) to fern fronds or fractals (Chettiparamb, 2013; Song, Havlin, & Makse, 2005; Strogatz, 2005). The identification of self-similarity is further evidence for quality as a complex system with the inherent property of emergence. Emergence at this micro level is enhanced reflective practice incorporating multiple strands of feedback (Figure 25). This has potential for action at the macro level, if other conditions in the system are also met, as it is the interactions of conditions that lead to the emergence of quality.

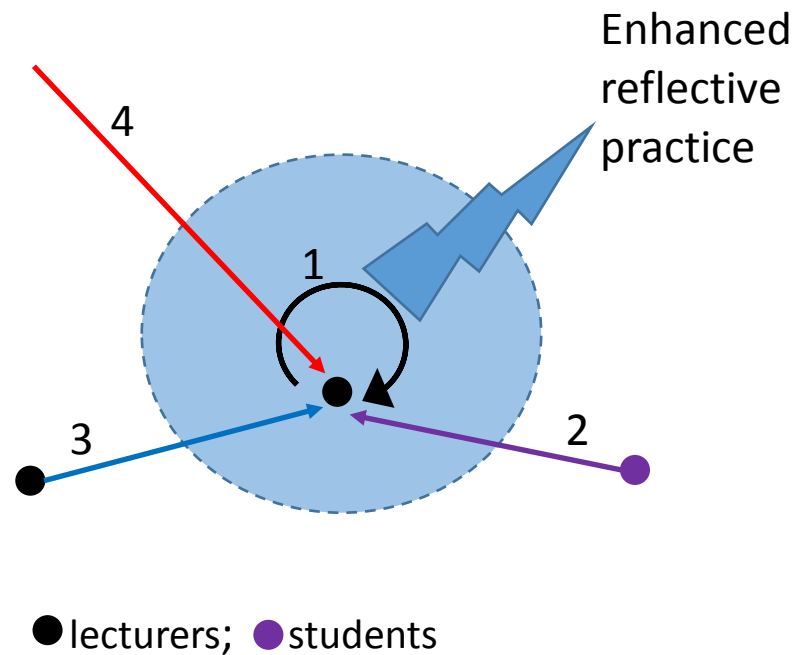


Figure 25. Model of a lecturer combining self-reflection and feedback from students and lecturers to enhance reflective practice. 1, self-reflection; 2, student feedback; 3, collegial feedback; 4, educators (educational development or formal tertiary teaching course). These combined interactions can lead to enhanced reflective practice (indicated by lightning arrow). Note: The figure illustrates the self-similarity of a complex system as it is the image in miniature of the whole system.

In my experience as a science lecturer, reflective practice has been a very strong driver of changing teaching to enhance quality. Reflecting on the good and not-so-good points of teaching and learning activities and how they can be improved has led to many small and large changes in my teaching. In agreement with Dewey (1910), I think reflection on an activity is a natural (intuitive) process that is often triggered by a disruptive (or critical) event, for example, negative student feedback or disastrous student exam performance on a topic. However, reflection does not always occur.

To use reflection effectively, it is helpful to know the type of questions to ask. For reflective practice, these questions constitute the nature of enquiry—or part of the ways of thinking and practising—in the discipline of education rather than science. As one member of the Delphi panel remarked:

I have continued to take full advantage of professional development opportunities that would help me to improve my reflective practice . . . (Panel member 5)

This suggests the need for lecturers to develop skills in reflective practice and a role for educational development to help science lecturers with this. In my experience, I learnt how to reflect much more deeply about my teaching and student learning as part of a formal teaching qualification. My experiences of combining self-reflection with student feedback from informal in-class surveys resulted in significant changes to my teaching and students' learning. For example, I changed a whole course that I had inherited from a traditional lecture and 'cookbook' style laboratory course to enquiry-led laboratories and 'flipped' classroom model of learning. This format has been in operation successfully for five years.

It is the interrelationship of a lecturer with all his/her experiences and relationships that is important, and his/her ability to reflect critically on his/her teaching, and feedback on his/her teaching from multiple sources, that has the potential to lead to quality enhancement (Šaric & Šteh, 2017; Tannebaum et al., 2013; Zepke, 2011a). Lecturers in this study and my personal experience indicate the potential of reflective practice that includes student feedback to influence lecturers to change their teaching and enhance student learning. Together with external influences, I suggest it should be possible to enhance these interactions and promote conditions within undergraduate science teaching to enable the emergence of quality.

8.5.2 Lecturers' teaching is hindered by institutional cultures and bureaucracy

Lecturers encountered barriers to making changes to their teaching in the form of institutional bureaucracy. The bureaucracy involved in making changes prevented many lecturers changing their courses, hindering innovation. This is likely to have adverse effects on quality by maintaining the status quo, or equilibrium in complexity terms, and therefore unlikely to enhance conditions for the emergence of quality. To enable lecturers to be innovative and to develop their teaching, for example, in response to their reflective practice, lecturers wanted barriers to making changes to course activities and assessments

removed (i.e. bureaucracy minimised). This study therefore provides an example of lecturers wanting to reclaim responsibility for teaching quality, for which institutional trust in lecturers' professionalism is required (Biesta, 2004). Without this trust, innovation that helps disrupt equilibrium, one of the conditions that promotes emergence, is stifled.

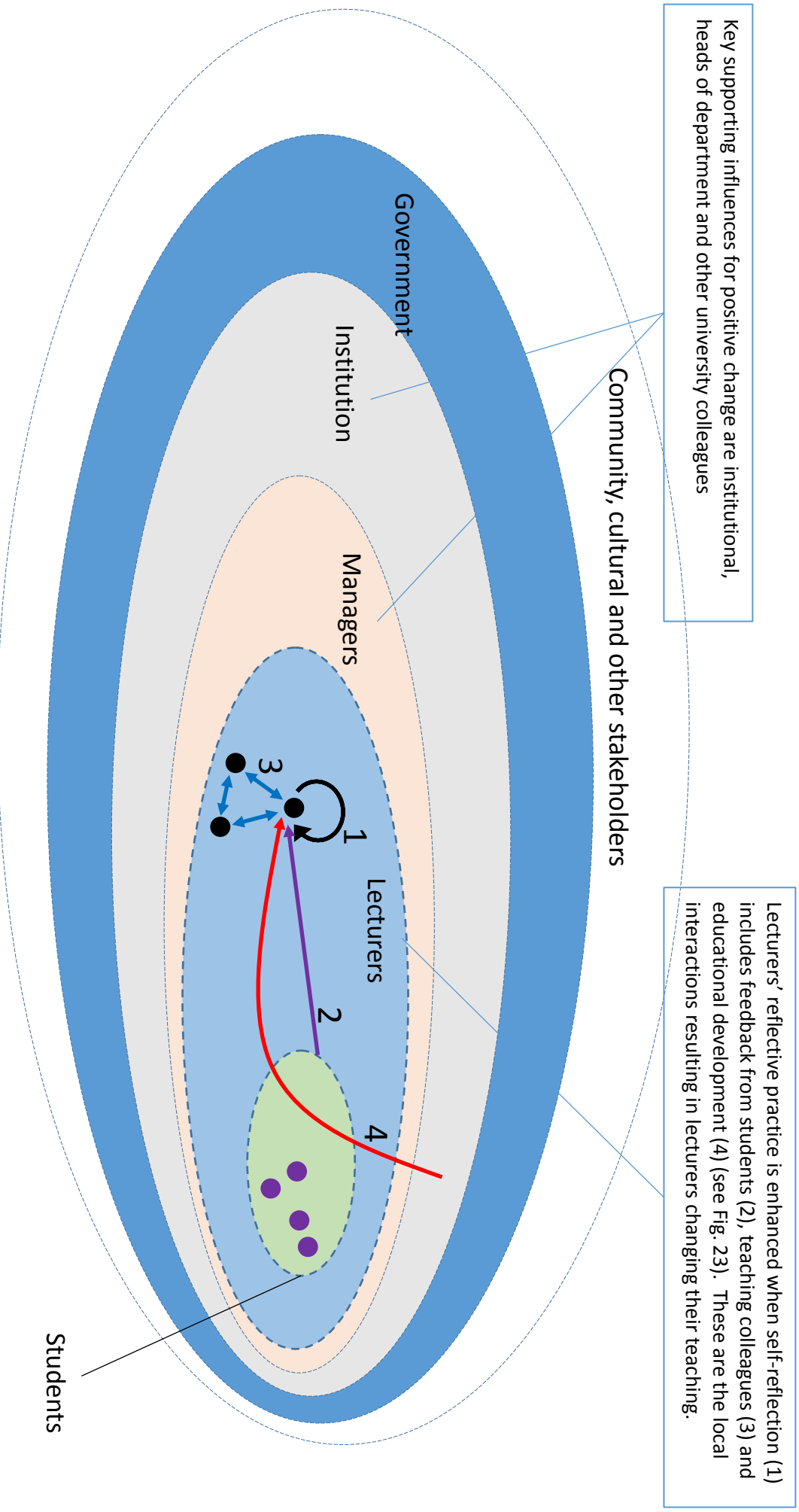
The combined findings also highlighted lecturers' concerns about the lack of priority of teaching relative to research due to the government funding system prioritising research outputs. These concerns accord with those of lecturers in a UK based study where funding also relied heavily on research outputs (Lea & Callaghan, 2008), suggesting that quality teaching and learning is adversely affected by research assessment exercises.

8.5.3 Lecturers' teaching is enhanced when supported by heads of department, institutional recognition and educational development

Lecturers greatly valued support and encouragement, especially for teaching innovation, from their heads of departments. An institutional climate that overtly encouraged and recognised teaching excellence, as well as teaching-based promotional criteria, also enhanced lecturers' teaching. The importance of local activity systems at the departmental level, and 'directed collegiality' where leadership by heads of departments was based on trust and lecturers had control of their environment, has been shown to lead to improvement of teaching and learning (Knight & Trowler, 2000a). The importance of institutional support and visionary leadership in promoting quality teaching were also highlighted by academics in a study in Canada (Scott & Scott, 2016). The multi-causality lens identified concerns of lecturers as largely institutional cultures and bureaucracy but institutions were also identified as key supporting factors. The supporting and constraining nature of institutional leadership found in this study was also shown by Leibowitz et al. (2015). These conflicting perceptions of the institution may reflect the contrasting roles of accountability and enhancement sometimes ascribed to quality in higher education, indicating the need for closer alignment of these roles.

The findings showed that lecturers who had undertaken formal educational development courses considered these to have profoundly influenced their understanding and philosophy of teaching. Lecturers who participated in informal educational development such as group

(peer) mentoring circles also felt these contributed to their development as a teacher, as found elsewhere (Darwin & Palmer, 2009; Kroll, 2016). However, most lecturers had no formal training in teaching and learning. Leibowitz et al. (2015) showed that lecturers' uptake of educational development is context dependent. Although lecturers in this study reported positive influences of educational development this generally referred to understanding teaching and learning rather than making substantial changes to teaching practice. Changes to teaching practice seemed to be related to an individual's interest in teaching innovation rather than participation in educational development. A recent study from the UK on the influence of a reflection based educational development scheme (Higher Education Academy Fellowship scheme) showed participants valued the program for its retrospective reflective practice rather than any application to change teaching practice (van der Sluis et al., 2017). The multiple external influences on lecturers in the complex system of the University are illustrated in Figure 26. Figure 26 shows lecturers and students at the centre of the quality teaching and learning in science process and that these are influenced by managers, for example, heads of departments, and the institution. Other groups, for example, the wider discipline, employers and governments as funders are also included as the findings showed these influenced quality. As cultural groups influence the context, and these and other social factors influence student engagement (Leach, 2016), these are also included in the Figure. The findings suggest lecturers' teaching is influenced by multiple factors but this influence is largely in the cognitive and attitude learning domains of the lecturer with little influence in the physical domain. There was a disconnect between reflective practice and implementation of actions. I discuss this next.



Lecturers' reflective practice is enhanced when self-reflection (1) includes feedback from students (2), teaching colleagues (3) and educational development (4) (see Fig. 23). These are the local interactions resulting in lecturers changing their teaching.

Figure 26. Interactions resulting in lecturers changing their teaching.
 Note: Collegial interactions (3) include team teaching, colleague feedback, interdisciplinary mentoring circles. Lecturer educational development operates across multiple boundaries.

8.6 A conceptual framework for the emergence of quality

8.6.1 Lecturers' reflective practice needs to be transformed into action

I propose that if lecturers' learning about teaching (in informal and formal educational development) can be harnessed, through reflective practice that includes multiple feedback, and enacted through teacher agency, in a supportive institutional environment, it has the potential to promote conditions for the emergence of quality.

The findings from the present study indicate the need for a transformative understanding of quality teaching in science that encompasses generic principles of good teaching, ways of thinking and practising in science, building good social relationships and variable context-dependent factors (Figure 24). However, such an understanding needs to be enacted and is incomplete as a complex system as it lacks details of conditions likely to promote change, and is not open to external influences (Figure 26). Consequently, maximising interactions with new experiences in ways of thinking and practising in science and generic principles of good teaching (openness), building relationships with others, and selecting appropriate context-related factors are insufficient for emergence on their own.

This study showed lecturers' reflection on student feedback was the main driver of changing teaching to enhance quality. Also, lecturers valued both institutional freedom and institutional support for teaching innovation and development. This suggests there is a need for space for innovation without being chaotic, flexibility for lecturers to adapt to suit their cultural, historical and sub-discipline context, and links to processes that enable lecturers to develop as teachers and implement the changes resulting from reflective practice. Many lecturers in this study undertook reflective practice that included multiple strands of feedback of their own volition. However, because of the self-selected nature of the research, it is very likely that these lecturers were especially interested in teaching and learning and likely to reflect on their teaching more than colleagues who give teaching a lower priority. This suggests reflective practice, as a driver of change, is underutilised and a potentially powerful mechanism for change.

In studying the development of reflective practice in American education, Tannebaum et al. (2013) noted the lack of consensus on how to define reflection but surmised the concept in teaching involved making deliberate choices about alternative courses of action. The need for reflection on teaching originated with Dewey's idea of reflective thought that is subsequently tested by observation and further reflection (Dewey, 1910). Dewey also noted the innate tendency to do this during times of disequilibrium and to use it to adapt to new situations. This is similar to the iterative process of adaptation necessary for emergence (Morrison, 2008). Dewey's notion of reflective thinking included having an open mind to others' perspectives, a plan of action and application of that plan. Schon (1995) also welcomed disequilibrium and added dimensions of professional and tacit knowledge with 'reflective conversations' to Dewey's previous problem-solving approach. The concept of reflective practice based on these ideas embracing disequilibrium and openness therefore accord with key concepts in complexity thinking. Schon's reflective practice also included many aspects similar to ways of thinking and practising in the disciplines, including disciplinary backgrounds, history and tacit knowledge. More recently, Farrell (2014) described a five-stage framework for promoting reflective practice in second language teachers that extended the reflective practice concept to include sociocultural dimensions and who the teacher wants to be.

Reflective practice that included student feedback on teaching, was the main driver of science lecturers changing their teaching to enhance student learning in this study. However, lecturers implemented some characteristics associated with quality teaching and learning less often than suggested by the importance ascribed to them, suggesting a barrier preventing change in some science lecturers and that reflective practice alone is not sufficient for action. I suggest this barrier is similar to a 'border crossing' between disciplines. Aikenhead (1996) highlighted the gulf between students' worldviews and the norms, values, beliefs, expectations and conventions of scientists suggesting that this was akin to a border between cultures through which teachers' helped students to transition in science education. I suggest there is a similar border crossing that science lecturers need to negotiate between their discipline and science education. This includes reflective practice, metacognition, and pedagogical content knowledge. In an Australian study (Krause, 2014),

lecturers within the disciplines of history and maths expressed a variety of views on the value of generic skills within the curriculum and the author suggested lecturers are more like 'nomads' than members of a discipline 'tribe' in regards to teaching (Becher & Trowler, 2001). In contrast, there was extensive agreement among the science lecturers in the present study that generic skills were part of quality teaching and learning in undergraduate science. Taken together, the previous research and my findings suggest that some lecturers may act more as individuals than members of a disciplinary group than previously thought but this varies with discipline. The interview findings from the openness lens in this study indicate that science lecturers as a group are potentially very open to new experiences and information (Table 18). Efforts to encourage collaboration within and between disciplines, including specialists in education, for teaching enhancement is therefore especially important to help negotiate crossing the border between education and science.

8.6.2 Reflective practice and action: teacher agency is the missing link

Reflective practice ideas based on the original ideas of Dewey and Schon have been implemented widely in teacher and lecturer education programs in the United States, UK, Australia and elsewhere. However, most research focuses on how to develop critical reflection and reflective practice and there is little on the next step of enabling lecturers to enact the results of their reflective practice; it remains a cognitive exercise. For lecturers to change what they do in practice, they need teacher agency. In contrast to the extensive research on student agency, there has been little research on teacher agency (Priestley, Biesta, & Robinson, 2015).

Teacher agency is a way of understanding how teachers might act. Fu and Clarke (2017) outline five perspectives on agency from the different theoretical standpoints of psychology, sociology, critical theory, historical studies and post-structuralism. These authors link *how* to prepare teachers with *what* teacher agency might mean in the context of helping classroom teachers to become 'agents of change' within schools in Canada. Each of the five perspectives can aid understanding in specific contexts. For example, they suggest teacher educators using First Nation (similar to Maori in New Zealand) concepts to interrupt prevailing discourses could find a post-structural perspective helpful. Although the five

different perspectives on agency focus on different dimensions, they share the notion that reflection and interaction with social structures are important. The various perspectives differ mainly in referring to agency as the capacity of an individual to act or to an emergent property arising from the interaction of the individual with their environment (Priestley et al., 2015).

Building on the concept of agency from sociology, Emirbayer and Mische (1998) highlight the importance of human agency as a temporal, situated process of social engagement with historical and future components. Extending Emirbayer and Mische's temporal/relational concept, Priestley, Biesta and Robinson (2013; Priestley et al., 2015) propose an ecological model of agency comprising three dimensions: the iterative, projective and practical-evaluative dimensions (Figure 27). I propose this model of agency as an emerging property for science lecturers in the complex system of quality teaching and learning science. Next, I will give a brief outline of its possible application in this context, based on the findings in this study.

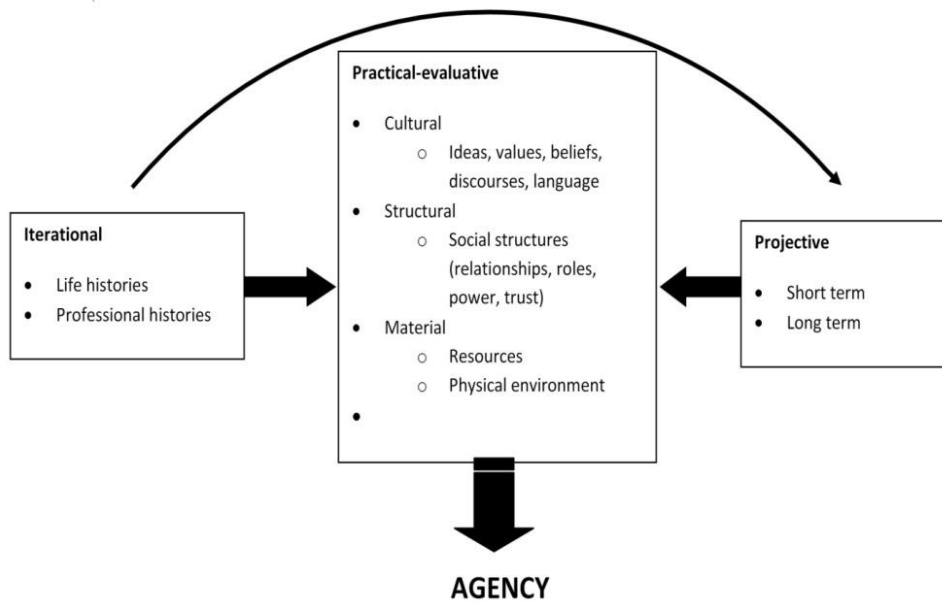


Figure 27. Key dimensions of the ecological model of teacher agency. Key elements of each of the three dimensions—iterational, practical-evaluative and the projective—are shown. Reprinted from ‘Teachers as Agents of Change: Teacher Agency and Emerging Models of Curriculum’, by M. Priestley, G. Biesta & S. Robinson, in M. Priestley & G. Biesta (Eds.), *Reinventing the Curriculum: New Trends in Curriculum Policy and Practice* (p. 190), 2013, London: Bloomsbury. Copyright 2013 by the authors. Reprinted with permission.

The iterational dimension recognises the influence and selection of relevant past experiences based on their education as a teacher and experiences of being a teacher (Priestley et al., 2015). As most university science lecturers are not trained teachers, they have little professional history in teaching. Hence, they have limited professional experiences on which to draw in this dimension. This highlights the need to professionalise lecturers as trained teachers as this background contributes to agency. The projective dimension refers to teachers’ goals or aspirations for their work and may relate to any aspect of their teaching from students’ futures to education policy to ‘playing the game’ to convince management that ‘all is well’ (Priestley et al., 2015). For university science lecturers, goals will vary depending on, for example, perceived institutional priorities or personal views on the purpose of higher education. Increased recognition of the importance of teaching by institutions may help this dimension of agency. Also, encouraging lecturers to

consider their personal philosophy of education, including its purpose, will aid this dimension.

Whereas the iterational and projective dimensions indicate the past and the future temporal aspects of agency, action must be in the present structural and social context (Emirbayer & Mische, 1998). This is referred to as the practical-evaluative dimension of agency (Priestley et al., 2015). Here, teachers consider alternative possibilities in a given context of place and time. In the context of quality teaching and learning in science, university lecturers should be encouraged, for example, to build relationships with teaching and other colleagues and consider cultural values relevant to their specific context. Knowing where to find appropriate discipline-specific teaching resources will be important here and educational development on digital technologies will be essential for this.

As outlined above, teacher agency, as an emergent property from interactions between the lecturer and his/her social environment may enable action, contributing to quality teaching and learning in science. Action is an essential part of reflective practice, however, it is the part that needs courage and encouragement and, for which, teacher agency is required. I suggest that the development of teacher agency is often a key missing link in universities; this is necessary to empower and enable lecturers to transform reflective practice into action. A recent study from the UK on the influence of a reflection based educational development scheme (Higher Education Academy Fellowship scheme) showed participants valued the program for its retrospective and reflective practice rather than any application to change teaching practice (van der Sluis et al., 2017). This supports the notion that reflective practice alone is insufficient for quality enhancement and there is a roadblock between educational development and action. It has also been suggested that universities need to 'foster individual growth of academic staff and support their professional development' (Cheng, 2016, p. 79) and quality should be developed as a virtue of lecturers' professional practice. Cheng (2016) advocates lecturers and students as active participants in the quality process and argues for refining quality evaluation to support enhancement of teaching and learning through trust in lecturers' professionalism. These proposals support

the idea of professionalising the teaching role of university lecturers through clearly linked educational development practices.

Although some lecturers reported using reflective practice that included feedback from multiple sources of their own volition, this study highlighted a need to transform this into action. The findings from this study indicated this requires (1) more reliable collection of student and colleague feedback on teaching, (2) help for lecturers to learn to become reflective practitioners, and (3) help for lecturers to enact the plans resulting from their reflective practice, that is, by building 'teacher agency' (Biesta, Priestley, & Robinson, 2015; Priestley et al., 2015). I propose a conceptual framework that focuses on (2) and (3) to promote conditions for the emergence of quality teaching and learning in science (Figure 28).

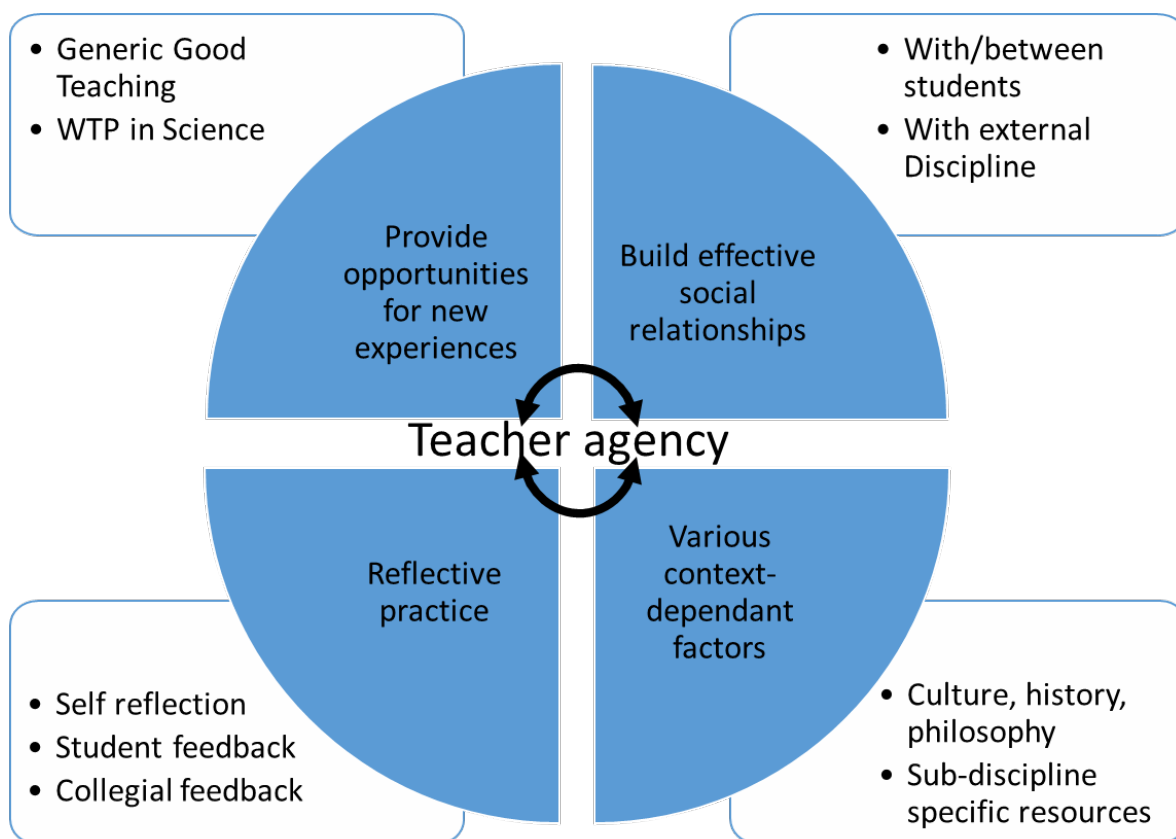


Figure 28. A conceptual framework for the emergence of quality teaching and learning in undergraduate science showing interrelated factors.

Note: Refer to Figure 24 for details of new experiences, social relationships and context-dependant factors. Enhancement is driven by lecturers' reflective practice and his/her teacher agency is brought to fruition by educational development or other support. The support of institutional processes and other interactions shown in Figure 26 are also required for enhancement.

Many proposals for quality teaching have been advocated (Chapter 2) but not for undergraduate science, and not linked to teacher agency. This study highlighted the need to link closely lecturers, quality teaching and learning, and lecturer/teacher agency, for example, through educational development. This is in agreement with Leibowitz et al. (2015) who argued that quality and quality teaching are linked through educational development.

8.7 Chapter summary

The transformative framework for understanding quality teaching and learning in undergraduate science proposed here (Figure 24) provides clarity that enables the proposals of conditions to enable its emergence (Figure 28). It is not a definitive blueprint or model for quality teaching in science as the results of this study are context bound and not generalizable outside science. If not a blueprint, then what does this contribute to an understanding of the complex issues around quality teaching in undergraduate science? It offers science lecturers an understanding of the possibilities for quality teaching in science; a starting point to develop their personal quality philosophy underpinning education. It raises awareness that quality teaching is influenced by generic principles drawn from the general teaching research literature and scientific ways of thinking and practising. It also highlights the need to build effective relationships and for flexible, context-specific factors including cultural, historical and sub-discipline specific factors.

Based on this transformative understanding, I proposed a conceptual framework for quality as an emergent property from the interrelationship of the above factors and lecturers' reflective practice on these, transformed into action by lecturers' teacher agency through, for example, educational development—informal and formal—within an institutional framework that visibly supports quality teaching.

The frameworks also open for debate whether quality teaching in undergraduate science should be narrowly based in traditional scientific epistemology and methods or whether it could also address problems that consider wider socio-political questions such as good citizenship (Kolstoe, 2000) and socio-cultural questions about the recognition of indigenous knowledge (Baquete, Grayson, & Mutimucuo, 2016). This question requires further research. Above all, the conceptual frameworks confirm that quality science teaching at undergraduate level is complex, that individual lecturers need a starting point for thinking about how they should act (Davis & Sumara, 2006) and open for debate future directions.

CHAPTER 9: RECOMMENDATIONS AND CONCLUSION

In this chapter, I make recommendations based on the findings from the research, supported by the literature and my experience. I start with summaries of the contribution this research makes to knowledge and limitations of the research. Then I present my recommendations for science lecturers, educational development and institutions. Finally, I make some suggestions for further research and present the overall conclusion.

9.1 A brief recap of the study

My research explored what university science lecturers' consider quality teaching and learning in undergraduate science, and the influences on these lecturers' quality teaching. The aim was to help understand why traditional teaching prevails in science in many universities and to develop a view of quality teaching and learning in undergraduate science from within the discipline. This would then form the basis for recommendations to enhance quality. To do this, I used sensitising concepts (lenses) based on complexity thinking and wickedity as an overarching framework to view quality as an emergent property. I used a multistage mixed methods research design consisting of an exploratory sequential design Delphi study in Phase 1 followed by an explanatory sequential design with a survey and interviews in Phase 2 to address the research question. The dissensus Delphi study in Phase 1 provided a range of statements describing characteristics associated with quality teaching and learning in undergraduate science that formed the basis of the survey and interviews in Phase 2.

The combined findings showed responses with varying extents of consensus that indicated the need for a transformative framework for understanding quality teaching and learning in undergraduate science based on generic principles of good teaching embedded in scientific ways of thinking and practising. The study identified the need for lecturers to foster social relationships, include values reflecting the New Zealand cultural and historical context, as well as relevant sub-discipline factors. This understanding of quality teaching and learning in science enabled it to be viewed as a complex system, rather than a wicked problem, making problem resolution possible through the proposal of conditions likely to promote its emergence.

The main driver of teaching change was lecturers' reflective practice with student feedback as a key contributor to this. Lecturers perceived colleagues, heads of departments and educational development as supporting influences. However, they perceived institutions as both supporting and hindering quality teaching. The study identified a gap between lecturers' reflective practice and action.

The complexity ideas of openness, inclusiveness and interrelatedness permeated throughout the study and culminated in (1) the proposed transformational framework for understanding quality teaching and learning in undergraduate science (Figure 24), and (2) a conceptual framework outlining conditions to promote its emergence (Figure 28).

9.2 Addressing the research questions

In this section, I briefly address the research sub-questions that were developed to help inform the main research question concerning what university science lecturers in New Zealand consider to be quality teaching and learning in undergraduate science.

Sub-questions 1 and 2 are considered together: What do national award-winning tertiary teachers, and a larger sample of university science lecturers, consider to be quality teaching and learning in undergraduate science? The study revealed views with varying extents of consensus on a range of quality characteristics. These are encompassed in the proposed transformational framework for understanding quality teaching and learning in undergraduate science and include characteristics associated with generic good teaching embedded in scientific ways of thinking, building effective social relationships and various context-dependent factors (Figure 24). Areas identified to be of emerging importance included social relationships and context-dependent cultural values. Providing a framework for understanding enabled quality teaching and learning in undergraduate science to be viewed as a complex, rather than a wicked, problem.

Sub-question 3 asked: What are the main influences on lecturers' quality teaching? The findings showed that student feedback and reflective practice were the main drivers of teaching change. Supporting influences on quality teaching included colleagues, Heads of Department, institutional recognition and reward, mentors and educational development,

especially early on in lecturers' academic careers. Lecturers also considered institutions as a negative influence on quality teaching as teaching was perceived to have a lower priority than research.

Sub questions 4 and 5 are considered together: What implications do these findings have for university science lecturer educational development programmes, and what other proposals for action arise from this? The findings indicate that student feedback and reflective practice are powerful mechanisms for changing teaching practice and suggest that these are underutilised by university science lecturers. I suggest that an important 'missing link' is teacher agency, enabling lecturers to move from reflection to action. I propose a conceptual framework outlining conditions to promote the emergence of quality, based on quality teaching and learning in science as a complex system that features teacher agency as one of the key interactions (Figure 28).

9.3 Contribution to knowledge

My research has made an original contribution to research in quality teaching and learning in science in several ways. It provides data on lecturers' views on quality teaching and learning in undergraduate science on which there has been little research, as well as their views on the concept of quality in higher education. Exploring these views and the influences on lecturers' teaching will help determine appropriate strategies for the educational development of university lecturers in New Zealand for whom there are currently no formal requirements for teaching although they have a significant influence on student learning. Specifically:

- The research provides a transformational framework for understanding quality teaching and learning in undergraduate science characterised by ways of thinking and practising in the discipline that includes generic principles of good teaching practice, building social relationships and context-dependent cultural and sub-discipline factors.
- The research identifies the need for science lecturers to build social relationships, recognise cultural factors related to New Zealand and encourage active citizenship as part of quality teaching and learning in undergraduate science.

- The research identifies lecturer reflective practice that includes student feedback as the main driver of teaching change for quality enhancement.
- The research highlights a potential gap between lecturer reflective practice and action, suggests this is due to a lack of teacher agency, and proposes an emergent conceptual framework in which this is an important link enabling action.
- Quality teaching and learning in undergraduate science is a complex system. Quality is an emergent property and proposals for resolution are possible; without these it remains a wicked problem.

In terms of methodology, the research also contributes the following:

- Complexity thinking and wickedity can be used as a conceptual framework to study a whole higher educational system using a sensitising lenses approach.

9.4 Limitations of the research

- *Small size of the Delphi panel:* the Delphi panel consisted of seven members, with six completing the three rounds (five for some questions). A larger panel may have provided a different or broader range of characteristics associated with quality teaching and learning in undergraduate science.
- *Low survey response rate:* the response rate in the survey was low (c. 13%) and may not have been representative of the science lecturer population as a whole. The format of the survey on SurveyMonkey with pull-down menus for the two options (importance and frequency) deterred some potential participants. The use of an alternative format, for example, qualtrics, may have increased the response rate.
- *Biased survey responses:* survey responses may have been biased towards lecturers particularly interested in teaching and learning. Most lecturers (82%) had 5 or more years teaching experience so do not represent new or novice teachers whose views may be different. There were very few lecturers who identified as Māori, Pasifika or Asian ethnicity. There was a relative over-representation of responses from lecturers from life sciences, and under-representation of lecturers from the physical sciences (physics and chemistry) in the survey. Also, there were relatively few respondents

from four universities and one university did not participate. These will have influenced the results.

- *Personal preferences and interpretations of the researcher.* My background and views will have influenced how I interpreted the data. I have tried to let others' voices be heard but accept that the interpretation will inevitably be influenced by my views.
- *Time constraints.* The interviews were limited to one hour. This meant that it was not possible to clarify or pursue questions in as much depth as I would have liked in some cases. In retrospect, seven questions was too many.
- *Lecturers' reported views.* This research explored lecturers' views of quality teaching and learning in undergraduate science and only considered what they reported. It did not investigate what they do in practice. Also, views of students or other groups were not considered.

9.5 Recommendations

I make the recommendations below based on the findings from this study, 15 years working as a scientist and 15 years as a university lecturer in science.

For quality to emerge, it is necessary to meet many conditions as it is the interaction of these that is important. As the teacher contributes to many of the conditions associated with teaching and learning, I recommend that university science lecturers become professional (trained) teachers, in the same way that they are professional (trained) science researchers. This will help build lecturers' professional histories and contribute to the iterational dimension of teacher's agency (Figure 27). In addition to professionalising the teaching role of lecturers, it is important to provide conditions to enable lecturers to implement changes to their teaching. For this, educational development needs to include the development of reflective practice and teacher agency. Institutional support is vital for removing bureaucratic barriers to change and providing an environment that visibly supports quality teaching and learning. Institutional support in terms of physical resources and social structures (including trust) contribute to the practical-evaluative dimension of agency (Priestley et al., 2015). Institutional trust in lecturers' professionalism is vital (Biesta,

2004). Without this, innovation that helps disrupt equilibrium, one of the conditions that promotes emergence, is stifled. Professionalising lecturers as teachers would provide a strong basis for institutional trust. Finally, building the projective dimension of teacher agency requires lecturers and institutions to perceive teaching quality as an equal priority to research.

The proposed recommendations have the potential to help provide the conditions necessary for the emergence of quality. None is sufficient on its own; it is the interaction of conditions for a given context that is important. My recommendations are summarised below. These need to be considered together with the appropriate context-dependent teaching and learning factors (Figure 24).

9.5.1 Specific recommendations for science lecturers

1. *Consider the characteristics associated with quality teaching and learning in undergraduate science (Table 23) and the proposed transformational framework (Figure 24):* these offer a starting point for lecturers to think about teaching and learning in their context. In particular, consider maximising opportunities for interactions with new experiences and social interactions provided for students.
2. *Reflective practice:* enhance reflective practice as a step to reclaiming responsibility for quality in teaching and learning in undergraduate science and engage in educational development or other support to aid implementation of changes.
3. *Actively participate in quality:* become an active participant in quality teaching and learning by providing constructive feedback on teaching to colleagues through peer review. Share experiences of teaching, for example, through mentoring circles, institutional celebrations of quality teaching.
4. *Consider the goals for teaching:* consider goals for students, lecturers and the purpose of higher education

9.5.2 Specific recommendations for science lecturer educational development

1. *Reflective practice*: this should form the basis of educational development for science lecturers as this is the main driver of changing teaching for quality enhancement. Critical reflection is a skill that can, and should, be learnt as a step towards professionalising lecturers as teachers.
2. *Develop lecturers' teacher agency*: provide teacher training, support and encouragement to help science lecturers build confidence to implement changes arising from their reflective practice, based on the ecological model of teacher agency (Priestley et al., 2015).

9.5.3 Recommendations for institutions

1. *Professionalise science lecturers as teachers and researchers*: Require all new science lecturers without a formal teaching qualification to complete a recognised tertiary education qualification within a defined time period of their appointment, during which time their teaching duties should be reduced. Professionalisation is key to restoring institutional trust so lecturers can reclaim responsibility for quality (Biesta, 2004; Cheng, 2016).
2. *Support continuing professional development of science lecturers*: support and encourage ongoing educational development programmes for science teaching staff, including mentoring circles to encourage interactions between lecturers within and between disciplines, as suggested by interviewees in this study.
3. *Raise the profile of teaching and learning quality*: raise the profile of teaching and learning quality in institutions, for example, with an annual 'Teaching week' where colleagues share innovations and experiences, as suggested by interviewees in this study.
4. *Include teaching quality in promotional criteria*: recognise teaching quality evidence for promotion as suggested by interviewees in this study, for example, evidence of reflection on student feedback, actions taken as a result, followed by further feedback and reflection.

5. *Reduce bureaucracy associated with making changes to teaching*: recognise the professionalism of lecturers and restore trust by minimising bureaucratic hurdles to making changes to courses, as suggested by science lecturers in this study (Biesta, 2004).

9.6 Suggestions for further research

- A follow-up study of teaching observations to see what lecturers do in the classroom and how these relate to their views of quality teaching and learning.
- An in-depth study on lecturers' reflective practice and teacher agency, specifically the ability of lecturers to implement planned changes from reflective practice. This could be a research study in collaboration with educational developers.
- A follow-up study of students' views of quality teaching and learning to see how these relate to lecturers' views.

9.7 Conclusion

My research explored New Zealand university science lecturers' views of quality teaching and learning in undergraduate science and the influences on their teaching. The combination of complexity thinking as an overarching framework to view quality as an emergent property, with a multistage mixed methods research design, enabled a pragmatic and inclusive approach to analysing and interpreting lecturers' views.

The findings revealed the need for a transformational framework for understanding quality teaching and learning in undergraduate science that encompassed generic principles of good teaching embedded in scientific ways of thinking and practising with the need to build social relationships and consider context-related cultural, historical and sub-discipline factors.

The evidence showed the main driver of teaching change was lecturers' reflective practice with student feedback as a key contributor to this. Lecturers perceived colleagues, heads of departments and educational development as supporting influences. However, they perceived institutions as both supportive and hindering quality teaching. The study identified a gap between lecturers' reflective practice and action and I suggested the

important missing link is teacher agency. I proposed a conceptual framework for the emergence of quality, based on quality teaching and learning in undergraduate science as a complex system, that features teacher agency as one of the key interactions.

9.8 Personal reflection

9.8.1 Developing a researcher identity (Changing my worldview)

I hadn't envisaged that this research would rock the foundations of who I am. The requirement in educational research to specify the researcher's ontological and epistemological beliefs (enquiry logics, paradigm, worldview, philosophical position) was the most disruptive aspect of this thesis for me. Whilst this aspect of the research has felt the most personal and made me the most uncomfortable, it has also been the beginning of a transformation. In the same way that someone needs to be outside their culture to see the shortcomings of that culture (as a British immigrant, I am now acutely aware of how inherently 'British' I am), this research has made me aware of the inherent scientist in me. I have needed to step outside my 'inner scientist' to explore my worldview and who I am. Does becoming an educational researcher mean that I am losing my scientist self?

So I opted for Dewey's pragmatism as a temporary lifeboat, but where am I heading? My head has been turned by Patti Lather and Elizabeth (Betty) Adams St. Pierre and others talking about 'the posts' in educational research. I would like to investigate Deleuze and Guattari's concepts of becoming 'other' (as I don't like binaries), and rhizomes with many entry and exit points, or lines of flight, and bodies without organs. I think complexity thinking fits well with many of these ideas. But these will have to wait for another time. I look forward to the ontological turn of a post-qualitative inquiry with new language and methods of inquiry, called for by Betty Adams St. Pierre (St. Pierre, 2017).

9.8.2 The future: the tale of two PhDs

Where do I go from here? At the moment, I think my inner scientist and 'becoming educational researcher' are in the process of reconciling. My long-standing curiosity to find explanations in the biological world of science, and more recent interest in seeking to understand in the social world of science lecturers, have emphasised the transformation I made to student-centred learning prior to this study, as part of a PGCertTT. Exploring other science lecturers' views in this PhD highlighted my change in focus from a perceived scientific need for evidence that often looks for causal explanations for actions, to

generating meaning based on lecturers' views. I think of these as retrospective and prospective inquiry. I think this change in focus enhanced my understanding of teaching and learning science by remembering how I learnt (and learn) science, and how I help research students learn in the lab environment. I think this 'remembering' (part of metacognition) is at the heart of reconciling the scientist and educational researcher in me and may provide a way forward for me, and other scientists, to embrace the cultures of science and science education.

My main personal finding on this journey has been that there is a huge difference between studying for a PhD in science and a PhD in education. One major difference is the extent of justification for the research methods chosen (methodology); this hardly features in PhDs in science. I think there is a misconception by many scientists that educational research lacks rigour, whereas this PhD has shown me that there is more rigour than in much scientific research and PhDs. It would be interesting to explore disciplinary differences in PhD theses and the influences of the various PhD processes on researcher identities in different disciplines. Such exploration may potentially aid interdisciplinary research and collaboration and help break down the barriers that exist between disciplines.

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Appendices

Appendix A: Ethics-related documents Note: permission/consent forms are not shown as these are of a standard nature.

Ethics approval letter



MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

26 February 2014

Dr Zoe Jordens
IFS
PN461

Dear Zoe

Re: HEC: Southern B Application – 14/01
An exploration of university science lecturers' views on quality teaching and learning

Thank you for your letter dated 26 February 2014.

On behalf of the Massey University Human Ethics Committee: Southern B I am pleased to advise you that the ethics of your application are now approved. Approval is for three years. If this project has not been completed within three years from the date of this letter, reapproval must be requested.

If the nature, content, location, procedures or personnel of your approved application change, please advise the Secretary of the Committee.

Yours sincerely

Prof John O'Neill, Acting Chair
Massey University Human Ethics Committee: Southern B

cc A/Prof Nick Zepke
Institute of Education
PN500

Dr Linda Leach
Institute of Education
PN500

Dr Peter Rawlins
Institute of Education
PN500

A/Prof Sally Hansen, Director
Institute of Education
PN500

Mrs Roseanne MacGillivray
Institute of Education
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Prof Simon Hall, HoI
IFS
PN461

Study Information sheet for the Delphi panel



An exploration of University science lecturers' views on quality teaching and learning

INFORMATION SHEET for 'expert' panel

I am Zoe Jordens, a PhD student in education at Massey University. I am exploring the concept of quality teaching and learning in science at universities. The project is supervised by A/Prof. Nick Zepke, Dr Peter Rawlins and Dr Linda Leach.

What is the whole project about?

This project aims to explore the views on quality teaching and learning held by science lecturers and 'experts' – national award-winning teachers recognised for their tertiary teaching excellence. The findings from each group will be compared for their differences and similarities and used as the basis to construct a framework for use by, and with, university science lecturers to influence teaching practice and enhance student learning in science.

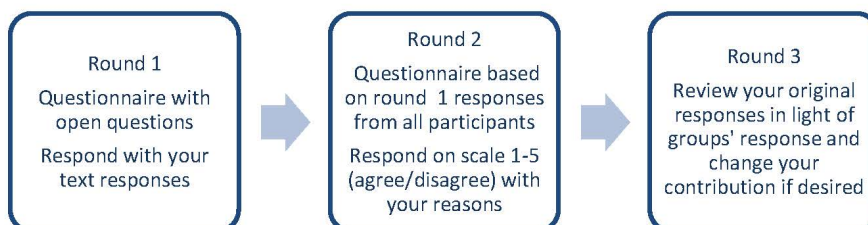
As an Ako Aotearoa tertiary teaching excellence award winner in science you are invited to participate as one of the 'experts' on a small panel (up to 16 members) in a Delphi study designed to collect a breadth of views on quality teaching and learning in science at university.

Who is involved in the 'Expert' Panel?

- Sixteen tertiary teaching excellence award winners from science disciplines with a 'wet' laboratory component (biology, chemistry, physics and similar) have been identified from the Ako Aotearoa website and will be invited to participate by personal email, with the exception of Zoe Jordens.
- Participation is entirely voluntary.
- As this group is small, some of you will be known to each other and/or me.

What is involved?

- You will be involved in answering questionnaires, conducted in three 'rounds' as follows:



- It is anticipated that you will contribute approximately 3 hours to the project in total.

Data Management

- Raw data will be analysed by the researcher and stored on a password-protected computer and in a locked filing cabinet. The data will be retained for five years after the project has finished and then destroyed.
- The consent form will be stored separately from the data, in secure storage as above.
- A summary of the project findings will be sent to you by email at the conclusion of the project. Publications arising from the project will be sent to you on request.
- All views are valued in this study. All reasonable efforts will be taken to ensure that the origin (identity) of questionnaire responses remains confidential (known only to the researcher) however it may be possible for some responses to be attributed to specific individuals as the 'expert' panel will be a small group and some of you will know each other. It is therefore important that this project operates within a 'culture of confidentiality' in which only the researcher reports any results.
- In other Delphi studies members have perceived some value in having their names subsequently published as part of the 'expert' panel (Steinert, 2009). Your views on this possibility will be sought at the consenting stage of this study and your name will be used only with your permission.

Steinert, M. (2009). A dissensus based online Delphi approach: An explorative research tool. *Technological Forecasting and Social Change*, 76(3), 291-300. doi: <http://dx.doi.org/10.1016/j.techfore.2008.10.006>

Your Rights and Responsibilities

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- Decline to answer any particular question.
- Withdraw from the study at any time.
- Ask any questions about the study at any time during participation.
- Provide information on the understanding that your name will not be used unless you give permission to the researcher.
- Be given access to a summary of the project findings when it is concluded.

Project Contacts

If you have any questions about the project please do not hesitate to contact:

Dr Zoe Jordens
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Massey University
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Palmerston North 4442
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Phone: 06 356 9099 extn 84746

Dr Linda Leach
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P.Rawlins@massey.ac.nz
Phone: 06 356 9099 extn 84403

This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern B, Application 14/01. If you have any concerns about the conduct of the research, please contact Prof John O'Neill, Acting Chair, Massey University Human Ethics Committee: Southern B, telephone 06 350 5799 x 81090, email humanethicsouthb@massey.ac.nz.

Study information sheet for University senior managers



An exploration of University science lecturers' views on quality teaching and learning

INFORMATION SHEET FOR PVCs & HEADS OF DEPARTMENTS etc

I am Zoe Jordens, a PhD student in education at Massey University. I am exploring the concept of quality teaching and learning in the natural sciences at universities. The project is supervised by A/Prof. Nick Zepke, Dr Peter Rawlins and Dr Linda Leach.

What is the project about?

This project aims to explore the views on quality teaching and learning in the natural sciences held by lecturers. The findings from this research will be used to construct a quality teaching and learning framework for university lecturers to inform teaching practice and enhance student learning in the natural sciences.

Who is involved?

- All lecturers in New Zealand universities teaching in disciplines within the natural sciences with 'hands-on' practical experiences, for example, experiment- or computer-based activities, or field-trips will be invited to participate in the project
- A central contact person (administrator) in each relevant university department will be asked to circulate an email to lecturers in their department inviting them to participate and containing a SurveyMonkey web link to the questionnaire
- A small number (about 20 in total) of the questionnaire participants will be selected for interviews
- Participation is entirely voluntary.

What is involved?

- Lecturer participants will be asked to complete a questionnaire on their views on quality teaching and learning in the natural sciences
- It is anticipated that completing the questionnaire will take no longer than 30 minutes
- It is anticipated that interviews will last no longer than 60 minutes.

Data Management

- Raw data will be analysed by the researcher and stored on a password-protected computer and in a locked filing cabinet. The data will be retained for five years after the project has finished and then destroyed.
- Consent forms will be stored separately from the data, in secure storage as above.
- A summary of the project findings will be sent to participants by email at the conclusion of the project. Publications arising from the project will be sent to participants on request.

Project Contacts

If you have any questions about the project please do not hesitate to contact:

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This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern B, Application 14/01. If you have any concerns about the conduct of this research, please contact Prof Julie Boddy, Chair, Massey University Human Ethics Committee: Southern B, telephone 06 350 5799 x 86055, email humanethicsouthb@massey.ac.nz

Study information sheet for lecturer survey



***An exploration of University science lecturers' views on
quality teaching and learning***

INFORMATION SHEET FOR LECTURERS (survey)

I am Zoe Jordens, a PhD student in education at Massey University. I am exploring the concept of quality teaching and learning in the natural sciences at universities. The project is supervised by A/Prof. Nick Zepke, Dr Peter Rawlins and Dr Linda Leach.

What is the project about?

This project aims to explore the views on quality teaching and learning in the natural sciences held by lecturers. The findings from this research will be used to construct a quality teaching and learning framework for university lecturers to inform teaching practice and enhance student learning in the natural sciences.

Who is involved?

- All lecturers in New Zealand universities teaching in disciplines within the natural sciences with 'hands-on' practical experiences, for example, experiment- or computer-based activities, or field-trips will be invited to participate in the project
- A central contact person (administrator) in each relevant university department will circulate emails to science lecturers at their university inviting you to participate and containing a SurveyMonkey web link to the questionnaire
- Participation is entirely voluntary

What is involved?

- You will be asked to complete a questionnaire on your views on quality teaching and learning in the natural sciences
- It is anticipated that this will take no longer than 30 minutes to complete

Data Management

- Completion of the questionnaire will constitute consent to participate
- Raw data will be analysed by the researcher and stored on a password-protected computer and in a locked filing cabinet. The data will be retained for five years after the project has finished and then destroyed.

Your Rights and Responsibilities

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- Decline to answer any particular question
- Access a summary of the project findings; details will be circulated to you by email by the central contact person (administrator) in your University department at the conclusion of the project.

Project Contacts

If you have any questions about the project please do not hesitate to contact:

Dr Zoe Jordens
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Study information sheet for interviewees



An exploration of University science lecturers' views on quality teaching and learning

INFORMATION SHEET FOR SCIENCE LECTURERS (interviewees)

I am Zoe Jordens, a PhD student in education at Massey University. I am exploring the concept of quality teaching and learning in science at universities. The project is supervised by A/Prof. Nick Zepke, Dr Peter Rawlins and Dr Linda Leach.

What is the project about?

This project aims to explore the views on quality teaching and learning in the natural sciences held by lecturers. The findings from this research will be used to construct a quality teaching and learning framework for university lecturers to inform teaching practice and enhance student learning in the natural sciences.

Who is involved?

- All lecturers in New Zealand universities teaching in disciplines within the natural sciences with 'hands-on' practical experiences, for example, experiment- or computer-based activities, or field-trips will be invited to participate in the project
- Lecturers selected for interview will have previously completed the questionnaire on views on quality teaching and learning in science and have at least 2 years teaching experience
- Participation is entirely voluntary

What is involved?

- It is anticipated that interviews will take no longer than 60 minutes to complete

Data Management

- Raw data will be analysed by the researcher and stored on a password-protected computer and in a locked filing cabinet. The data will be retained for five years after the project has finished and then destroyed.
- Consent forms will be stored separately from the data, in secure storage as above.
- A summary of the project findings will be sent to you by email at the conclusion of the project. Publications arising from the project will be sent to you on request.

Your Rights and Responsibilities

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- decline to answer any particular question;
- withdraw from the study at any time;
- ask any questions about the study at any time during participation;
- provide information on the understanding that your name will not be used unless you give permission to the researcher;
- be given access to a summary of the project findings when it is concluded.

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Transcriber’s confidentiality agreement

Attachment 13

Zoe Jordens



An exploration of University science lecturers’ views on quality teaching and learning

TRANSCRIBER’S CONFIDENTIALITY AGREEMENT

I (Full Name - printed) agree to transcribe the recordings provided to me.

I agree to keep confidential all the information provided to me.

I will not make any copies of the transcripts or keep any record of them, other than those required for the project.

Signature: **Date:**

Appendix B: Surveys

Questions for Delphi Round 1 (also in the main text)

1. From your experience, how do you think students learn science?
2. What do you consider to be quality teaching in science at university? Please describe two or three examples that come to mind.
3. How well, and in what ways, do you think that current methods of teaching science prepare students for the wider world of using science/working in the science field?
 - 4a. What have been the main positive influences on your development as a university/tertiary teacher? Please describe the impact of these influences on your teaching.
 - 4b. What have been the main negative influences on your development as a university/tertiary teacher? Please describe the impact of these influences on your teaching.

Questionnaire for Delphi Round 2 (from Survey Monkey)

Quality teaching in science Delphi Round 2

Responses to question 1: From your experience, how do you think students learn science?

Your responses to Round 1 suggested that students learn science through variety, making connections, doing science, understanding the scientific process (including scientific evidence & problem-solving) and motivation. The following statements have been extracted from the responses of the expert panel to represent the range of views of the group.

Please indicate the extent to which you agree or disagree with each statement, and add any comments you have about any of the statements. Your comments will be used to modify the statements for Round 3. The final statements will be used to inform a large-scale national survey of university science lecturers.

1. Students LEARN science by...

	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
A. a variety of different methods, reflecting differences in their educational background, culture and personality.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
B. making connections to their prior knowledge, knowledge in other subjects, and life outside the University.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
C. doing prescribed laboratory experiments that are guaranteed to work.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
D. understanding the scientific process and how to formulate hypotheses, design experiments to test these, interpret experimental data and revise hypotheses.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
E. completing exercises, assignments and solving problems.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
F. seeing and hearing the evidence of science from authorities ranging from parents to lecturers etc. and from other forms of authority such as television and Wikipedia.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
G. being motivated and wanting to learn. This may be an innate desire or one that is gained during the course of teaching by, for example, seeing relevance to their future.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. Please provide comments on any of the statements above (please indicate letter of question to which comment/s refers)

Quality teaching in science Delphi Round 2

Responses to question 2: What is quality teaching in science at university?

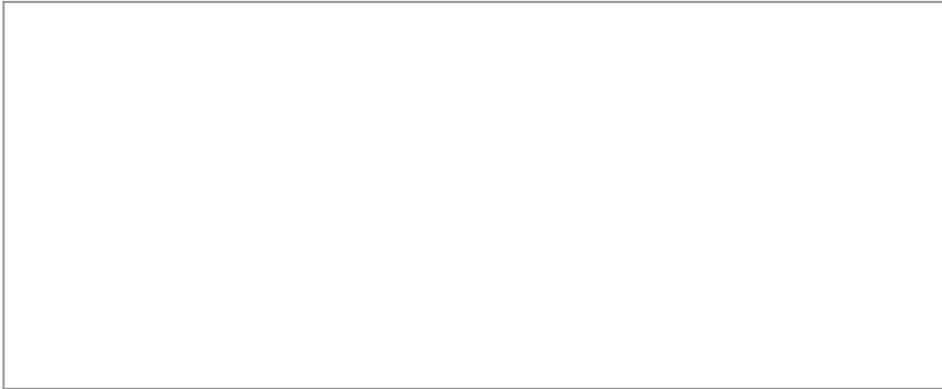
Your responses to Round 1 question 2 suggested that quality teaching in science means authentic, connecting, critical thinking, reflective, interactive teaching, New Zealand context. The following statements have been extracted from the responses of the expert panel to represent the range of views of the group.

Please indicate the extent to which you agree or disagree with each statement, and add any comments you have about any of the statements. Your comments will be used to modify the statements for Round 3. The final statements will be used to inform a large-scale national survey of university science lecturers.

3. Quality teaching in science at university means...

	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
A. providing authentic scientific experiences by connecting students with current research.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
B. providing opportunities for students to explore and discover.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
C. helping students to learn to become independent in the laboratory by asking students to design their own experiment, then carry it out themselves and critique the strengths and weaknesses of their experimental design, as well as the results and conclusions.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
D. engaging with Maori and Pacific Island students and helping these students to make connections to their own lives.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
E. providing opportunities for students to be more critical of information than they may have been previously.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
F. providing opportunities for students to reflect on their learning.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
G. being interactive and breaking down the barriers between lecturer and student to create a relaxed atmosphere in which the student can learn.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
H. interacting with students, including provision of pastoral care.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I. using lectures with demonstrations and activities at intervals to re-focus the class.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
J. using inquiry based learning (or guided inquiry).	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
K. encouraging students to discuss their own experiences of the topic.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
L. providing opportunities for students to apply knowledge from one area to another.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
M. students learning about the history of New Zealand and the impacts of humans on the environment, and being encouraged to consider current issues at a philosophical level.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

4. Please provide comments on any of the statements above (please indicate letter of question to which comment/s refers)



Quality teaching in science Delphi Round 2

Responses to question 3: How well does current teaching prepare students for working in science?

Your responses to Round 1 question 3 suggested that current methods of teaching science prepare students WELL for the wider world of using science/working in the science field because of authentic tasks, and relationships with industry & stakeholders

Responses also suggested that current teaching prepare students POORLY for the wider world of using science/working in the science field because content is over-emphasised, there is little authentic science, and specific teaching skills are required. The following statements have been extracted from the responses of the expert panel to represent the range of views of the group.

Please indicate the extent to which you agree or disagree with each statement, and add any comments you have about any of the statements. Your comments will be used to modify the statements for Round 3. The final statements will be used to inform a large-scale national survey of university science lecturers.

5. Current methods of teaching science prepare students WELL for the wider world of using science/working in the science field because...

	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
A. Authentic tasks are being used, for example, internships, 'scenario' assessments and independent project work where experiments may not work and original thought is required to overcome obstacles	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
B. Ongoing mutually-supportive relationships between universities/institutions and stakeholder industries ensure that programme content and delivery is developed so it is relevant to students, up to date and responsive to industry needs.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

6. Current methods of teaching science prepare students POORLY for the wider world of using science/working in the science field because...

	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
A. Content is over-emphasised and the development of lasting mastery of the discipline is questionable	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
B. There is too little authentic science, for example, independent project work, internships, 'scenario' assessments	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
C. Students often work in silence...The labs may deliver some useful skill sets, but they do nothing to capture the excitement of real science.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
D. A 'traditional' lecture ... does little to challenge enquiring minds, or to improve the creative and critical thinking skills.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
E. Inquiry-based learning strategies require sophisticated teaching and skilful teachers and are often the province of expert teachers which beginning academics are usually not.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

7. Please provide comments on any of the statements above (please indicate letter of question to which comment/s refers)

8. Please add any other comments you have.

Quality teaching in science Delphi Round 2

Thank you for completing Round 2 of this Delphi study.

The results of this round will be collated and analysed and returned to you for your final comments in Round 3 of the study.

Questionnaire for Delphi Round 3 (from Survey Monkey)

Quality teaching in science Round 3 and draft national survey

Survey Introduction

This survey is part of an exploration of quality teaching in science at universities in New Zealand. Science lecturers at all universities are being invited to participate and contribute their views. The aim is to use the findings to improve undergraduate science education at universities.

In this section, please tell us about yourself and your teaching experiences.

1. At which New Zealand university are you based?

Other (please specify)

2. What is your main science discipline?

Other (please specify)

3. Does your subject (discipline) use 'wet' laboratory classes? These are laboratory classes where students conduct hands-on science experiments (rather than all computer-based or written exercises)?

Yes

No

4. Do you currently teach undergraduate students?

Yes

No and I have never taught them

No but I have in the past

5. How long have you been teaching at Universities (any university, anywhere)?

<2 years

2-5 years

5-10 years

10-15 years

>15 years

6. What preparation did you have for your university teaching?

7. Do you have any formal teaching qualifications?

- No
- Yes (please specify)

8. Have you received any teaching awards?

- No
- yes (please specify)

Quality teaching in science Round 3 and draft national survey

Quality teaching in undergraduate science at university

The following statements represent views on quality teaching in undergraduate science. Please rate *how important* you think each of these is in quality teaching in science.

I am also very interested in what you do in your teaching practice, *whatever your views*.

Please indicate *how often* you are able to implement each item in your teaching practice. I understand there may be some differences between your view of how important an activity is and how often you are able to use that activity in your practice.

Please select one option from each drop down menu

9. Quality teaching in science at university means...

	Importance to me	I am able to do this in my teaching
a. using a variety of teaching approaches, rather than a 'one size fits all', because of the diverse characteristics and backgrounds of students.	<input type="text"/>	<input type="text"/>
b. making connections to students' prior knowledge, other subject knowledge, and life outside the university.	<input type="text"/>	<input type="text"/>
c. providing authentic scientific experiences by connecting students with current research.	<input type="text"/>	<input type="text"/>
d. using prescribed laboratory experiments that are guaranteed to work for entry level students to learn techniques.	<input type="text"/>	<input type="text"/>
e. helping students to learn the scientific process (method) including how to formulate hypotheses, design experiments to test these, interpret experimental data and revise hypotheses.	<input type="text"/>	<input type="text"/>
f. providing opportunities for students to explore and discover to capture the excitement of real science, for example, in laboratory-based projects or field trips.	<input type="text"/>	<input type="text"/>
g. helping students to learn to become independent in the laboratory by providing opportunities where experiments may not work and original thought is required to overcome obstacles.	<input type="text"/>	<input type="text"/>
h. engaging with Maori and Pasifika students and helping these students to make connections to their own lives.	<input type="text"/>	<input type="text"/>
i. using approaches to promote students' active learning, for example, exercises, assignments, problem-solving.	<input type="text"/>	<input type="text"/>
j. providing opportunities for students to learn to evaluate evidence from various sources ranging from parents to lecturers etc. and from other forms of 'authority' such as television.	<input type="text"/>	<input type="text"/>
k. motivating students by highlighting the relevance to their future, including their careers.	<input type="text"/>	<input type="text"/>
l. motivating students by highlighting why and how things work.	<input type="text"/>	<input type="text"/>
m. providing opportunities for students to be more critical of information than they may have been previously.	<input type="text"/>	<input type="text"/>

	Importance to me	I am able to do this in my teaching
n. providing opportunities for students to reflect on their learning.	<input type="text"/>	<input type="text"/>
o. creating a social environment for learning, for example by being interactive and breaking down the barriers between lecturer and student to create a relaxed atmosphere.	<input type="text"/>	<input type="text"/>
p. interacting with students, including provision of pastoral care.	<input type="text"/>	<input type="text"/>
q. using lectures that present ideas well and challenge, stimulate, motivate and inspire students.	<input type="text"/>	<input type="text"/>
r. using inquiry based learning (or guided inquiry).	<input type="text"/>	<input type="text"/>
s. encouraging students to discuss their own experiences of the topic.	<input type="text"/>	<input type="text"/>
t. providing opportunities for students to apply knowledge from one area to another.	<input type="text"/>	<input type="text"/>
u. encouraging students to learn about the history of New Zealand and the impacts of humans on the environment.	<input type="text"/>	<input type="text"/>
v. encouraging students to consider current issues at a philosophical level.	<input type="text"/>	<input type="text"/>
w. using authentic tasks, for example, internships, 'scenario' assessments.	<input type="text"/>	<input type="text"/>
x. having ongoing mutually-supportive relationships between universities and stakeholder industries to ensure that programme content and delivery is developed so it is relevant to students, up to date and responsive to industry needs.	<input type="text"/>	<input type="text"/>
y. focusing on understanding concepts and not over-emphasising content.	<input type="text"/>	<input type="text"/>
z. using alternative methods to lectures that can take time and confidence to plan and implement.	<input type="text"/>	<input type="text"/>

Quality teaching in science Round 3 and draft national survey**Impact of teaching on student learning**

10. Please complete the following statement in the box below:

Students learn science by... (NOT FOR EXPERT PANEL AS COMPLETED PREVIOUSLY):

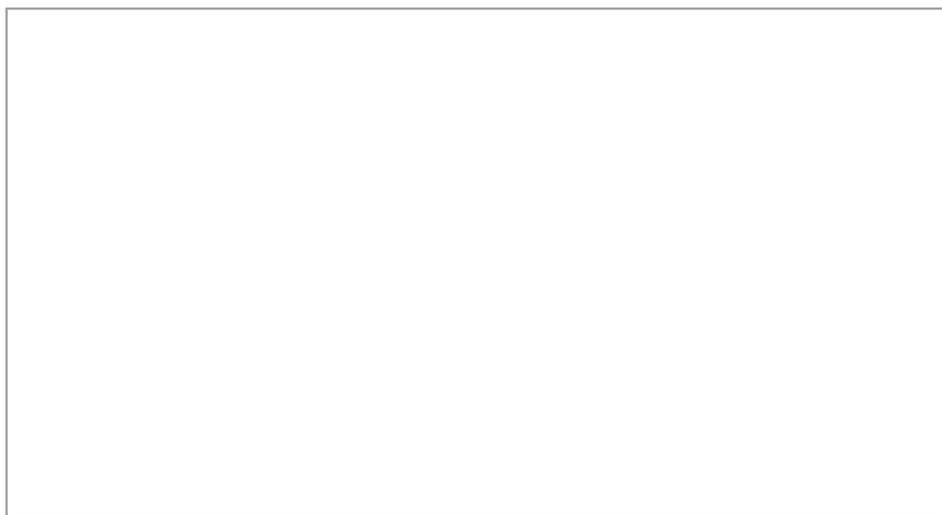
11. What impact do you think your teaching has on student learning? (NOT FOR EXPERT PANEL AS COMPLETED PREVIOUSLY)

12. Would you be willing to participate further in this research by being interviewed?

- No
- Yes - please provide a contact email address below for this purpose

Quality teaching in science Round 3 and draft national survey**Expert Panel Comments Please**

13. Please suggest any improvements to this draft survey for science lecturers at universities in New Zealand.



Thank you for your participation and comments throughout the Delphi process.

The results of this round will be used to finalise the survey on quality teaching in undergraduate science for science lecturers at universities in New Zealand planned for 2015.

Lecturer Survey (from Survey Monkey)

Quality teaching in the natural sciences lecturer survey

Survey Introduction

This survey is part of an exploration of quality teaching in the natural sciences at universities in New Zealand. Lecturers at all universities are being invited to participate and contribute their views. The aim is to use the findings to improve undergraduate education in the natural sciences at universities.

In this section, please tell us about yourself and your teaching experiences.

1. At which New Zealand university are you based?

Other (please specify)

2. What is your main discipline?

Other (please specify)

3. Does your subject (discipline) use 'hands-on' practical experiences, for example, experiment- or computer-based activities, or field-trips?

Yes

No

4. Do you currently teach undergraduate students?

Yes

No and I have never taught them

No but I have in the past

Quality teaching in the natural sciences lecturer survey

5. Please indicate any ethnic group to which you belong (select all that apply)

- New Zealand European
- Māori
- Pacific Peoples (please specify below)
- Asian (please specify below)
- Other (please specify below)
- I prefer not to answer this question

Please specify here

Quality teaching in the natural sciences lecturer survey**Teaching preparation and awards****In this section, please tell us more about your teaching experience**

6. How long have you been teaching at Universities (any university, anywhere)?

- <2 years
- 2-5 years
- 5-10 years
- 10-15 years
- >15 years

7. What preparation did you have for your university teaching?

8. Do you have any formal teaching qualifications?

- No
- Yes (please specify)

9. Have you received any teaching awards?

- No
- yes (please specify)

Quality teaching in the natural sciences lecturer survey

Quality teaching at undergraduate level at university

The following statements represent views on quality teaching at the undergraduate level. Please rate *how important* you think each of these is in quality teaching in the natural sciences.

I am also very interested in what you do in your teaching practice, *whatever your views*.

Please indicate *how often* you are able to implement each item in your teaching practice. I understand there may be some differences between your view of how important an activity is and how often you are able to use that activity in your practice.

Please select one option from each drop down menu

10. Quality teaching in the natural sciences at university means...

	Importance to me	I am able to do this in my teaching
a. using a variety of teaching approaches, rather than a 'one size fits all', because of the diverse characteristics and backgrounds of students.	<input type="text"/>	<input type="text"/>
b. making connections to students' prior knowledge, other subject knowledge, and life outside the university.	<input type="text"/>	<input type="text"/>
c. providing authentic scientific experiences by connecting students with current research.	<input type="text"/>	<input type="text"/>
d. using prescribed laboratory experiments that are guaranteed to work for entry level students to learn techniques.	<input type="text"/>	<input type="text"/>
e. helping students to learn the scientific process (method) including how to formulate hypotheses, design experiments to test these, interpret experimental data and revise hypotheses.	<input type="text"/>	<input type="text"/>
f. providing opportunities for students to explore and discover to capture the excitement of real science, for example, in laboratory-based projects or field trips.	<input type="text"/>	<input type="text"/>
g. helping students to learn to become independent in the laboratory by providing opportunities where experiments may not work and original thought is required to overcome obstacles.	<input type="text"/>	<input type="text"/>
h. engaging with Maori and Pasifika students and helping these students to make connections to their own lives.	<input type="text"/>	<input type="text"/>
i. using approaches to promote students' active learning, for example, exercises, assignments, problem-solving.	<input type="text"/>	<input type="text"/>
j. providing opportunities for students to learn to evaluate evidence from various sources ranging from parents to lecturers etc. and from other forms of 'authority' such as television.	<input type="text"/>	<input type="text"/>
k. motivating students by highlighting the relevance to their future, including their careers.	<input type="text"/>	<input type="text"/>
l. motivating students by highlighting why and how things work.	<input type="text"/>	<input type="text"/>
m. providing opportunities for students to be more critical of information than they may have been previously.	<input type="text"/>	<input type="text"/>

	Importance to me	I am able to do this in my teaching
n. providing opportunities for students to reflect on their learning.	<input type="text"/>	<input type="text"/>
o. creating a social environment for learning, for example by being interactive and breaking down the barriers between lecturer and student to create a relaxed atmosphere.	<input type="text"/>	<input type="text"/>
p. interacting with students, including provision of pastoral care.	<input type="text"/>	<input type="text"/>
q. using lectures that present ideas well and challenge, stimulate, motivate and inspire students.	<input type="text"/>	<input type="text"/>
r. using inquiry based learning (or guided inquiry).	<input type="text"/>	<input type="text"/>
s. encouraging students to discuss their own experiences of the topic.	<input type="text"/>	<input type="text"/>
t. providing opportunities for students to apply knowledge from one area to another.	<input type="text"/>	<input type="text"/>
u. encouraging students to learn about the history of New Zealand and the impacts of humans on the environment.	<input type="text"/>	<input type="text"/>
v. encouraging students to consider current issues at a philosophical level.	<input type="text"/>	<input type="text"/>
w. using authentic tasks, for example, internships, 'scenario' assessments.	<input type="text"/>	<input type="text"/>
x. having ongoing mutually-supportive relationships between universities and stakeholder industries to ensure that programme content and delivery is developed so it is relevant to students, up to date and responsive to industry needs.	<input type="text"/>	<input type="text"/>
y. focusing on understanding concepts and not over-emphasising content.	<input type="text"/>	<input type="text"/>
z. using alternative methods to lectures that can take time and confidence to plan and implement.	<input type="text"/>	<input type="text"/>
11. Please use the box below to add anything else that you consider important for quality teaching in the natural sciences at undergraduate level at university in New Zealand		

Quality teaching in the natural sciences lecturer survey**Impact of teaching on student learning**

12. Please complete the following statement in the box below:

In the natural sciences, students learn by...

13. In the box below, please describe the impact you think your teaching has on student learning.

14. Would you be willing to participate further in this research by being interviewed?

No

Yes - please provide a contact email address below for this purpose

Quality teaching in the natural sciences lecturer survey

Thank You

Thank you for your participation in this research.

Questions for semi-structured lecturer interviews Ethics approval letter

Question number	Interview questions
1	From your experience, how do you think students learn science?
2	What do you consider to be quality teaching in science at university? Please describe two or three examples that come to mind.
3	How well, and in what ways, do you think that current methods of teaching science prepare students for the wider world of using science/working in the science field?
4	How has your teaching changed over time and why? And who has been influential?
5	How has your university encouraged, constrained or supported your teaching practice?
6	To what extent does having knowledge of different worldviews, for example, cultural and religious worldviews, contribute to quality teaching in science?
7	If you could ask for anything to help with the quality of your teaching, what would it be?

Appendix C: Supplementary Figures for Chapter 5

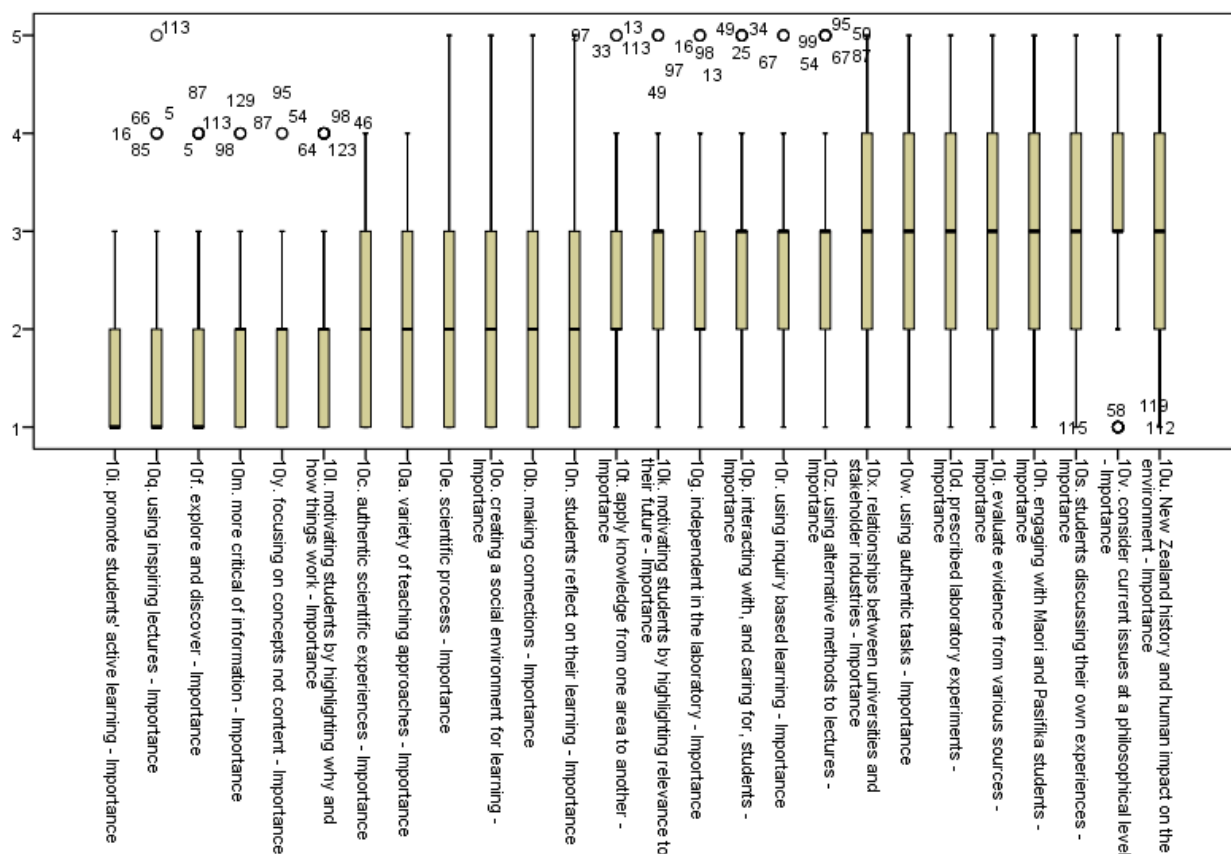


Figure 29. Box and whisker plot showing distribution of responses to the relative importance of characteristics associated with quality teaching.

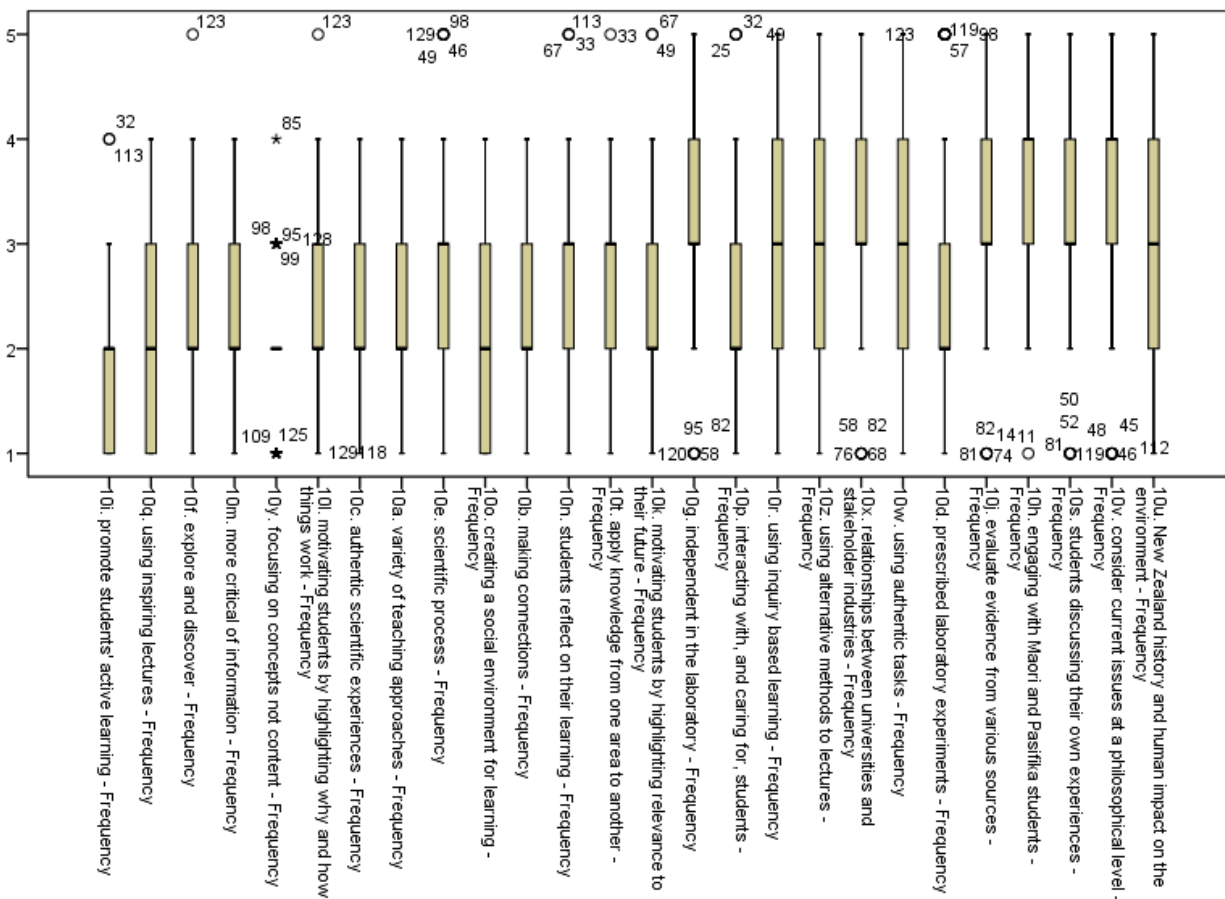


Figure 30. Box and whisker plot showing distribution of responses to the frequency of implementation of characteristics associated with quality teaching.

Factor Analysis graphs comparing mean factor scores for Factors 1, 2 & 3 for grouped disciplines

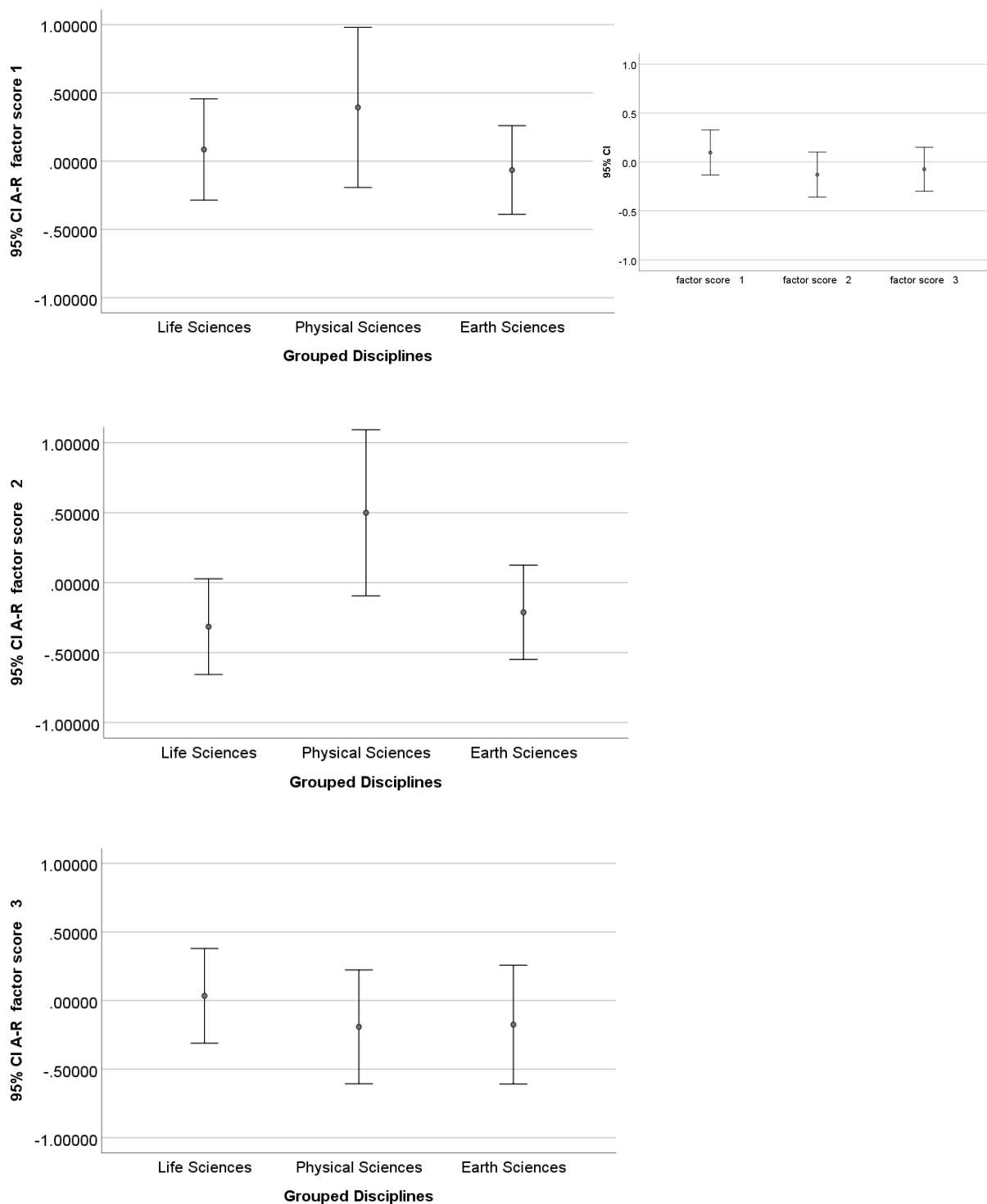


Figure 31. Means and 95% confidence intervals for Factors 1, 2 and 3 for grouped disciplines. Factor 1 (student-centred teaching) (top left figure), Factor 2 (culture and context) (middle figure), and Factor 3 (scientific ways of thinking) (lower figure) for each of the grouped disciplines indicated. Note: Factor scores represented as Anderson-Rubin variables for comparison (sample means = 0, means for dataset with grouped disciplines shown on small figure, top right)

Factor Analysis graphs comparing mean factor scores for Factors 1, 2 & 3 for universities

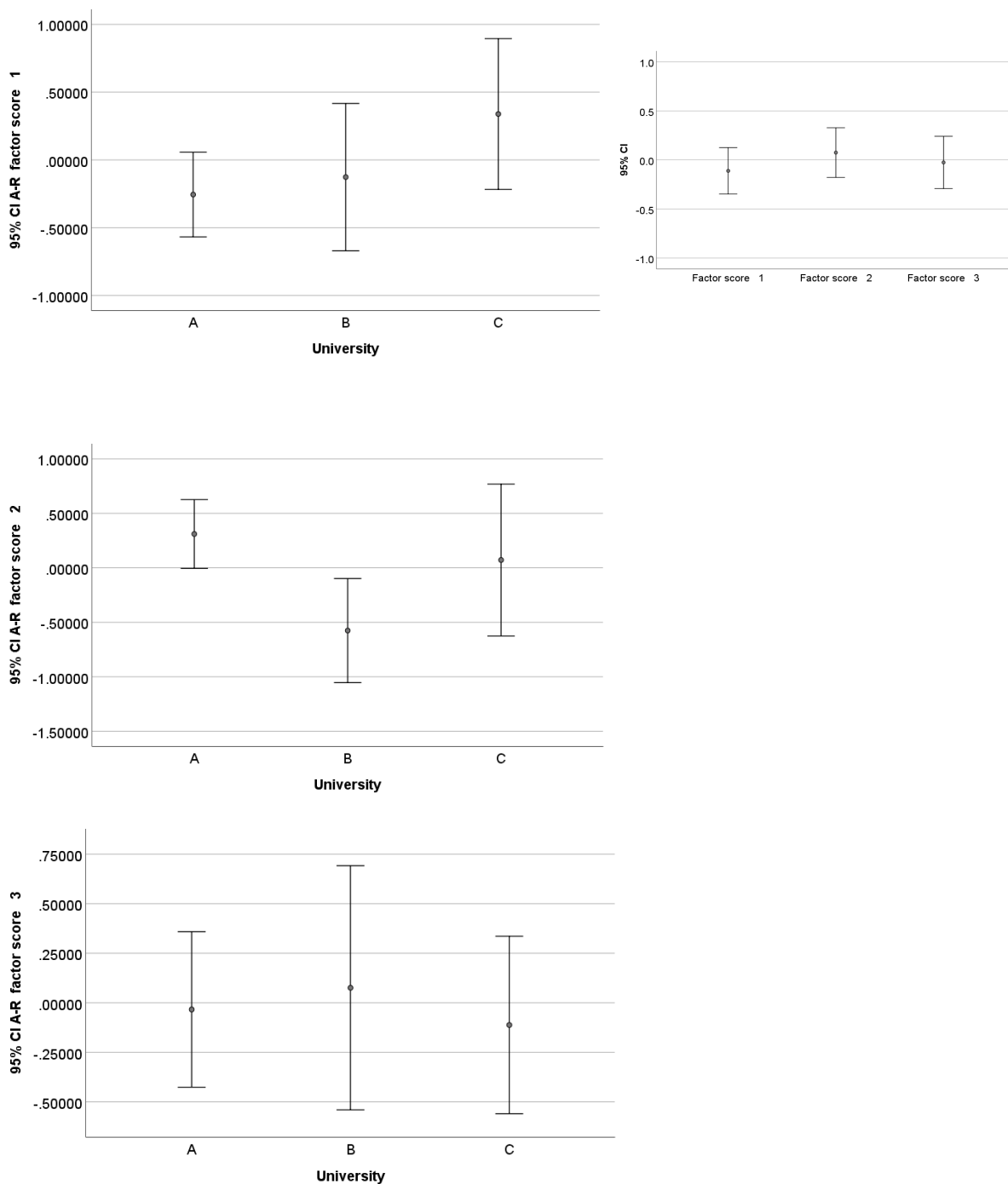


Figure 32. Means and 95% confidence intervals for Factors 1,2 and 3 for universities A, B and C. Factor 1 (student-centred teaching) (top left figure), Factor 2 (culture and context) (middle figure), and Factor 3 (scientific ways of thinking) (lower figure) for each of the universities indicated Note: Factor scores represented as Anderson-Rubin variables for comparison (sample means = 0, means for dataset with universities A, B & C shown on small figure, top right).

Appendix D: Descriptive statistics for Factors identified in exploratory factor analysis

Descriptive statistics used to compare Factor 1 for each of the combined disciplines used in the one way ANOVA and post hoc Tukey tests

DISCIPLINES	N	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min.	Max.	Between-Component Variance
					Lower Bound	Upper Bound			
Life Sci.	37	0.085	1.112	0.183	-0.285	0.456	-1.946	2.302	
Physical Sci.	14	0.394	1.015	0.271	-0.193	0.980	-1.135	2.287	
Earth Sci.	23	-0.065	0.751	0.157	-0.390	0.260	-1.624	1.547	
Total	74	0.097	0.994	0.116	-0.133	0.327	-1.946	2.302	
Model	Fixed Effects		0.995	0.116	-0.134	0.328			
	Random Effects			0.116	-0.401	0.595			-0.003

Descriptive statistics used to compare Factor 2 for each of the combined disciplines used in the one way ANOVA and post hoc Tukey tests

DISCIPLINES	N	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min.	Max.	Between-Component Variance
					Lower Bound	Upper Bound			
Life Sci.	37	-0.315	1.025	0.169	-0.656	0.027	-1.880	1.953	
Physical Sci.	14	0.499	1.027	0.275	-0.094	1.093	-1.870	1.872	
Earth Sci.	23	-0.212	0.780	0.163	-0.549	0.125	-1.802	1.096	
Total	74	-0.129	0.992	0.115	-0.359	0.101	-1.880	1.953	
Model	Fixed Effects		0.956	0.111	-0.350	0.093			
	Random Effects			0.235	-1.140	0.883			0.112

Descriptive statistics used to compare Factor 3 for each of the combined disciplines used in the one way ANOVA and post hoc Tukey tests

DISCIPLINES	N	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min.	Max.	Between-Component Variance
					Lower Bound	Upper Bound			
Life Sci.	37	0.034	1.035	0.170	-0.310	0.379	-2.264	3.260	
Physical Sci.	14	-0.192	0.719	0.192	-0.607	0.223	-1.506	0.812	
Earth Sci.	23	-0.176	1.002	0.209	-0.609	0.258	-1.725	2.731	
Total	74	-0.074	0.967	0.112	-0.298	0.150	-2.264	3.260	
Model	Fixed Effects		0.974	0.113	-0.299	0.152			
	Random Effects			0.113	-0.561	0.414			-0.023

Warning: Between-component variance is negative. It was replaced by 0.0 in computing this random effects measure.

Descriptive statistics used to compare Factor 1 for each of the universities used in the one way ANOVA and post hoc Tukey tests

UNI- VERSITY	N	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min.	Max.	Between- Component Variance
					Lower Bound	Upper Bound			
A	36	-0.256	0.923	0.154	-0.568	0.057	-1.878	2.302	
B	13	-0.127	0.900	0.250	-0.671	0.417	-1.624	1.237	
C	12	0.339	0.876	0.253	-0.218	0.895	-0.662	1.755	
Total	61	-0.111	0.924	0.118	-0.348	0.125	-1.878	2.302	
Model	Fixed Effects		0.910	0.116	-0.344	0.122			
	Random Effects			0.181	-0.889	0.666			0.044

Descriptive statistics used to compare Factor 2 for each of the universities used in the one way ANOVA and post hoc Tukey tests

UNI- VERSITY	N	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min.	Max.	Between- Component Variance
					Lower Bound	Upper Bound			
A	36	0.311	0.932	0.155	-0.005	0.626	-1.880	1.953	
B	13	-0.576	0.791	0.219	-1.054	-0.098	-1.802	0.621	
C	12	0.072	1.097	0.317	-0.625	0.769	-1.864	1.706	
Total	61	0.075	0.989	0.127	-0.179	0.328	-1.880	1.953	
Model	Fixed Effects		0.939	0.120	-0.166	0.315			
	Random Effects			0.294	-1.189	1.338			0.166

Descriptive statistics used to compare Factor 3 for each of the universities used in the one way ANOVA and post hoc Tukey tests universities

UNI- VERSITY	N	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min.	Max.	Between- Component Variance
					Lower Bound	Upper Bound			
A	36	-0.034	1.160	0.193	-0.426	0.359	-2.264	3.260	
B	13	0.076	1.019	0.283	-0.540	0.692	-1.363	2.731	
C	12	-0.112	0.705	0.203	-0.560	0.336	-1.195	0.812	
Total	61	-0.026	1.043	0.133	-0.293	0.241	-2.264	3.260	
Model			1.058	0.136	-0.297	0.246			
				0.136	-0.609	0.557			-0.058

Warning: Between-component variance is negative. It was replaced by 0.0 in computing this random effects measure.

Appendix E: One Way ANOVA Tables

Factor 1 for the combined disciplines

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.84	2	0.92	0.929	0.4
Within Groups	70.312	71	0.99		
Total	72.152	73			

Factor 2 for the combined disciplines (also in the main text)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6.959	2	3.48	3.805	0.027
Within Groups	64.927	71	0.914		
Total	71.887	73			

Robust Tests of Equality of Means

A-R factor score 2 for analysis 27

	Statistic ^a	df1	df2	Sig.
Welch	3.279	2	33.681	0.05
Brown-Forsythe	3.866	2	45.009	0.028

^a Asymptotically F distributed.

	(I) Grouped Disciplines	(J) Grouped Disciplines	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Life Sciences	Physical Sciences	-.814*	0.300	0.023	-1.532	-0.096
		Earth Sciences	-0.103	0.254	0.914	-0.710	0.505
	Physical Sciences	Life Sciences	.814*	0.300	0.023	0.096	1.532
		Earth Sciences	0.711	0.324	0.079	-0.065	1.487
	Earth Sciences	Life Sciences	0.103	0.254	0.914	-0.505	0.710
		Physical Sciences	-0.711	0.324	0.079	-1.487	0.065

* The mean difference is significant at the 0.05 level.

Factor 3 for the combined disciplines

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.867	2	0.434	0.457	0.635
Within Groups	67.354	71	0.949		
Total	68.221	73			

Factor 1 for universities A, B and C

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.184	2	1.592	1.924	0.155
Within Groups	47.995	58	0.827		
Total	51.178	60			

Factor 2 for universities A, B and C (also in the main text)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6.959	2	3.48	3.805	0.027
Within Groups	64.927	71	0.914		
Total	71.887	73			

	Statistic ^a	df1	df2	Sig.
Welch	5.297	2	23.191	0.013
Brown-Forsythe	4.134	2	30.289	0.026

^a Asymptotically F distributed.

Multiple comparisons

	(I) NewUni	(J) NewUni	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey							
HSD	1	2	.887*	0.304	0.014	0.156	1.618
		3	0.239	0.313	0.727	-0.514	0.992
	2	1	-.887*	0.304	0.014	-1.618	-0.156
		3	-0.648	0.376	0.205	-1.552	0.257
	3	1	-0.239	0.313	0.727	-0.992	0.514
		2	0.648	0.376	0.205	-0.257	1.552

* The mean difference is significant at the 0.05 level.

Factor 3 for universities A, B and C

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.225	2	0.113	0.1	0.905
Within Groups	64.984	58	1.12		
Total	65.209	60			

Appendix F: Supplementary graph for chapter 7

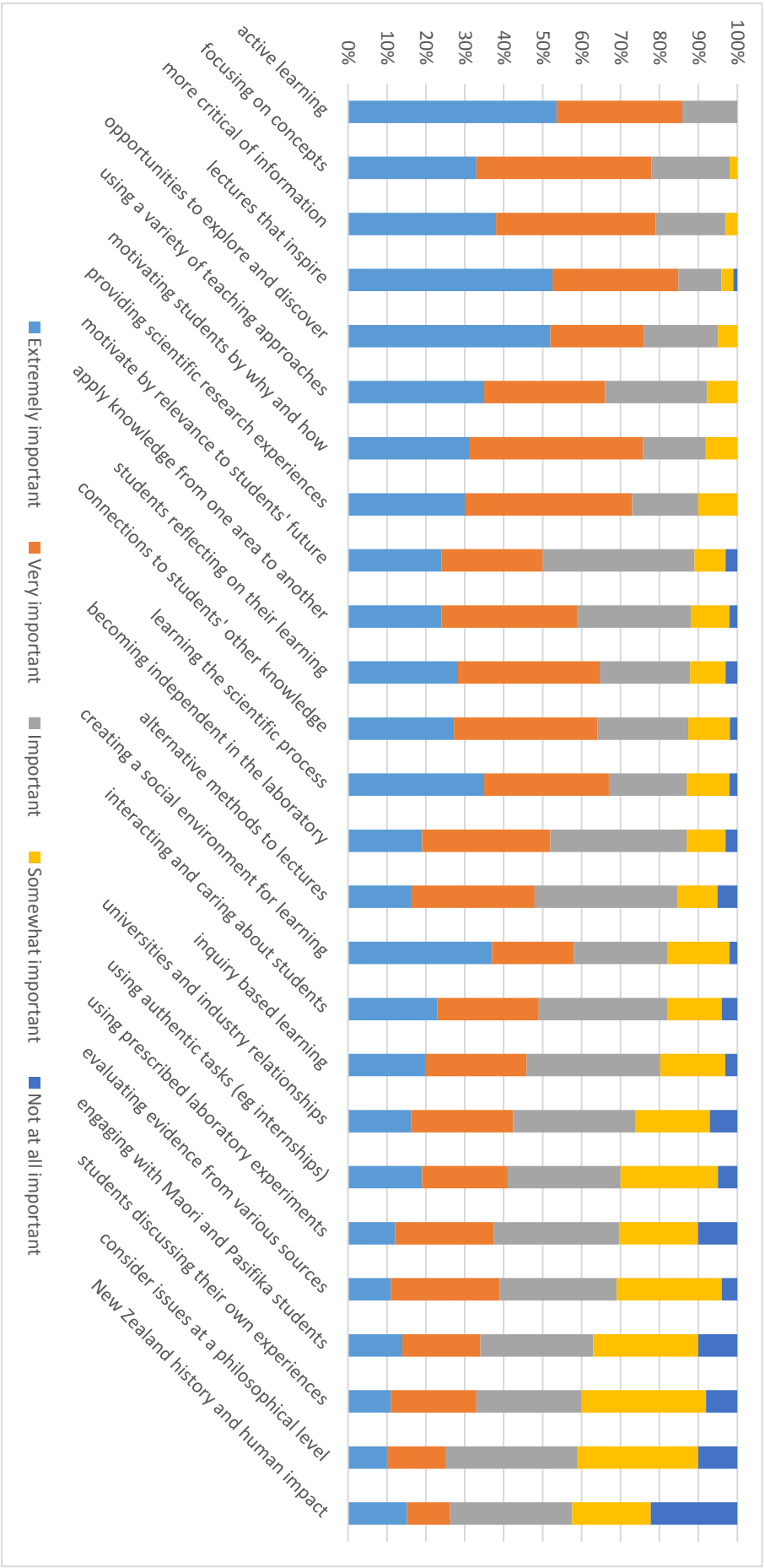


Figure 33. The relative frequency of uncombined relative importance responses from Phase 1 and Phase 2 to the lecturer survey on quality teaching in science. The importance ascribed to the survey statements by lecturers is indicated by the colours on the figure. The items are sorted in order of importance with the most important on the left. Note: This shows the data before responses were amalgamated into combined 'Important' and combined 'Unimportant' categories (Figure 23).

