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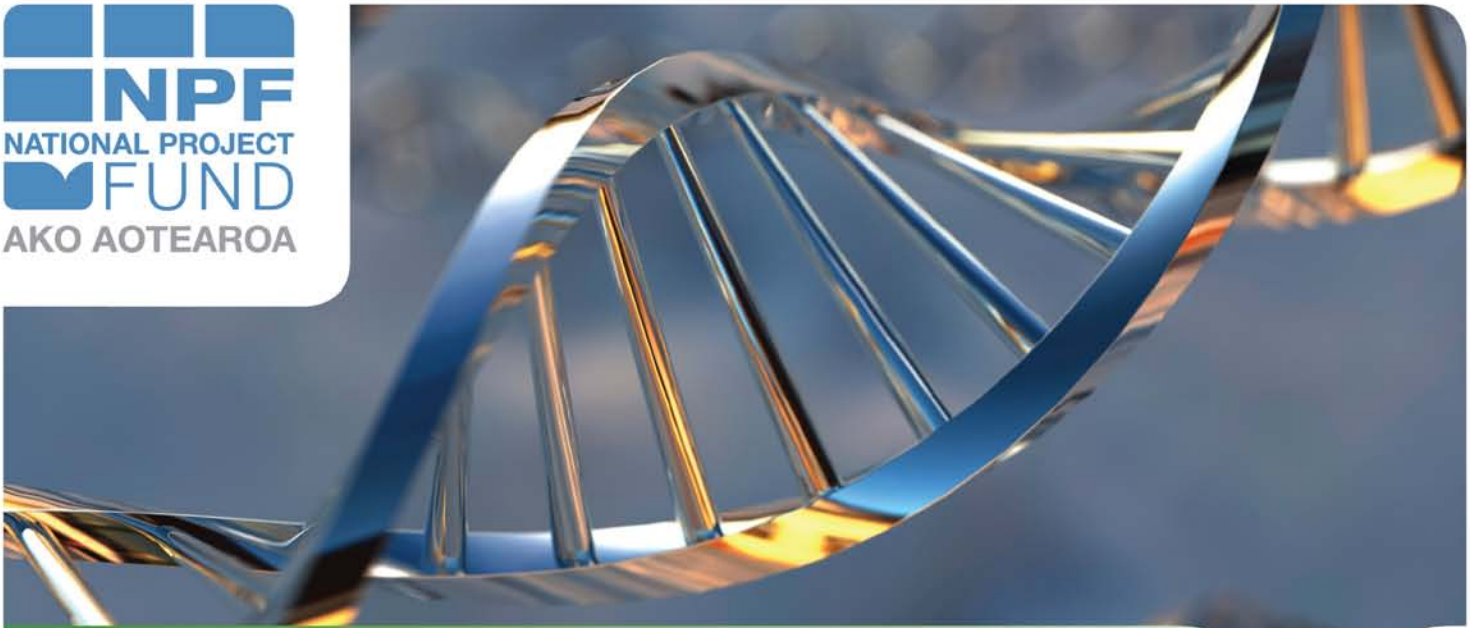

Full Report

Engaging Learners Effectively in Science, Technology and Engineering

THE PATHWAY FROM SECONDARY TO UNIVERSITY EDUCATION

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NATIONAL CENTRE FOR TERTIARY TEACHING EXCELLENCE

Massey University

Full Report

Engaging Learners Effectively in Science, Technology and Engineering: The pathway from secondary to university education

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Contents

Executive summary

The aim of the research was to understand how university students become, or remain, engaged in science during their transition from school to university, with the aims of (a) improving student engagement in the study of science at university, (b) improving the transition from the school learning environment to that of university, and (c) identifying and promulgating pedagogical ‘best practice’ for science education in the first year at university. Specifically, this required investigation of how university lecturers influence learners to engage in the sciences, the extent to which lecturers recognised the qualitative differences that exist between the learning environments of the secondary and tertiary sector, and the strategies adopted by universities (at an institutional level and at the level of individual lecturers) to ensure that learners make the intellectual progression between these environments. It also required investigation of whether learners recognised qualitative differences between the pedagogical and assessment environments of the secondary and tertiary sectors, and understanding whether such perceptions/differences contribute to negative choices (i.e. departure intentions, loss of engagement).

Methodology

Data were collected by questionnaire, focus groups and individual interviews. Quantitative data were subjected to principal component analysis, analysis of variance and regression analysis; qualitative data were subjected to thematic analysis.

Key Observations

Teachers/lecturers influence student engagement

Students’ engagement, both at school and university, is strongly influenced by the teaching environment.

‘Lecturer/teacher qualities’ are the most important aspect of the teaching environment. Other factors that affect engagement are the extent to which teaching material allows the development of relevant contexts and of students’ scientific critical thinking skills, supports individual students’ choices regarding content, and is supported by appropriate technology. An environment based primarily on the assimilation of ‘science facts’ is detrimental to student engagement.

There are different perceptions between students and lecturers

Students’ perception of their engagement was greater than that of their lecturers/teachers, while teachers’ and lecturers’ perceptions of their teaching qualities were greater than that of their students.

Consequently, there appears to be a culture in which students and staff are more ready to attribute their short-fallings to each other than they are to reflect on their own involvement.

It's not *wha*t is taught, but *how* it is taught

Science teaching at school and university is traditionally based on transmission methods of instruction in an environment that is discipline based, teacher focused and does not stimulate active learning. Teaching that is integrative, student focused, stimulates active learning and allows some student choice over content promotes engagement. Technology is only an effective aid to teaching when it is used as part of an active learning environment.

Science students want to be scientific

Relevance and context are important to students. Many students are attracted into the sciences because they consider them to be contemporary and meaningful to people, society and technology. Similarly, students enjoy the ability to explore scientific methods by generating and testing hypotheses in practical classes. Students who consider that these concepts are not duly emphasized are unlikely to be excited about their learning.

Student engagement is not lost in transition

First-year university students consider themselves to be committed to a high standard of performance in their science studies, and are no less committed than are senior high school students.

The process of transition

Key differences between the university and school environments are that at school, one teacher usually teaches all of a subject and has a considerable pastoral oversight of the progress of the student, whereas at university, subjects are usually taught by many lecturers, each of whom has very limited pastoral oversight of an individual student's progress.

Ideally, university teaching should place greater emphasis on independent learning and critical thinking than that of school; yet the results of the present study show that this is not necessarily evident during the first year of study at university.

Heterogeneity of study at school means that universities cannot accurately predict the knowledge with which a student will enter university study. Early units of study therefore run risks of either (i) teaching to the 'lowest common denominator' or (ii) presenting material that 'goes over the heads' of a significant proportion of students in the class. Either of these situations impairs engagement.

Key issues facing universities

Universities need to identify what core content is essential for entry to tertiary study in a given discipline. Universities and schools need to liaise to ensure that this core content is met by the units that school students study.

Universities need to determine how best to build on the diversity of knowledge that results from the unit-based NCEA high school education. Universities need to liaise with schools to ensure universities are conversant with the content and process knowledge that students have attained at the end of secondary education, and tailor their entry-level programmes accordingly.

Universities should consider how best to promote integration in first-year tertiary study, particularly with respect to determining how the pedagogical advantages of integration between disciplines can best be achieved in institutions that are largely organised into discipline-based ‘silos’.

Promoting a more active dialogue about key issues

Underpinning such questions is the need for a more fundamental dialogue about the pedagogical environment in which science education takes place:

The pedagogical environment of science education needs to be developed to promote students’ attainment of intellectual independence and high order cognitive and non-cognitive skills, at all levels of their studies.

Assessment practices at school and university need to promote engagement, particularly by rewarding critical thinking rather than reinforcing low order learning.

Lecturers, and perhaps teachers, need to be assisted to develop skills in the ‘teacher efficacy’ parameters identified by the present research as being critical for students’ engagement.

Consideration needs to be given to the structures and systems that are needed to create institutional environments that are favourable for such developments to occur.

Introduction

The purpose of this project was to help universities understand how better to engage learners in the sciences. It achieved this by first identifying gaps between the learning environment for science at the senior high-school and university levels and then by providing a framework to allow development of a pathway to facilitate learners' transition between these sectors. The project paid close attention to developments in curricula and the teaching methods in both sectors in the development of this framework.

Project team

The project was undertaken by:

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Reference Group

The project team worked with a reference group that was representative of the key stakeholder groups of education in the 'natural sciences', including schools significant within the Massey catchment. The Reference Group (below) contributed to project design and implementation, and to dissemination of the findings:

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Background and literature review

In New Zealand, there is a decline in the number of young people who are choosing a tertiary education in the sciences with a view to taking up science careers (Hipkins & Bolstad, 2005). The Skills Insight Tool of the New Zealand Department of Labour indicates that if completions of post-secondary qualifications in Science, Technology, Engineering and Mathematics (STEM) continue to grow at as low a rate between 2008 and 2013 as between 2001 and 2006, domestic supply will cease to meet demands of STEM-based occupations.

This problem is by no means isolated to New Zealand, and is especially evident in physics, chemistry and mathematics. For example, in Australian universities between 1989 and 2005, enrolments decreased by 33.7% in the Mathematical Sciences, in the Physical Sciences by 19.4%, and in Chemical Sciences by 5.3%. European countries have also seen declining numbers of students choosing to pursue the study of physical sciences, engineering and mathematics at university. For example, in the United Kingdom, between 1996 and 1997 and 2001 and 2002, the number of students registered in physical sciences decreased by 10.2%. Meanwhile, a different story is apparent in the biological and computer sciences. The same study in the UK reported that registrations increased 15.7% for life sciences and 61% for computer science (European Commission, 2004); and in Australia, Biological Sciences increased by 74.9% (Dobson, 2007).

In New Zealand, Australia, Europe, and the United States, significant government funding has been directed towards research into tertiary education and why there is a high level of departure intention among first-year university students. Much of this research has been towards general reasons why students withdraw from university study, rather than from the study of science in particular. For example, a study by the Higher Education Funding Council for England (HEFCE) in 1997 estimated the direct costs to taxpayers of higher education non-completion to be about 90 million pounds a year (Evans, 2000). In Australia, McInnis et al. (2000) found that 18% of their first-year sample withdrew from at least one module and about one-third considered deferring their studies. The results of a longitudinal study among first-year students in Australia revealed that departure intention fell significantly between 2004 and 2009 but still remained at 23% (James et al., 2009). Less positive results from the Australasian University Study of Student Engagement indicated that 34.5% of first-year students expressed ‘departure intention’ (AUSSE, 2009). In a New Zealand study of tertiary institutions, Zepke et al. (2006) found that full withdrawal ranged from 13% to 58% and that, on average, 33% of remaining students had considered at least partial withdrawal.

Moreover, there appears to be a parallel trend to fewer students progressing from undergraduate to postgraduate study of science, which in turn eventually translates to fewer scientists entering the workforce. For example, between 1993 and 2003, the percentage of graduates studying for a PhD, which is the most common route to becoming a professional scientist, dropped in all European countries (European Commission, 2004). In Australia, the number of graduates with a PhD in chemistry per million people dropped from eighteen in 1969 to eight in 2003 (Sydney Morning Herald, 2004). Of those people who do actually graduate with a Bachelor of Science degree in New Zealand, around 25% do not progress to work in science oriented jobs (Koslow, 2005).

The combination of fewer students choosing a tertiary education in physics, chemistry and mathematics; a general increase in the proportion of students who decide to quit their tertiary studies (Zepke et al., 2006; AUSSE, 2009); a declining number of PhD students in the sciences; and an overall decline in scientists entering the workforce all pose problems for national economies and have become a matter of high priority for governments. For example, in Australia, the government expressed the view that the decline in student uptake of post-compulsory Science, Technology, Engineering and Mathematics (STEM) study, the shortage of a skilled science qualified workforce, and a decreasing number of qualified science teachers in Australia restrict the development and expansion of science and technology based industry and compromise Australia's capacity to maintain a sufficient market share in these key areas (Tytler et al., 2008). Consequently, Australia declared that the country had six years to find 75,000 additional scientists to meet the demands of the 'knowledge economy' and most would need PhDs in physics, chemistry and mathematics (Sydney Morning Herald, 2004). Similar issues have been identified in the United States (National Science Foundation, 2009).

In New Zealand, the Ministry of Research, Science and Technology (MoRST) stated that New Zealand's economic success depends, to a large extent, on the growth of smart companies based on the ideas coming from universities and Crown Research Institutes, or the support these research organizations can provide to business. Consequently, one of their strategic priorities is 'Engaging New Zealanders with science and technology' (MoRST, 2010). However, there is evidence that New Zealand is performing poorly in comparison to other OECD countries when it comes to generating quality employment prospects for science graduates. On one hand, when it comes to researchers as a percentage of total employment, at 1.0%, New Zealand scores above every country except Finland, Iceland and Japan, and is considerably higher than the OECD average of 0.75%. On the other hand, gross expenditure on Research and Development (R&D) as a percentage of Gross Domestic Product (GDP) in New Zealand in 2007 was 1.17%, compared with the average OECD at 2.25% (OECD, 2009). New Zealand invests less GDP per researcher than any other OECD country (MoRST, 2009).

The factors that lead students to choose science subjects once they cease to be compulsory have been investigated on a number of occasions, emphasising positive and negative influences of pedagogy, context, perceptions of difficulty, and teacher personality in the development of students' engagement with these subjects (Osborne & Collins, 2001; Hipkins et al., 2006; Lyons, 2006). These, together with other factors such as perceptions of the value of degrees in the employment market, the cost of obtaining the degree and parent/peer pressure affect the propensity of students who have studied science at the secondary level to progress on to study science, engineering and technology at the tertiary level. At the tertiary level, transmissive pedagogies and decontextualised content have been identified as inhibiting, (Ramsden, 1991; European Commission, 2004; Lyons, 2006), and active-learning pedagogies and a student-centred learning environment as promoting, engagement with study across a range of disciplines (although there has not been a strong focus on students who are studying science, engineering and technology students per se in such investigations).

A high proportion of students who have entered tertiary science study do not complete their degrees. A number of studies undertaken in the UK (HEFCE, 1997; Evans, 2000), Australia (McInnis et al., 2000; AUSSE, 2009), and New Zealand (Zepke et al., 2006) have reported very substantial proportions of students who fully or partially withdraw from degree programmes (including those in science-based subjects) during their first year of study, a trend that was confirmed by the substantial numbers of students in the present study who failed or withdrew from individual units of study (‘papers’) or their entire degree programme. It is both curious and alarming that such high proportions of students, who were motivated to choose science during post-compulsory secondary education, and even as their primary choice of degree for tertiary study, should fail to successfully complete their science education. The major questions arising from such statistics relate to whether students were insufficiently prepared by their secondary education studies to be able to cope with the [intellectual] demands placed on them during tertiary studies, or whether the study skills they had developed at school were adequate to enter the tertiary sector and were recognised and appropriately developed by tertiary teachers during the students’ transition from the secondary to the tertiary sectors. Perhaps, however, the most important question relates to students’ overall engagement with their science studies, i.e., the extent to which there might be a failure of engagement between the post-compulsory secondary sector and the tertiary sector, and especially whether any such failure of engagement is related to the pedagogy, learning environment and contents of tertiary education in sciences, engineering and technology.

A conundrum faced by universities relates to the ‘teaching-research nexus’. There is a statutory expectation of New Zealand’s universities that degrees are taught by staff who are ‘active in research’ (Woodhouse, 1998), based on the premise that this will ensure both the currency of knowledge imparted to students and the intellectual rigour of their learning (Fairweather, 1996). However, the concept of a teaching-research nexus is based on the assumption that teaching quality and research quality are positively related to each other and the evidence for this is scanty. Hattie and Marsh (2010) showed that the correlation between teaching quality and research quality is zero, and that this zero correlation is robust and repeatable across a great many studies and institutions. In other words, good researchers may be good or bad teachers, and poor researchers may be good or bad teachers. Hattie and Marsh also found that the ‘*teaching-research relation was highest for those who spent the highest amount of their time teaching, almost zero for those who spend moderate amounts of time teaching and negative for those who spend the lowest proportion of time teaching’* (p. 29). However, there is evidence for academic staff being *both* good researchers and good teachers. Hattie and Marsh (2010) and, indeed, most authors who have researched the teaching-research nexus in universities, agree that institutional practices can be created that encourage, develop and reward teaching as an important activity within academe, and which allow the display of the nexus at a personal, departmental and institutional level. Woodhouse (1998) points out that institutional-level benefits in the teaching-research nexus can be achieved by encouraging the development of teaching skills amongst academic staff, and validating/valuing the academic track whose primary focus is teaching; yet, for the nexus to truly operate, it is at the personal/individual level that tandem development of teaching and learning skills need to be developed.

Student engagement

The aim of the research was to understand how university students become, or remain, engaged in science during their transition from school to university. Hu and Kuh (2002) define student engagement as, ‘the quality of effort students themselves devote to educationally purposeful activities that contribute directly to desired outcomes’ (p. 555). McMahon (2003) offers two perspectives on student engagement:

- Engagement stands for active involvement, commitment, and concentrated attention, in contrast to superficial participation, apathy or lack of interest (Newman et al., 1992, p. 11).

- Engaged students were involved in their school work in more than a superficial way that signified some level of commitment and that this engagement extended beyond oneself and one's own work to encompass the wider world of the school and its community (Smith et al., 1998, p. 5).

McMahon's reference to the two perspectives indicates that student engagement is a complex construct. What it looks like and how to describe it cannot be attributed to two or three factors. There is the notion that student engagement involves more than just the 'student' and their interactions with the influences and pressures of the wider community. Krause (2005) supports that assertion and goes on to argue that this multi-perspective construct is not necessarily positive all the time. Watene (2006) noted that much of the research on student engagement has been linked to success with their learning and retention within the educational system and not on the 'student' in the context of the wider community. Watene (2006) highlighted the need to maintain a broader perspective of student engagement and not focus only on the learner and/or the institution. Therefore a definition of student engagement will need to be viewed from multiple perspectives that include the learner, her or his teacher(s), the context of learning/engagement, the wider community, and the institution.

Establishing a method of assessing student engagement from a complex set of interrelated factors involves identifying common characteristics that can be used with a range of contexts (i.e. secondary and tertiary students, as well as for secondary and tertiary teachers). The broad interrelated factors identified in secondary school and tertiary students' engagement are cognitive, behavioural and psychological (Ainley, 2006), student-student, student-teacher and student-institute interactions (Hu & Kuh, 2002; McMahon, 2003; Krause, 2005).

Evaluation of student engagement

Three well-known quantitative instruments focus on surveying student engagement. First, there is the National Survey of Student Engagement (NSSE) and its predecessor from the 1980s, the College Student Experiences Questionnaire (CSEQ). The 85 questions focused on the responses of first and last year baccalaureate degree students to a range of institutional activities (Kuh, 2004). The NSSE study identified seven student engagement scales: Transition Engagement Scale (TES), Academic Engagement Scale (AES), Peer Engagement Scale (PES), Student–staff Engagement Scale (SES), Intellectual Engagement Scale (IES), Online Engagement Scale (OES), and Beyond-class Engagement Scale (BES).

The second survey, the Australasian Survey of Student Engagement (AUSSE), was presented in 2007 to 25 institutions in Australia and New Zealand, including Massey University. At the time of this report, there are three survey instruments used to collect the data found in AUSSE. The first survey instrument is called the Student Engagement Questionnaire (SEQ). It is closely aligned to NSSE (ACER, 2009) and surveys first and last year baccalaureate students. The second is the Postgraduate Student Engagement Questionnaire (PSEQ), and the last is the Staff Student Engagement Questionnaire (SSEQ) that incorporates much of the Faculty Survey of Student Engagement (FSSE) from Indiana University's Centre for Postsecondary Research. All three instruments collect data from the same six student engagement scales, namely: academic challenge, active learning, students and staff interactions, enriching educational experiences, supportive learning environment, and work-integrated learning.

The third generic student engagement survey to appear (2007) focused on high school students instead of tertiary students. The High School Survey of Student Engagement (HSSSE) mirrored many of the NSSE questions as it attempted to provide a picture of high school student engagement.

All three of these surveys assume that the consequences of engagement, or, in other words, the benefits of having students that are engaged, is that the educational 'learning outcomes' (the responses by students) are related to how the student engages with educational activities in secondary or tertiary settings (Hu & Kuh, 2002). While the direct links between 'engagement' and outcomes are, perhaps, not clearly defined, it is clear that 'motivation' is closely linked to learning outcomes (e.g., Wlodskowski, 1999) and that factors that are considered to result in improved motivation are largely the same as those that are associated with engagement with study.

Although the Longitudinal Surveys of Australian Youth (LSAY) does not set out to survey student engagement (per se) in Australian secondary schools, it does identify factors that influence subject selection and participation (Fullerton et al., 2003). Students were surveyed in Year 9 and again in Year 12 (final year) and the results indicated that the foundations for student specialization in the senior school occurred during earlier stages of school and remained constant throughout secondary schooling. In the work of Hipkins and Bolstad (2005), Lyons (2006) and Tytler (2007) on student engagement in science, all made reference to LSAY and believed that the factors identified in that study influence, directly and indirectly, engagement with science in the senior school. It is interesting to note that the four generic studies on student engagement – NSSE, AUSSE, HSSSE and LSAY – all used a quantitative methodology via a survey/questionnaire to collect their data, and that approach in itself limits students' responses to pre-determined categories. The opportunities to identify the context or meaning behind their responses are greatly reduced with such an approach.

Student engagement with science

There are at least four studies that focus specifically on student engagement with secondary school science. Osborne and Collins (2001) examined students' values, beliefs and experiences with secondary school science in the UK. They used focus groups to collect qualitative data that were interpreted using thematic analysis. The work of Lindhal (2003) in Sweden also used qualitative methods to study students' experiences and attitudes in lower secondary school science. Her methodology was based on participant observation and interviews. Lyons' (2003, cited in Lyons, 2006) study in Australia explored the influences of peers, family, community, etc. (sociocultural factors) on students' decision-making in their enrolment in science classes. He surveyed teachers and students and then interviewed students individually. The research carried out by Hipkins et al. (2006) in New Zealand started with focus group interviews in secondary schools so as to inform their follow-up survey. These key studies support the collection of qualitative data as appropriate and critical representations of students' reality in the secondary science classroom.

The authors of the four studies concluded separately that the problems associated with engaging students in science did have an impact on their future decisions about science. Lyons (2003) identified a transmission-based, teacher-centred pedagogy, non-engaging curricula, and the notion that science is delivered as a 'difficult' subject as those problems. Osborne and Collins (2001) and Lindhal (2003) also confirm these three themes as impacting on engagement and therefore influencing subject selection. The study by Hipkins et al. (2006) concluded "*that different students need different types of information, provided at different times, and from a range of sources, if they are to make productive study and career choices* (p. 72)." In other words, while their conclusions had a slightly different emphases, they still demonstrate links to the three themes. These four studies support the use of student voices, which can provide a rich, descriptive picture of secondary school science experiences, authentic and similar yet coming from different countries.

Fostering student engagement

An important goal of this research was to identify ways in which student engagement with the study of science can be developed, especially in terms of transition from school to university and during the first year of science education at university. Factors that have previously been found to be related to student engagement include the support provided to students at school and university, and the use of appropriate pedagogical approaches.

Institutional and academic support

It is important to identify how an institution can shape its systems to encourage student engagement (Pascarella & Terenzini, 2005). The NSSE suggests a need for effective systems to identify and respond to students who are disengaged; enrolment procedures and assistance to help match students to appropriate courses and institutions; consideration of a national framework for academic standards in the first year; and strategies to inform students of the kind of engagement that effective higher education requires to enable them to take responsibility for their own academic progress (Kuh et al., 2005).

Zepke et al. (2006) found that 'learner-centeredness' improved student retention. They describe 'learner-centeredness' as a situation where students 'feel they belong in an institutional culture, where they experience good quality teaching and support for their learning and where their diverse learning preferences are catered for' (p. 598). The longitudinal study of first-year university students in Australia by James et al. (2009) found that 77% of students believed 'the quality of teaching is generally good'; 78% believed their subjects 'fitted together well'; and 75% considered their subjects to be relevant for future studies and career prospects. Only 10% did not find their course stimulating, were not enjoying their course or were dissatisfied with their university experience overall. On the other hand, James et al. (2009) found that one-third of the students criticized the quality of the feedback that teachers provided on their progress; and that only 26% of first-year students believed that staff were actually interested in their progress.

When it comes to academics' understanding of how students feel, results from the AUSSE showed that staff perceptions concerning their interactions with students were much more positive than student perceptions (AUSSE, 2009). For example, 34.5% of first-year students admitted to having had departure intentions but academic staff who taught these students perceived that only 10.9% had departure intentions. Similarly, the 'Student and Staff Interaction' score was 19.8 for first-year students, compared with 41.3 for their teachers.

A combination of factors makes it challenging to create engaging learning environments. Large class sizes result in students being anonymous to their teachers, and economic pressure for high levels of university admissions mean that staff are required to teach students with a wide range of academic abilities (Kuh et al., 2005). Academic staff are under pressure to deliver research excellence as well as teaching excellence. The European Commission (2004) recommends that universities become more committed to evaluating and rewarding teaching excellence that engages and maintains students in the sciences. Biggs (1999) argues that many academics do not question their assumptions about traditional transmission theories of teaching despite known variations in teaching competency. There exists a 'blame-the-student' assumption that risks accounting for variability in student learning by reference to student ability, attitude, study skills, motivation, and even ethnicity (Biggs, 1999).

Effective teaching and learning

In secondary education, problems with engagement in science have been attributed to three issues: transmissive pedagogies, decontextualized content and students' perceptions that science is difficult (Osborne & Collins, 2001; Hipkins et al., 2006; Lyons, 2006). Ramsden (1991) and the European Commission (2004) identified transmission-based pedagogies and decontextualised science content as two issues associated with poor engagement with science education in tertiary institutions.

Ramsden (2003) provided an insight into the experiences of university students studying the sciences and engineering (which they distinguished from Health Sciences). Senior teachers in the sciences and engineering relied on surface approaches (i.e., transmission/teacher-focused approaches) in teaching large first-year classes more frequently than senior teachers in the arts and social sciences. The critique of tertiary education in science and technology by the European Commission (2004) also identified a reliance on what they called simplistic and epistemologically unsound pedagogic structures that may result in students failing to perceive their learning as relevant to their own situations.
Effective teaching and learning in the tertiary institution is grounded in the principles of adult education. One model identifies seven principles for good practice in undergraduate education (Chickering & Gamson, 1987). An effective teacher:

- Encourages contact between students and faculty
- Develops reciprocity and cooperation among students
- Encourages active learning
- Gives prompt feedback
- Emphasizes time on task
- Communicates high expectations
- Respects diverse talents and ways of learning.

The principle of active learning is anchored in the concept of metacognition, which encourages students to exercise greater responsibility for and control of their own learning (Gunstone & Northfield, 1992; Mitchell, 2000; Tytler, 2003). It is based on two assumptions: (i) that learning is by nature an active endeavour and (ii) that different people learn in different ways (Meyers & Jones, 1993; retrieved on 27/05/2010 from http://cte.gmu.edu/Teaching/active&collaborative.html). Some key characteristics of active learning are that it:

- Involves interaction amongst students

- Promotes deep learning, not surface learning of facts
- Teaches students to monitor their own learning
- Helps students build competencies (problem-solving, critical analysis/thinking) as well as knowledge content
- Develops higher order thinking (analysis, synthesis and evaluation).

A move to active learning may require a shift by academic staff from teaching to facilitating learning (Clarke, 2000). Although traditional lectures are seen as the antithesis of active learning, lectures can be turned into sessions in which students are active participants (Biggs, 1999). Research by Ramsden (1991) and Trigwell et al (1999) suggests that higher quality learning outcomes (including improved perceptions of teaching quality) are associated with student-centred active learning while lower quality learning outcomes are associated with surface, teacher-focused information transfer approaches.

In relation to secondary education, the government of Victoria (Australia) funded a project called School Innovation in Science (SIS) to investigate the effective teaching and learning of science in primary and secondary schools. The research project identified eight components that effectively support student learning and engagement in science (Tytler, 2003; 2007b):

- Students are encouraged to engage actively with ideas and evidence
- Students are challenged to develop meaningful understandings
- Science is linked with students' lives and interests
- Students' individual learning needs and preferences are catered for
- Assessment is embedded within the science learning strategy
- The nature of science is represented in its different aspects
- The classroom is linked with the broader community
- Learning technologies are exploited for their learning potentialities

While these components were observed in primary and secondary classrooms, they might also be observed and relevant to effective teaching and engagement in the tertiary science environment.

Summary

In summary, there appears to be a need to:

- Develop an understanding of how to effectively engage school-leavers in the sciences at university
- Describe how the transition from studying science at school to studying the sciences at university impacts on the educational outcomes for learners
- Describe how the relationships between science learners, university teachers and university science curriculum managers impacts upon the educational outcomes for learners.

This knowledge therefore needs to be represented as a conceptual framework that contributes to the teaching and learning knowledge base in both the secondary and tertiary education sectors in New Zealand, and that can be transferred to secondary school teachers and to university lecturers and programme directors.

Methodology

Data were gathered using two main tools: first, a two-part questionnaire based primarily on previous studies in the Australian Science in Schools project (Tytler, 2003), which was intended to measure 'teacher efficacy' and 'student engagement'; and, second, focus groups/interviews in which participants were asked to explore in greater depth the factors that promoted or inhibited their (or their students') engagement in science study. Approval to conduct the study was granted by the Massey University Human Ethics Committee: Southern B 09/12.

Engagement in science was studied with four cohorts of participants: (i) first-year university students, (ii) university teachers of these students, (iii) Year 12 secondary school students studying at least one science subject, and (iv) the secondary school science teachers of these students.

Year 12 school students were included because (i) they have made post-compulsory choices to study science, but have not yet necessarily decided to study science at the tertiary level, and (ii) have already have experience with the NCEA assessment regime. Year 13 students were not included as they have already made their decisions to study (the) science(s) and are on their way to making their transition into the tertiary environment. Likewise, Year 11 students were considered to be not sufficiently far progressed with their academic choices to provide useful data for the purposes of this study.

Data from the four cohorts were collected using a quantitative methodology based on a survey questionnaire, while focus groups and individual interviews were used to provide detailed qualitative information about the experiences of participants in the tertiary and secondary sectors. Collection of questionnaire survey data was undertaken before the focus groups and individual interviews. The mixed methodology allowed for an initial statistical analysis of the items in the survey, followed by gathering critical insights into the contexts behind students' and teachers' responses from the focus groups/interviews.

Questionnaire survey

A cross-sectional anonymous survey was used to collect the data. Massey University and five high schools in the Manawatu and Greater Wellington regions of New Zealand agreed to participate in the study.

Participants were recruited into the survey as follows:

- First-year university students in the College of Sciences were addressed by a member of the research team during class times that had been pre-arranged with lecturers/paper coordinators. As they left the lecture theatre, participants received a paper copy of the survey, which they were asked to complete and return at the end of a subsequent lecture. Students could also access and complete the survey anonymously via www.surveymonkey.com. As compensation for their time, all participants received a token for free coffee when they returned their survey to a box.

- University lecturers were recruited via email. Participants received a paper copy of the survey via internal mail. They were asked to complete and return the survey via internal mail. Participants also received one reminder via email.

- School students were recruited by their science teachers. Participants received a paper copy of the survey, which they were asked to complete during an allocated period of class time and return to their science teacher in an anonymous envelope.

- School teachers were recruited by their Principal/Head of Science. Participants received a paper copy of the survey, which they were asked to complete and return to their Principal/Head of Science before the scheduled date of their Focus Group.

Participants

Demographic information on participants in the questionnaire surveys is given in Table 1.1 (Year 1 university students), 1.2 (university lecturers), 1.3 (Year 12 school students) and 3.4 (school science teachers). Of the Year 1 university students who responded to the questionnaire, the highest numbers were female, Pakeha/Europeans, those who had left school in 2007/9, and those who undertook the NCEA curriculum. There was a good representation from across all degree programmes in the College of Sciences.

For Year 12 school students, there were slightly more males than females, the majority (65%) were also European/Pakeha, English was the most common first language. There were approximately equal numbers of students studying biology, chemistry and physics.

A significant majority of the university lecturer respondents were male. The highest number of responses came from senior lecturers, although there was good representation from across the hierarchy. Most respondents taught/tutored students for <10 hours per week. The gender ratio of school teacher respondents was virtually 1:1. Most had undertaken teacher training in New Zealand and most had been teaching science at Year 12 for between 4 and 11 years.

Table 1.1

Demographic information for Year 1 University Students

		N	%
Total		630	100
Gender	Male	235	37
	Female	388	62
	No response	7	1
Ethnicity	European / Pakeha	449	71
	Māori	21	3
	Pasifika	14	2
	Other	128	21
	No response	18	3
Programme	BSc Only	283	45
	BVSc Only	85	13
	Other	256	41
	No response	6	1
School Curriculum	NCEA	462	73
	Other	149	24
	No response	19	3
Year left school	2007/8	416	66
	Before 2006	206	33
	No response	8	1

Table 1.2

Demographic information for University Lecturers

		N	%
Total		69	100
Gender	Male	48	70
	Female	21	30
Job Title	Professor	9	13
	Assoc. Professor	4	6
	Senior Lecturer	29	42
	Lecturer	16	23
	Other	11	16
Hours per week spent teaching and tutoring students	0–10	49	71
	11+	15	22
	No response	5	7
Preference (“do you prefer disseminating or discovering information?”)	Disseminating	19	28
	Discovering	24	35
	No response	26	38

Table 1.3

Demographic information for Year 12 School Students

		N	%
Total		421	100
Gender	Male	235	56
	Female	181	43
	No response	5	1
Ethnicity	European / Pakeha	275	65
	Māori	18	4
	Pasifika	10	2
	Other	113	28
	No response	5	1
First Language	English	351	83
	Other	62	15
	No response	8	2
Subjects	Biology	237	
	Chemistry	249	
	Physics	235	
	Others	82	
Plan to study science at university	Yes	167	40
	No	104	25
	Maybe	146	35
	No response	4	1

Table 1.4

Demographic information for School Teachers

		N	%
Total		33	100
Gender	Male	17	52
	Female	16	48
Years teaching science at Year 12 level	0–3	7	21
	4–11	17	52
	12+	9	27
Teacher Training	New Zealand	27	82
	Overseas	6	18

Measures

The survey comprised 100 Likert-scale items: 50 items measuring 'Teacher Efficacy' (Tytler, 2003) and 50 items measuring 'Student Engagement.' The intention of the design was to link to the literature on engagement in science (Lyons, 2003; Hipkins et al., 2006; Tytler, 2007; Osborne & Dillon, 2008), the nature of science, and the pedagogy for teaching science effectively in the classroom (Tytler, 2003). Questions were identified that linked to:

- The broad range of affective experiences the students/teachers might encounter in a secondary or tertiary setting
- The declarative/procedural experiences the students/teachers might encounter in a secondary or tertiary setting.
- Effective science teaching in classrooms, as proposed by Tytler (2003).

All four cohorts were given the same questionnaire items, but reworded according to whether they were students or teachers. For example:

Teacher questionnaire	I give students the opportunity to influence the way that they are taught
Student questionnaire	I am given the opportunity to influence the way that I am taught.
Teacher questionnaire they are taught.	Students take opportunities to influence the way that
Student questionnaire	I take opportunities to influence what topics I am taught.

All items were on a scale of 1 to 5, where 1 = never; 2 = rarely; 3 = sometimes; 4 = often; 5 = always.

The questionnaires also included demographic information relevant to the participant groups. The questionnaire used for university students is given in Appendix 1.1 and the demographic questions (which differed between participant groups) in Appendix 1.2.

Qualitative data

Qualitative data were collected through focus groups and individual interviews. A total of eight focus groups were held with Year 1 university students, 12 with Year 12 school students, seven with university lecturers and five with the teachers of science to Year 12 school students. Totals of 46 Year 1 university students, 43 Year 12 school students, 41 university lecturers, and 30 school science teachers participated in focus groups or interviews.

Written consent was provided by all participants. Focus groups were facilitated by two members of the research team, one of whom led the discussion while the other asked supplementary questions and kept written records.

University students were recruited by a team member and focus group(s) were conducted either during class time or at a mutually agreed time. Focus groups comprised groups of eight participants or less.

Lecturers of first-year students in the College of Sciences were invited by e-mail to participate in one of a series of focus groups. Respondents were selected on a first-come-first-served basis, up to a maximum of eight participants per group.

The study was introduced to school students by their science teachers, who had been briefed by the Research Team. Focus groups were held either during the time scheduled for a science class (with teacher permission) or during 'free' periods. Participants provided written consent and were randomly placed into groups of eight participants or less.

School teachers were informed of the study and invited to take part by their Principal or Head of Science. Focus groups were held either after school or during the hour normally allocated to a departmental meeting. There were one or two focus groups per school.

The questions asked during focus groups were specific to each participant group (Appendix 1.3). Focus group discussions and individual interviews were digitally recorded and transcribed by an independent person who had signed a Confidentiality Agreement.

Analysis of data

Scale construction (quantitative data)

The initial stages of analysis were based exclusively on university student and school student data. Analysis of the questionnaire data based on the original eight categories of the SIS project (Tytler, 2003) suggested these were not good descriptors of the responses. Principal component analysis with Promax oblique rotation was conducted to assess the underlying structure for items 1–50 of the Questionnaire and, separately, for items 51–100. Factors with Eigenvalues over 1.0 were initially identified. A total of 10 factors for items 1–50 and 7 factors for items 51–100. To assess whether the items that loaded against each of the ten factors formed reliable scales, Cronbach's alpha was computed. Scales where alpha values were >0.70, which indicated they had reasonable internal consistency reliability, were used for further analysis; the remaining factors were not analysed further. Further information is presented in the Results section.

The five scales derived from items 1–50 were provisionally named Lecturer Qualities, Relevant Contexts, Scientific Method, Self-Directed Learning, and Maximising Technology to reflect the individual items that composed each scale (see Table 2.1), while those derived from items 51–100 were named Commitment to Performance, Learning with Excitement, and Developing Meaning (see Table 2.2). Each respondent's score on each scale was computed as the arithmetic mean of the scores on the items comprising that scale.

Each scale was examined for violations of normality by computing skewness and applying the guideline that, if skewness was >+1.0 or <–1.0, the distribution was significantly skewed. Distribution of all eight scales was normal, except Lecturer Qualities among university lecturers (skew = –1.120) and Self-directed Learning among school teachers (skew = 1.512).

To examine the associations between teacher performance and student engagement, correlation and regression analysis was carried out. Identification of between-group differences on teacher performance and student engagement was carried out using Student's t-test or univariate analysis of variance with post hoc tests to identify which of the main effects were significant. Games-Howell was selected for post hoc comparison as it takes unequal group sizes into account (Field, 2009). Categorical data were compared using chi-square analysis.

Focus Groups/Interviews (qualitative data)

The qualitative analytic method adopted was thematic analysis. Thematic analysis is a method for identifying, analysing and reporting themes within data. A theme captures something important about the data in relation to the research question, and represents some level of patterned response or meaning within the data set (Braun & Clarke, 2003). In this study, thematic analysis followed a 'realist' method in which the experiences, meanings and the reality of participants were reported. An inductive approach ('bottom-up') was applied. This means the themes identified arose from the data, rather than from the specific questions that were asked of the participants or from *a priori* interests in the area.

Thematic analysis followed a six-step process (Braun & Clarke, 2003):

- *Familiarization*. This involves a detailed reading and re-reading of transcribed data in order to develop preliminary ideas about themes and codes.
- *Generating initial codes*. Relevant features of the data were identified and coded in a systematic fashion across the entire data set, and data relevant to each code were collated into a spread sheet.
- *Searching for themes*. Codes were collated into overarching themes, and all data relevant to each potential theme was identified. As this phase progressed it became evident that some codes clustered to reflect items (sub-themes) and scales (themes) from the quantitative data.
- *Reviewing themes*. Themes were reviewed to ensure sub-themes were meaningful, and their interrelationships were explored.
- Defining and naming themes. During the ongoing process of identifying and analysing themes, each theme was refined and given a clear definition and name.
- *Reporting contents of themes*. The findings were compiled and suitable examples were extracted to illustrate each theme. Each stage of the analysis was conducted with the research questions and aims in mind, and with consultation between research team members regarding data analysis and theme development.

Results

Questionnaire results

Principal Component Analysis

Initial analysis was undertaken to establish the factor structure of the scales using exploratory factor analysis. Principal component analysis of Items 1–50 of the questionnaire identified 10 factors that had Eigenvalues over 1.0. Cronbach's alpha for five out of these ten scales was >0.70, which indicated they had reasonable internal consistency reliability. Scales with alpha values of <0.70 were not analysed further.

The five scales with alpha reliability >0.70 accounted for 40.7% of the variance in student responses. These 'teacher efficacy' scales were labelled as Lecturer Qualities (LQ), Relevant Contexts (RC), Scientific Method (SM), Self-directed Learning (SD) and Maximising Technology (MT). The same methodology was applied to items 51–100 of the Questionnaire. Factor analysis resulted in three scales with alpha values >0.70, which accounted for 39.1% of the variance in student responses. These 'student engagement' scales were labelled as: Commitment to Performance (CP), Learning with Excitement (LE), and Developing Meaning (DM). Individual items composing each of these scales, their relative loadings, and Cronbach's alpha values for each scale are given in Table 2.5 (teacher efficacy scales) and 4.6 (student engagement scales). Items that loaded on more than one factor were not included in scale development or further analysis.

Each respondent's score on each scale was computed as the arithmetic mean of the scores (on a scale of 1 to 5, where 1 = never; 2 = rarely; 3 = sometimes; 4 = often; 5 = always) on the items comprising that scale.

Table 2.1

Factor loadings for items 1–50: teacher efficacy scales

Principal Components Extraction; Promax (Oblique) Rotation	LQ	RC	SM	SD	MT	α
My lecturers inspire me with their enthusiasm	0.87					0.84
My lecturers stimulate me with the way they teach content	0.78					
My lecturers use a variety of techniques to help me learn a topic	0.74					
My lecturers care for me by creating a class environment that protects my individuality	0.53					
My lecturers value my contribution in class	0.47					
My lecturers relate science to things that interest me	0.47					
The criteria on which I will be assessed have been made clear to me	0.47					
My lecturers encourage me with their positive comments	0.43					
My lecturers support me with constructive feedback to go forward	0.42					
I am asked to learn how science impacts people, society and technology		0.71				0.75
I am asked to consider ethical issues surrounding science		0.61				
I am asked to learn about how science relates to contemporary issues		0.60				
I am asked to learn about major 'break-throughs' in science		0.60				
I am asked to learn how scientific ideas have developed over time		0.52				
I am assessed on my ability to interpret scientific data			0.73			0.74
I am expected to evaluate then interpret scientific data/evidence for myself			0.68			
I am expected to use data/evidence to solve scientific problems			0.63			
I am expected to plan the investigations that I undertake			0.48			
I am expected to use data/evidence to develop a logical scientific argument			0.47			
I am assessed on my ability to discuss scientific concepts			0.47			
I am given the opportunity to influence the way that I am taught				0.69		0.75
I am given the opportunity to influence what topics I am taught				0.67		
I am given the opportunity to interact with the wider science community				0.56		
I am given the opportunity to listen to external people talk about science				0.50		
I am given the opportunity to use up-to-date technology during investigations					0.74	0.77
I am given the opportunity to use up-to-date technology to develop my knowledge					0.73	
My lecturers use up-to-date technology for teaching					0.72	
I am given the opportunity to use up-to-date technology to complete assignments					0.67	
						total
% Variance Explained	23.7	5.7	4.7	3.7	2.9	40.7

LQ: Lecturer Qualities; RC: Relevant Contexts; SM: Scientific Method; SD: Self-directed Learning; MT: Maximising Technology

Table 2.2

Factor loadings for items 51–100: student engagement scales

Principal Components Extraction; Promax (Oblique) Rotation	CP	LE	DM	α
I strive to do my best in science	0.83			0.88
I try to attend science classes	0.82			
I strive to get good grades in science	0.77			
I complete science assignments by their deadlines	0.77			
I strive to keep up to date with my science studies	0.70			
I intend to stay in science	0.65			
I work hard to understand things I find confusing about science	0.48			
I use the set texts and study guides to study science	0.48			
I set high performance standards for myself in science	0.47			
If I can, I study in an environment that is free from distraction	0.45			
I tell other people how much I enjoy studying science		0.87		0.84
I discuss science issues with other people		0.81		
I challenge myself to explore the 'deepest secrets' of science		0.71		
I get excited when I discover things about science		0.64		
I apply my knowledge of science to things in my life		0.63		
I do more science study than is required just to complete assignments		0.48		
After science class, I reflect on what I've learned		0.48		
I learn how science impacts people, society and technology			0.81	0.79
I learn about major 'break-throughs' in science			0.79	
I consider ethical issues surrounding science			0.74	
I learn how scientific ideas have developed over time			0.70	
I learn about how science relates to contemporary issues			0.66	
				total
% Variance Explained	28.2	6.7	4.2	39.1

CP: Commitment to Performance; LE: Learning with Excitement; DM: Discovering Meaning

Differences between demographic groups

Analyses of differences between demographic groups are given in Appendix 2. Overall, there were relatively few significant differences related to demographic factors.

Gender (Appendix 2.1)

The mean score for Commitment to Performance was significantly higher (p<0.001) for female than male students. No other differences between gender were present for any of the response groups.

Ethnicity (Appendix 2.2)

The mean score for Self-directed Learning was significantly higher for Māori (p<0.01), Pasifika (p<0.001) and Other (p<0.001) than for European or Pakeha university students. The mean score for Scientific Method was lower for Pakeha than for Pasifika university students. However, the scores for Lecturer Qualities, Relevant Contexts, Self-directed Learning and Developing Meaning were higher for Pasifika school students than for other groups. There were also significant differences between the responses of school students for whom English was, or was not, their first language, but there were no consistent trends in the differences.

Programme of study (Appendix 2.3)

The mean score for Commitment to Performance was significantly higher (p<0.01) for university students studying for the BVSc than for other science programmes.

There were no significant differences related to the programme of study that university students had followed while they were at school.

Mean scores for Commitment to Performance and Learning with Excitement were higher (both p<0.01) for school students who planned to study science at university than for those who did not.

University lecturers (Appendix 2.4)

University lecturers who spent ≥16 h teaching in either Semester 1 (p<0.01) or Semester 2 (p=0.07) gave higher scores for Self-directed Learning than did those who taught for a smaller number of hours.

No scores varied according to position title, and there were no consistent patterns of difference related to being full vs. part time, or whether their preference was for discovering or disseminating information. Paper coordinators gave higher (p<0.01) scores to the scale Scientific Methods than did those lecturers who were not paper coordinators.

School teachers (Appendix 2.5)

There were few differences between scores given by any groups of school teachers for any of the eight scales.

Group differences on scales

Data for each of the five teacher efficacy and three student engagement scales are presented in Appendix 3, Table A3.1–A3.8.

Lecturer Qualities

Differences in mean scores for Lecturer Qualities (Table A3.1) between groups were significant ($F(3, 1057) = 52.7$, $p<0.001$; Figure 1).

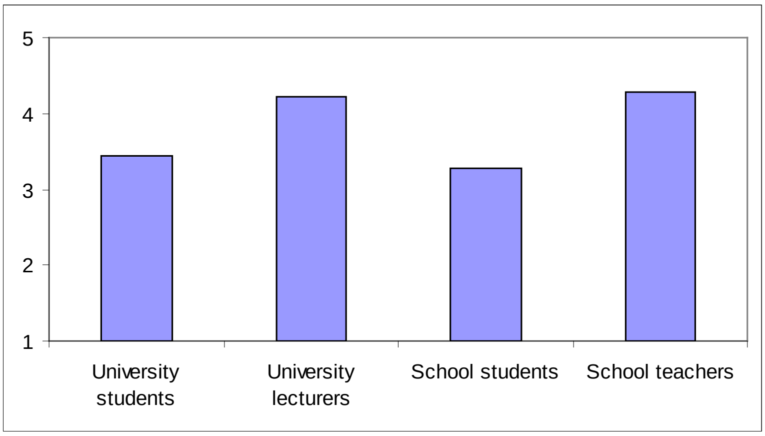

Figure 1. Mean scores for Lecturer Qualities

Mean scores for university students were significantly lower than for university lecturers ($p<0.001$) and significantly higher than school students ($p<0.001$). The mean scores for School Students were significantly lower than school teachers ($p<0.001$).

Scores for school students studying a single science subject were significantly lower than Year 1 university students, but not from school students studying more than one subject, $F(3, 890) = 3.79$, $p=0.01$.

There was a significant difference between the frequency distribution of scores between school and university students, $\chi^2(9) = 219.95$, $p<0.001$. Lecturers and school teachers had significantly higher proportions of mean scores >4.0 than did university or school students (Table A3.1).

Relevant Contexts

Differences of mean scores for Relevant Contexts (Table A3.2) between groups were significant, $F(3, 1102) = 67.6$; $p<0.001$. (Figure 2).

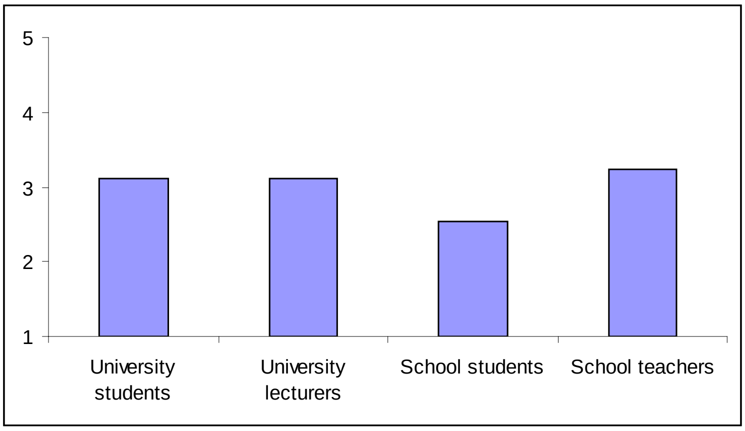

Figure 2. Mean scores for Relevant Contexts

Mean scores were significantly (p<0.001) higher for university than for all school students. Mean scores given by school students were significantly (p<0.01) lower than those given by school teachers.

Mean scores of school students studying 1, 2 or 3 sciences subjects were significantly lower than those of first year undergraduate students (F(3, 917) = 57.43, p<0.001).

There were significant differences (p<0.001) of distribution of responses for Relevant Contexts between groups ($\chi^2(9) = 183.02$, p<0.001). Responses of university students and university lecturers were similar to each other (50% and 52% of scores >3.0, respectively), whereas the scores of school students (21% of scores >3.0) were substantially lower than those of university students (49% of scores >3), and lower than those of school teachers (70% of scores >3.0).

Scientific Methods

There were no statistically significant different responses between participant groups for mean scores for Scientific Methods (Table A3.3: F(3, 1087) = 1.3, NS; Figure 3). There were also no differences between groups in the frequency distribution of responses, and no differences between students studying 1 or more science subjects and university students (F(2, 278)=1.80, p>0.05).

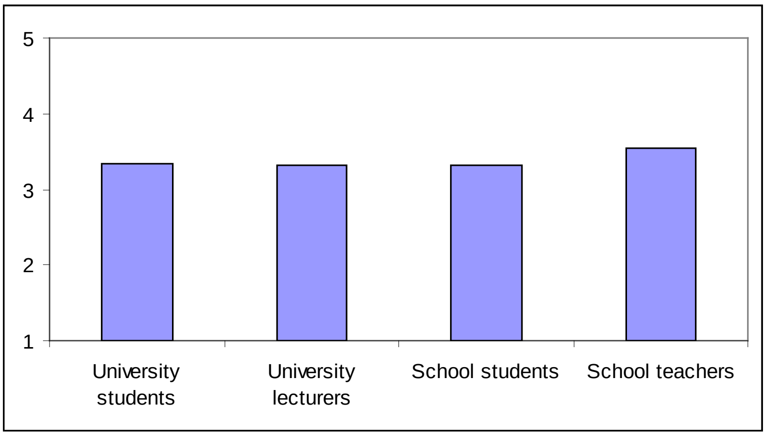

Figure 3. Mean scores for Scientific Methods

Self-directed Learning

Mean scores for Self-directed Learning (Table A3.4) differed significantly between groups (*F*(3, 1111) = 17.5: *p*<0.001; Figure 4). Scores were significantly higher for university students than for university lecturers (*p*<0.01).

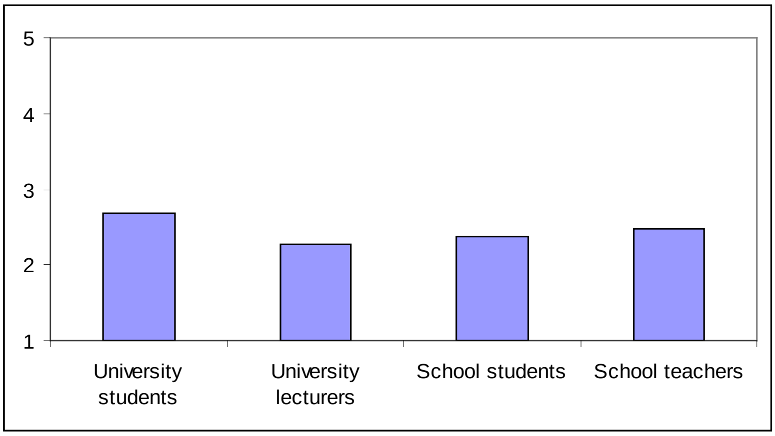

Figure 4. Mean scores for Self-directed Learning

Scores for school students studying a single science subject were significantly lower than those of Year 1 university students (*F*(3, 926) = 13.63, *p*<0.001).
Only 22% of all respondents gave scores >3.0, and 3.5% scores of >4.0 for this scale. Numbers of responses >3.0 were higher amongst university students (27%) than other groups ($\chi^2(9) = 53.67$, *p*<0.001).

Maximising Technology

Mean scores for Maximising Technology (Table A3.5) differed significantly between groups (*F*(3, 1107) = 40.3, *p*<0.001; Figure 5). Scores were significantly (*p*<0.001) higher for university students than for school students.

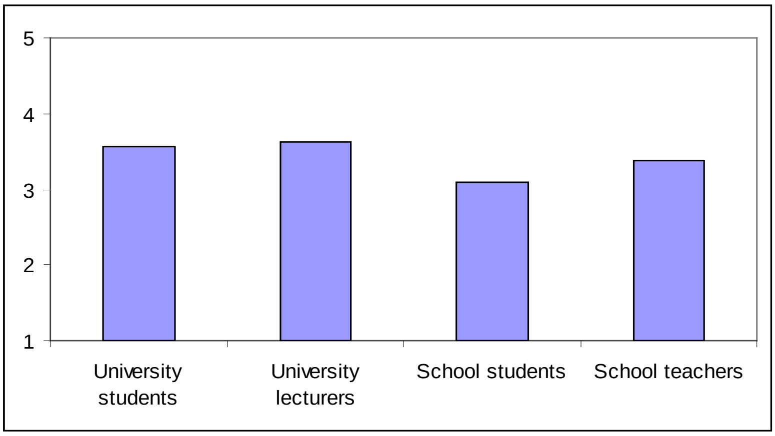

Figure 5. Mean scores for Maximising Technology

School students taking 1, 2 or 3 science subjects had lower scores than first year university students (F(3,924) = 29.86, p<0.001).

The distribution of scores for Maximising Technology differed between groups ($\chi^2(9) = 116.71$, $p<0.001$), although only the proportion of school students giving scores ≤3.0 was markedly below the expected values. Only 50% of school students gave mean scores >3.0, compared with an overall average of 76% amongst the three other groups.

Student Engagement Scales

Mean scores for the three scales of Commitment to Performance (Table A3.6), Learning with Excitement (Table A3.7) and Developing Meaning (Table A3.8), all differed significantly between groups $F(3, 1053) = 34.2$, $p<0.001$, $F(3, 1078) = 43.9$, $p<0.001$, $F(3, 1097) = 39.2$, $p<0.001$, respectively; Figure 6). Mean scores for Commitment to Performance and Learning with Excitement for university students were significantly higher than for either university lecturers ($p<0.001$) or school students ($p<0.01$).

Students taking only one science subject showed lower Commitment to Performance than students taking more subjects and first-year undergraduates, but there was no significant difference between students taking 3 core science subject and undergraduates, $F(3, 895) =36.55$, $p<0.001$. Learning with Excitement was rated more highly by students taking 3 core science subjects and undergraduates than by students taking one or two science subjects, $F(3, 918) = 43.45$, $p<0.001$. Developing Meaning was rated more highly by undergraduates than by school students taking 1, 2 or 3 subjects, $F(3, 924) = 35.22$, $p<0.001$.

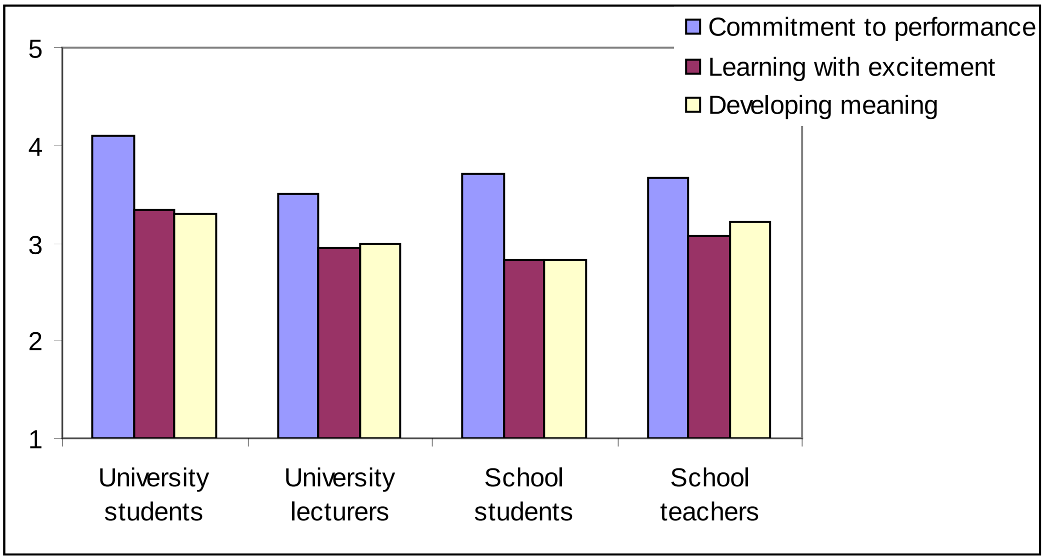

Figure 6. Mean scores for Commitment to Performance, Learning with Excitement and Developing Meaning

Correlation and regression analysis

In order to examine relationships between teacher performance and student engagement, bivariate correlations were carried out (Tables 2.3 (university students) and 2.4 (school students)). At the simple bivariate level, all teacher efficacy scales were positively related to the three student engagements scales, except that Commitment to Performance was not significantly related to Self-directed Learning for university students.

Table 2.3

Correlations (Pearson's-r) between scales of teacher efficacy and student engagement for Year 1 university students

	LQ	RC	SM	SD	MT	CP	LE	DM
Lecturer Qualities (LQ)	1.000							
Relevant Contexts (RC)	0.500***	1.000						
Scientific Method (SM)	0.459***	0.547***	1.000					
Self-directed Learning (SD)	0.407***	0.451***	0.481***	1.000				
Maximizing Technology (MT)	0.480***	0.396***	0.466***	0.324***	1.000			
Commitment to Performance (CP)	0.382***	0.267***	0.288***	-0.083	0.327***	1.000		
Learning with Excitement (LE)	0.409***	0.448***	0.396***	0.254***	0.207***	0.463***	1.000	
Developing Meaning (DM)	0.453***	0.624***	0.513***	0.358***	0.323***	0.292***	0.540***	1.000

*** Correlation is significant at the 0.001 level (2-tailed)

Table 2.4

Correlations (Pearson's-r) between scales of teacher efficacy and student engagement for Year 12 school students

	LQ	RC	SM	SD	MT	CP	LE	DM
Lecturer Qualities (LQ)	1.000							
Relevant Contexts (RC)	0.457***	1.000						
Scientific Method (SM)	0.335***	0.364***	1.000					
Self-directed Learning (SD)	0.490***	0.554***	0.264***	1.000				
Maximizing Technology (MT)	0.508***	0.455***	0.247***	0.466***	1.000			
Commitment to Performance (CP)	0.461***	0.144***	0.348***	0.163***	0.154***	1.000		
Learning with Excitement (LE)	0.358***	0.287***	0.274***	0.347***	0.161***	0.615***	1.000	
Developing Meaning (DM)	0.371***	0.636***	0.237***	0.390***	0.300***	0.312***	0.522***	1.000

*** Correlation is significant at the 0.001 level (2-tailed)

The next step in the analysis of the quantitative data was to explore which of the teacher efficacy scales made significant unique contributions to each of the three student engagement variables for university students (Table 2.5) and school students (Table 2.6).

For university students, the predictors of Commitment to Performance were higher Lecturer Qualities, Scientific Method, and Maximising Technology and lower Self-directed Learning (Table 2.5a). Learning with Excitement and Developing Meaning were predicted by Lecturer Qualities, Relevant Contexts, and Scientific Method, but not by Self-directed Learning or Maximizing Technology.

Table 2.6 presents the teacher efficacy measures predicting student engagement for school students. Only Lecturer Qualities and Scientific Method predicted stronger Commitment to Performance in this group, while Lecturer Qualities, Scientific Method and Self-directed Learning predicted Learning with Excitement.' For Developing Meaning the sole predictor was Relevant Contexts.

The overall relationship between teacher qualities and commitment to performance was stronger for university students (46% of variance accounted for by the regression model) than for school students (25% of the variance accounted for). Similarly, with scores for Learning with Excitement, the overall model was more strongly predictive for university (42% of variance) than school (17% of variance) students. Scores for Developing Meaning were strongly predicted by the model for both groups of respondents: 85% of total variance explained for university students and 49% for school students.

Tthe regression analyses indicate that different facets of student engagement are predicted by different aspects of teacher performance, a finding that will be considered in more detail in the Discussion.

Overall, the analysis of the quantitative data has indicated the ways in which Lecturer Qualities, Relevant Contexts, Scientific Methods, Self-directed Learning, and Maximising Technology were related to three different facets of student engagement. The implications of these findings are presented in the Discussion.

Table 2.5

Linear regression analysis of teacher efficacy scales and student engagement scales for Year 1 university students

(a) Commitment to Performance

Dependent variable	B	β	*t*	Adjusted R^2	*F*
Lecturer Qualities	0.325	0.307 ***	6.700		
Relevant Contexts	0.120	0.116	2.497		
Scientific Method	0.212	0.210 ***	4.403	0.294	45.54***
Self-directed Learning	-0.336	-0.412 ***	-9.515		
Maximizing Technology	0.163	0.175 ***	3.981		

*** $p<0.001$

(b) Learning with Excitement

Dependent variable	B	β	*t*	Adjusted R^2	*F*
Lecturer Qualities	0.277	0.243 ***	5.247		
Relevant Contexts	0.322	0.289 ***	6.106		
Scientific Method	0.219	0.201 ***	4.156	0.275	41.89 ***
Self-directed Learning	-0.040	-0.045	-1.037		
Maximizing Technology	-0.099	-0.099	-2.243		

*** $p<0.001$

(c) Developing Meaning

Dependent variable	B	β	*t*	Adjusted R^2	*F*
Lecturer Qualities	0.148	0.134 **	3.268		
Relevant Contexts	0.481	0.451 ***	10.742		
Scientific Method	0.240	0.227 ***	5.338	0.437	85.30 ***
Self-directed Learning	-0.010	-0.012	-0.306		
Maximizing Technology	-0.036	-0.038	-0.962		

*** $p<0.001$.

Table 2.6

Linear regression analysis of teacher efficacy scales and student engagement scales for Year 12 school students

(a) Commitment to Performance

Dependent variable	B	β	*t*	Adjusted R^2	*F*
Lecturer Qualities	0.497	0.474 ***	8.128		
Relevant Contexts	-0.081	-0.074	-1.203		
Scientific Method	0.318	0.257 ***	5.079	0.265	25.46 ***
Self-directed Learning	-0.061	-0.061	-1.009		
Maximizing Technology	-0.074	-0.073	-1.284		

*** $p<0.001$

(b) Learning with Excitement

Dependent variable	B	β	*t*	Adjusted R^2	*F*
Lecturer Qualities	0.239	0.211 ***	3.420		
Relevant Contexts	0.086	0.073	1.125		
Scientific Method	0.216	0.163 **	3.064	0.184	16.74 ***
Self-directed Learning	0.222	0.206 **	3.263		
Maximizing Technology	-0.118	-0.110	-1.840		

*** $p<0.001$

(c) Developing Meaning

Dependent variable	B	β	*t*	Adjusted R^2	*F*
Lecturer Qualities	0.106	0.103	1.973		
Relevant Contexts	0.625	0.586 ***	10.521		
Scientific Method	-0.002	-0.002	-0.035	0.404	48.69 ***
Self-directed Learning	0.022	0.022	0.407		
Maximizing Technology	-0.024	-0.025	-0.481		

*** $p<0.001$.

Qualitative data

The qualitative component expanded on the research questions in the quantitative survey, particularly regarding how school teachers and university lecturers influence learners to engage in the sciences. It also explored the extent to which lecturers and students recognise the differences that exist between the learning environments of the secondary and tertiary sectors, and the strategies adopted to assist learners to progress between these environments (see Appendix 1.3 for specific questions).

The thematic analysis identified themes that corresponded with those identified in the quantitative analysis. These themes were developed, explored and clarified and are presented below with particular reference to the ways in which participants experienced and engaged with their education in science.

In this section quotes that are prefaced with [I] refer to the interviewer, those prefaced with [R] to respondents. Numbers following the [R] refer to different responses to the same question.

Lecturer Qualities

The enthusiasm of the lecturer was recognized as an important factor in the engagement of students by most Year 1 university students and some of their lecturers. In every student focus group, comment was made about the relationship between an enthusiastic teacher and students' levels of engagement. Students commonly said that when a teacher was enthusiastic, it made them more interested in learning. For example:

> *[I really like it when…..] R: The lecturer is very enthusiastic – it keeps you interested and keeps you awake.*

On the other hand, students considered that enthusiasm was by no means universal in their lecturers. Students were asked to indicate what proportion of lecturers were enthusiastic, made them very interested, and kept them awake. Responses varied between '*1 or 2 out of 8'* to between 1 and 5 within a teaching year.

The link between lecturer enthusiasm and student engagement was also made through student complaints about lecturers who did not appear enthusiastic. For some, tone of voice was equated with a lack of enthusiasm, in that unenthusiastic lecturers spoke in monotone.

> *[I really don't like it when...] R: The lecturer drones on – the voice is the same or varies a little. It is so boring. It seems like they are not enjoying it.*

Other students reflected on the reasons why lecturers might not appear enthusiastic. Some concluded that it might be difficult for lecturers to remain enthusiastic about presentations that they have delivered '*over and over*'. These students interpreted the ability to overcome this difficulty as a sign of enthusiasm among lecturers:

> *R: He [the lecturer] changes his PowerPoints every time he lectures a subject. He changes them because he finds out more information so he's still enthusiastic about it.*

Similarly, a number of lecturers expressed their awareness of the relationship between their own enthusiasm and the engagement of students. For example, one lecturer response to the question ‘what do you think it is that an excellent teacher does’ was:

> *R: Part of good teaching is to be passionate – even if you are not passionate about it. You’ve got to go in and you’ve got to enthuse about what you are doing, what you are teaching.*

For school students, there was a similar link between the enthusiasm of the teacher and the students’ engagement. Many school students found themselves more inclined to learn when their teachers were enthusiastic:

> *[I really don’t like it when’…] R: When the teachers aren’t passionate about what they are teaching. They have to be really interested in it to get us interested in it.*

School students also related teachers’ enthusiasm to their tone of voice; specifically equating the use of monotone with a lack of enthusiasm:

> *R: It would be better if he tried to make his work be more interesting, like show some enthusiasm instead of being like monotone the whole time.*

Similarly, links were made between teachers’ enthusiasm and their presence in the classroom. Several focus groups of school students mentioned teachers who were always late, or who left the classroom to perform other tasks; concluding that such teachers had a limited commitment to teaching. A further reason proposed for a lack of enthusiasm among school teachers was that some science teachers were obliged to teach subjects in which they did not specialize. The most common example was chemistry teachers having to teach physics.

A desire for a variety of teaching techniques was a common theme among Year 1 university students. Two key reasons for the desirability of variety emerged. First, students found that a change of technique refocused their attention. For example, there was a consensus in one focus group that, without variety, ‘*after about twenty minutes you start falling asleep*’. Second, students highlighted that different teaching styles enhanced their ability to learn:

> *R: I like lecturers who recognize the different learning styles [within a lecture theatre]… They can recognize that the students are getting disengaged and they do something a little bit different next time or within the lecture.*

Recurring themes were reported by students who wanted lecturers to use a greater variety of teaching techniques:

- Several students spoke of humour as an effective means of communication. The ability to present information in a light-hearted manner was connected to a more enjoyable and stimulating learning experience. For example: ‘*There’s one lecturer who sort of makes it very kind of casual and humorous at the same time giving us the facts. So we can enjoy listening somehow.’*

- Students frequently mentioned diagrams. These students typically believed their memory was more effectively triggered by something visual than by text alone. For example: ‘*I like it when lecturers use visual situations because when I’m in an exam or something I’m like, oh, what does this key word mean and I will relate it back to some visual diagram or something*.’

- Several students spoke about their enjoyment of YouTube. Movie clips were reported to help them connect theory to reality in situations when live demonstrations were inappropriate. For example, '*Like in animals last year he went on YouTube and it was really good. You could actually see the baby happening so it just wasn't him saying this is what happens in animals*.'

- Other students strongly advocated the value of demonstrations. One student commented: *'I like it when they – during the demo – they show us everything... We saw everything like they explain it and do it. You read it and, oh, you can't – this thing will not convince you – you will not believe – but once you saw everything…'*

- Students frequently desired more practical experiments. The opportunity for a 'hands-on' education was cited as a key reason for pursuing science. For example, '*I think it's more effective if you get in there and do it yourself.'*

- Several students stated a preference for lecturers who adopted a discursive style rather than reading exclusively from their notes. A discursive style involved lecturers who turned to face the class, allowing opportunities for elaboration and explanation. For example: '*I don't like it when there's a lot of facts and figures and tables and numbers and they just put the table up and they don't explain each part and how it relates back to what we are learning*.'

- A common topic among students was the benefits of lecturers employing questioning as an effective means of developing student engagement with the lecture. For example: '*I like it when they will actually ask you questions… and they don't sort of let you sleep basically*.' While some students acknowledged that questions were frequently met with silence, even if they had previously found themselves feeling uncomfortable trying to answer a question under the spotlight, they agreed that questioning helped them learn. One student advocated a peppering of questions throughout the presentation slides, while another suggested ten questions at the end of every lecture. Some students from disciplines in fundamental sciences advocated the benefits of 'clickers' (i.e. in-class immediate-response devices) to help questioning. A student with previous experience in a polytechnic described how questions could be integrated into the study guide by leaving spaces for students to complete.

- Students frequently mentioned the benefits of summarizing as an aid to developing clarity of understanding, rather than questioning. For example: '*I like it when they do a summary. They tell us information over a set of lectures and then they summarise it into quite a simple way but it's the whole picture and things slot in for us.'*

However, notwithstanding students' desire for a variety of teaching techniques, students stated that there was a substantial proportion of lecturers who appeared to rely solely on reading an entire lecture directly from notes that were written on PowerPoint slides. The following were typical responses when the interviewer asked students what they disliked about science classes:

> *R1: They [lecturers] just talk and talk…. they just sort of rambling on.*

> *R2: When the lecturer just reads what it says on the slide.*

R3: You'll know there's going to be just a PowerPoint and guys sitting up front, and you know you are just going to have to sit there for an hour and just take notes.

In this context, a number of students debated the value of attending lectures and concluded that accessing lecture slides online via WebCT/Stream then reading them independently at home was a viable option, thus rendering lectures almost redundant:

I: If you think of your study as a whole, how important are lectures in terms of your whole learning experience?

R1: Not very important.

R2: Not really. As long as they put the slides up on WebCT you can pretty much get what they are on about.

Generally similar responses were given by school students. School students, especially boys, reported that humour stimulated their learning. One focus group believed that a teacher telling bad jokes was better than no jokes. The same group claimed that the ability to connect with a student's sense of humour was not age related, although some teachers were said to be '*past their sell-by date*.'

As with university students, school students found a variety of teaching methods desirable. However, similar problems were reported, such as the expectation for students to spend extended periods copying notes from slides, whiteboards or text books. Like university students, school students found themselves wondering about the value of some lessons. Instead they asked for more practical experiments, and one focus group advocated field trips.

School students also enjoyed the variety of questioning, especially when it progressed to a class discussion. Unlike university students, they did not report a particular fear of answering questions in class.

School teachers reported that they could not adequately meet student demands for practical demonstration due to excessive focus of the curricula on content (declarative) knowledge, student numbers, timetabling difficulties and a lack of equipment for practical teaching. One teacher sympathized with students disengaged by '*note driven*' teaching in science.

My lecturers relate science to things that interest me

Year 1 university students reported a strong relationship between content that did not interest them and immediate disengagement. Things that interested students were typically associated with content that they perceived could be useful in their future careers, or with content that was explicitly connected to their chosen specialisation. The following comment was typical:

R: If it's things that we can easily relate to our future job that's easy to stay focused for.

However, there were many issues about relating contents to individuals' interests in compulsory 100-level papers. A number of students gave examples of compulsory papers that superficially appeared to be linked to their degree programme but in which they struggled to understand the relevance of some content, or in which content was taught in a way that did not make its relevance apparent. It was particularly notable that, where the lecturer did not relate content to things that interested students, students were likely to become disengaged. One student expressed her feelings thus:

> *R: At the moment … I'm not really seeing any relevance to it so it's kind of like making me disengage.*

Students who were studying aspects of biological science in humans commonly stated that studying papers with a bias towards animal sciences was unfavourable and not guarantee good engagement. Specifically, having to undertake compulsory, generic 100-level papers that were taught with a bias towards the animal sciences was widely cited as a cause of disengagement:

> *R: My degree is Sport and Exercise Science and sometimes when I'm learning all about, say, enzymes in a cow's digestive tract, I can't really see the relevance or it's not made apparent of how that's related to Sport and Exercise Science.*

Others of these disengaged students cited compulsory 100-level papers that were not specific to a programme; notably papers on communications. Students considered that such papers were not interesting because the content duplicated that from NCEA English. A few students defended the value of papers in communication: one who had been home-schooled found it *'a really useful experience in getting to work with groups more'.* However, on balance, there were more negative than positive reports on the relevance of these papers.

For university lecturers, there were likewise a number of instances when they acknowledged that many students were obliged to study content that was not explicitly linked to the 'reasons they came to university'. One of these lecturers reported that science programmes are organized in 'silos', which artificially force some students into inappropriate compulsory 100-level papers. The key example was students of Food and Nutrition, who were taught physics in the context of Engineering rather than that of Life Sciences because *'there's a great decree that food and nutrition is engineering'.* The same lecturer went on to propose a solution:

> *R: Each piece of core science needs to be put in a position in the curriculum where it can be closely associated with the discipline that they want to go into.*

School students also reflected the sentiment that content that seems to be irrelevant is difficult to learn. One student said he wanted teachers to '*show you what you can actually do with what they are teaching you when we are older*.' To aid this process, students thought that teachers should talk more frequently about their own personal experiences and career history in science.

The criteria on which I will be assessed have been made clear to me

University students commonly expressed a desire for lecturers to be more explicit about assessment criteria. A common request was for more examples of previous exam questions and answers, and the suggestion was made that these examples could be reviewed during lectures. At one extreme, one student thought that lecturers should '*completely outline and go over*' everything that was required to pass their paper. However, the following comment was a more typical response:

R: I like it when lecturers explain exactly what they are looking for in tests and exams and science and stuff instead of just leaving you in the dark.

There were a few instances when lecturers talked about clarifying assessment criteria with students. One focus group briefly discussed their reservations about being too prescriptive about assessment, because the current system did not prepare students for employment. The following proposal was discussed at some length in a focus group of lecturers and, although the idea was eventually discarded as too ambitious for 100-level students, it was indicative of the direction in which such lecturers wanted to move:

R: What about getting rid of assessment driven by the lecturer… but leaving it up to the student at the end of the semester to come to us and demonstrate or show or prove what they can do?

My lecturers support me with constructive feedback to go forward

Year 1 university students valued individual feedback from their lecturers, with several expressing a desire for *more* feedback on assessments. Typically, these students wanted to recognize clearly the areas of knowledge in which they were deficient/needed improvement:

R: They could give you feedback on, say for your assignments and things, like what you might have missed to go over and see where you are and what you actually do need to focus more on.

Students were asked about their thoughts on feedback that they had previously received from their lecturers. A few students gave positive examples:

R: With one lecturer, after our exam or our test, he went through where we went wrong individually when we pick up our test from him. He'll just go through where you went wrong and what he was looking for. You didn't even ask he just said, 'this is where you went wrong; what you learnt; this is good'. That sort of feedback is always good.

Conversely, other students gave negative examples.

I: Did you get good feedback on the assignment when you did get it back?

R: No… One comment, one tick and a mark.

Students who desired feedback reported a limited number of opportunities to obtain it from lecturers in a one-on-one situation. Several students attributed class size and the lecture theatre environment as the greatest limitation. These students typically recognized small group environments as a better alternative. One student suggested that more tutorials might lead to more feedback:

R: It would be really good if there were more tutorials to discuss what's happened in the lecture/labs, so there's more one-on-one. More feedback given.

Another limitation to receiving feedback was reported to be lecturer 'approachability': some students specifically reported that lecturers could be 'unapproachable'. One of these students made a direct connection between unapproachability and feeling too 'scared' to request feedback. However, more commonly students did not seek feedback from lecturers because:

> *R: I don't like it when they are really short with you like they don't want to help you.*

Several lecturers confirmed the connection between their level of approachability and student bravery for seeking feedback. In respect to interpersonal interaction, lecturers frequently acknowledged the problems of class size and the lecture theatre environment. A couple of lecturers described a preference for interpersonal interaction to occur in small group environments. One lecturer reported that, in the absence of an environment that facilitates interpersonal interaction, students perceive lecturers to be nothing more than inaccessible '*speaking heads at the front [of the lecture theatre]*.'

One focus group of school students reported how much they appreciated teachers who went through assessments, telling everyone what they did right and wrong, and how they could do better. In another case, students reported that some teachers just gave the mark back and said, '*sign here – you don't pass'*. In one of these cases, a school student reported that they had considered seeking feedback after class but concluded that the teacher was probably too busy. At worst, one focus group of students described a teacher who seemed to have no time or positive comments for teenagers in general.

Teaching and Research

The relationship between teaching and research was an important theme in focus groups held with university lecturers. Most lecturers felt that both institutional imperatives and their own desires to be strongly active in research, could be inimical with developing their teaching practice. Indeed, research and teaching were seen as being more likely to be antithetical – in tension with each other – than to be complementary to each other.

Consequently, there was no recognition of an active 'nexus' between the teaching and research, although it was noted that some highly productive researchers were also very good teachers. However, this was seen as a serendipitous characteristic of individual, rather than being promoted by institutional structures.

Some lecturers noted that performance across the areas of teaching and research were both important for academic advancement:

> *R: To be ambitious you've got to do certain things. You've got to do research, have postgraduates, publish papers and you've got to teach undergraduates and be recognised as an undergraduate teacher.*

More commonly, the demands of research, particularly as focused on performance in PBRF, were regarded as being in competition with teaching activities. This was largely attributed to the distorting effect of PBRF-related funding upon institutions that were perceived as already being underfunded:

R: [With] the reduced [core] funding from the government, PBRF and contract trading becomes more important: that has an impact on the quality of teaching I think, because that's not rewarded.

Consequently, lecturers believed that the primary focus of their activities should be in the research domain, even if this was at the expense of that of teaching:

R: The current situation we've got is there is too much pressure on returning a good PBRF; and the only way you can get your good PBRF is to create time, and one of the ways of creating time is to shut your door on students.... So there's a pressure on lecturers not to be student friendly.

and

R: My impression is... minimise the time you spend on teaching because we need you to go into PBRF and research. Therefore, teaching is not important because they [i.e. the students] are here anyway... don't spend too much time on this teaching.

Relevant Contexts

This section considers the extent to which students perceive science to be meaningful in the context of their own experiences. A few students explicitly stated that the fundamental nature of science was meaningful. To some students, it was the fundamental nature of science that engendered meaning:

'I like science because pretty much without science there'd be no life really'.
For other students (and more commonly), the applicability of science to their everyday lives was the aspect of science they enjoyed:

I: [What it is you really like about science?] *R: The relevance it has to understanding how things in the world fit together.*

Students made a connection between being taught science in the meaningful context of everyday life and their own level of engagement: '*I really like it when the teacher challenges me to apply the knowledge to real-life situations'*. Other students were able to recall occasions when teachers had explicitly connected science content in a meaningful way to everyday life scenarios:

R: I like it when you have a moment of realization when you are going to be using that information they just told you about. Like you can imagine yourself talking to a client about their animal and it's like, okay, I know that at least one of those points is going to be used.

The link between science and meaningful understandings was also made outside the domain of future career prospects:

R: I reckon taking something like chemistry you start to think about – you used to think, for example, of a fire. It was just a fire but now it's all these chemical reactions.

Several students reported a desire to be taught science in a contemporary context. There was a link between higher levels of student engagement and being exposed through teaching to an area where '*new stuff is always coming out'*. Building on this theme of emerging science in a contemporary context, there was plenty of discussion about enjoyment of learning when it was combined with a sense of discovery:

> *R: Say, ten years ago you could have learnt something completely different to what it actually is now or they'll make a new discovery about it… It's real interesting.*

Lecturers frequently reported an awareness that students want to learn science in a meaningful context. When lecturers were asked to reflect on what they considered that students most loved about science, there was a strong consensus about 'real world' application:

> *R: We should bring the real world into the classroom and connect chemistry or whatever it is to things that are going on and I try and do that.*

However, lecturers also reported three reasons why a focus on meaningful understandings was often overshadowed by a focus on content. First, lecturers frequently made reference to unavoidable content:

> *R: Well, certainly content is quite important because you have a certain amount of language that you have to be familiar with in order to develop the more difficult concepts so there is a definite or certain amount of content.*

Second, there is a tension between assessment and learning. Overloaded periods of assessment distracted lecturers from challenging their students to develop meaningful understandings, particularly because assessments are far more often focused upon recalling content than upon using information in more creative contexts:

> *R: You can actually teach them to pass an assessment but at the end not have a lot of knowledge.*

Last, teaching can be primarily driven by content per se, rather than the material the students need to be able to understand to utilize knowledge in an area. One lecturer who felt that his peers were somewhat 'obsessed' with disseminating content from their specialist area expressed his concerns thus:

> *R: We all become a bit obsessed that they must know this and they must know that and it's the end of the world if they don't know that.*

School students were equally engaged by content that could be meaningfully associated with the world around them. One student reported how meaningful his understanding of new grasses had become when he saw them in action at home on the farm. Other students spoke about science being meaningful to contemporary society and technology. One student highlighted that science featured regularly in the news saying, '*they find new things anywhere in the world and you can relate it back to science'*. Finally, like university students, school students found that connecting theoretical science to meaningful contemporary issues made their whole learning experience worthwhile.

Self-directed Learning

Students are given the opportunity to influence the way they are taught

Although students reported being stimulated by the use of a variety of teaching techniques, they generally felt they had limited opportunities to affect how they were taught. As previously noted, some lecturers would change style when they noted that students were becoming disengaged. However, a much more common response was for students to express frustration that lecturers did not teach content in a way that suited their personal learning style:

> I: Do you feel that your lecturers are teaching to you to suit you as individuals?
>
> *R: In general, no. No, I don't think so. If we ask them. Sometimes. Sort of. Me personally, not really. No. No.*

Despite this, or, perhaps, consequentially, the majority of students did not seem to *expect* lecturers to take their personal learning styles into account. Several students reported that their apathy was connected to the realization that they represented just one of many learning styles in a lecture environment:

> *R: It is hard when you are only one person out of a hundred and everyone learns differently.*

In this context, some students specifically questioned the value of lectures. One student was explicit in his belief that lectures were 'not very important'. Several other students claimed that, rather than attend a lecture that did not cater for their individual learning styles, they preferred to access lecture material on-line and teach themselves from home. Interestingly, there was relatively little consideration given by either students or lecturers to significant alternatives to the standard teaching repertoire of lectures and practicals. Tutorials were used by some lecturers, and, depending upon the mode of delivery of the tutorial, were valued by some students. However, innovative technologies, on-line techniques, problem-based learning and other contemporary learning techniques were rarely mentioned by either lecturers or students.

Students are given the opportunity to influence what they are taught

The relevance of compulsory 100-level papers was a major topic of discussion. Some students found that a broad education in science was relevant, and had no objections to the compulsory nature of some papers:

> *R: I think the science degree in general. Science, first year, seems pretty broad.*
>
> I: Is that something that you are okay with?
>
> *R: I think so. I think it's a good idea because… lot of people change their subjects so it's good to get a broad understanding to start with.*

Other students complained about being forced to study compulsory material they did not think was relevant to their personal interests. Following on from the conversation above, one student offered a contrasting point of view:

> *R: But if you're specific on what you have to do… then but having broad papers is not helping in any way.*

Other students used a financial argument to emphasize their objection to compulsory papers. The following comment was specifically in connection with a paper in communication:

> *R: Really, [you're] only wasting $500 on a paper which you would rather spend advancing your course for your degree.*

Lecturers found themselves in a difficult situation in relation to some of the compulsory papers with unpopular content. On one hand, they recognized that it could be difficult to maintain students' engagement in such papers. However, on the other hand, and in defence of compulsory papers and unpopular content, they experienced great difficulty with developing the content of these papers, given that students educated in the NCEA system enter university with a highly variable level of content knowledge.

> *R: It's hard to know what they actually do know by looking at their NCEA marks. I've had students that have NCEA Level 3 Physics and I'd swear that I was teaching them the material for the first time. I'm looking at the NCEA Level 3 exam going – look this is what I'm teaching, I'm only teaching NCEA Level 3 to you students – why can't you do it if you have the credits?*

As a consequence of this variation, much of the unpopular content at 100-level was necessary to create a 'level playing field' before second year. Lecturers appreciated that, consequently, some students found that neither their preferences for topics nor for teaching pace could be accommodated:

> *R: You have to explain concepts again which they [able students] consider are trivial – a lot of them are trivial. They [able students] think, why are we wasting time going over this?*

This situation proved to be just as frustrating to lecturers as to students. Lecturers recognized the need to 'stretch' able students at the same time as needing to teach the basics to students who were either less able or who had not encountered material during their school studies. Some suggested 'high' and 'low' level first-year papers, but recognized the difficulties implicit in such a system for the maintenance of the overall standard required for the degree. Others suggested that minimum standards for entry from school should not be defined solely in terms of numbers of credits, but perhaps also either in terms of numbers of credits at levels higher than 'achieved', or in terms of specific units of [NCEA] study that were prerequisites for entry to particular papers or degrees.

Regardless of the problems inherent in a heterogeneous intake to 100-level papers, lecturers offered few examples of situations in which students could choose what material to study within individual first year papers. Hence, the main opportunity that students had to influence what they were taught lay with their selection of non-compulsory papers. In Year 1, for some programs, there was either one or no non-compulsory paper choice available, and, even where such choice could be exercised, the students again had no control over the content of the papers they had selected.

Focus group conversations with school students and their teachers reported very similar issues to those experienced at university. Commonly, school students felt their teachers did not provide them with the opportunity to influence the contents that was taught, or the context in which it was taught. This, however, varied between teachers. For example, in one focus group, a student noted that, '*the entire class* *having to adapt to the way of the teacher, especially if they have got an obscure teaching style*.' On the other hand, a different focus group described a teacher who found ways to teach all his pupils in different ways until the class had developed a common understanding. One student expressed particular appreciation towards a teacher who allowed students to control their own learning by, for example, choosing whether or not to undertake a practical.

When it came to influencing topics, there was similar discontent among biology students who wanted more opportunity to choose between human, animal and plant biology. There was also objection to repetition of the same concepts year-on-year, taught from a slightly more challenging angle. Students generally appeared to prefer a wider range of topics representing the breadth of science.

Maximizing Technology

Year 1 university students appreciated the web-based learning support provided by electronic learning platforms (i.e. Moodle and WebCT), but indicated that their value was as a convenience rather than being pivotal to their learning. One student described using Stream to access presentation slides before lectures so that he could write notes on the slides during lectures. Another student described using Stream to access presentation slides after lectures in order to review them for content missed. However, several students indicated that they used Stream or WebCT to access presentation slides instead of attending lectures:

> *R: As long as they put the slides up on WebCT you can pretty much get what they are on about and if not you can just go into the discussion on WebCT and find out what other people are saying.*

Some annoyance at the types of technology used in teaching was also expressed by students. Some students described their personal frustration with complexities of scientific computer programmes. However, the majority of adverse comments surrounded lecturers who seemed uncomfortable with technology, leading to time-wasting technical problems:

> *R: Probably would help if some of the professors got a little more tech-savvy before they started. I think it's been at least one lecture where a good ten minutes at the start waiting for them to get organized and set up the screen.*

Lecturers expressed a mixture of enthusiasm and hesitation towards technology. The more enthusiastic comments reflected a common perception among lecturers that students adapted well to technology; referring to students as 'whizz bangs.' Connected to this perception, some lecturers believed that the advancement of technology in teaching would lead to improvements. For example:

> *R: One thing that we've started doing which I'm really keen on developing further is using the 'mastering biology' website. There's one for 'mastering physics' as well. Comes with a textbook where the students can get one-on-one interactive tutoring and weekly assignments and things and doing more of that kind of stuff, I think, is really useful.*

Other lecturers expressed concerns about the limitations of computer-based learning technology. One lecturer agreed with the principle of providing students with additional 'tools', but with the caveat that they should be '*the right tools'*. A subsequent discussion revealed why the value added to students' learning by current web-based teaching support can be limited:

> *R: I think the way we use these tools can't be just to put everything and kitchen sink on to WebCT so they just consume it. It has to be in such a way that they make – it facilitates students to independent thinking and problem-solving.*

School students, like university students, expressed reservations about their teachers' use of online learning technology. First, they felt that teachers need to remember that online learning does not automatically make it relevant to students 'because it is online'. Second, there are limitations to online learning when computers are not always accessible or have broken down. Finally, many reported that the equipment in science laboratories was rarely clean, up-to-date or in adequate supply.

Generally, school students did not report having readily available access to an online learning environment such as Moodle or WebCT, yet there was a clear consensus that they favoured more exposure to computers and resources on the internet. A couple of school students described websites [e.g. http://sci.waikato.ac.nz/evolution/], that were similar to the 'mastering biology' site [http://www.masteringbio.com/], as having been beneficial to their learning.

Commitment to Performance

I strive to do my best in science

The motivation of first-year students was a recurring theme in focus group discussions with university lecturers. The following comment provided a good summary of the characteristics that they would like to see in motivated students with a good work ethic:

> *R: It would be nice if your students had the idea that they were students and being a student means you work 50 hours a week on study. You don't just go to lectures, you don't just go to labs, you do background, you do reading, you think, you try and tie everything together.*

Lecturers spoke frequently about the current level of motivation among school leavers. Although one group of lecturers agreed that school leavers were 'sweet' and 'keen to learn', none of the lecturers interviewed indicated that school leavers were 'striving'. Instead, lecturers more often than not suggested that school leavers lacked motivation. The following comment is a good example:

> *R: They want to get a degree. But they want to get a degree with the least amount of work possible and with the least amount of inconvenience actually.*

However, lecturers had different perceptions of students who were not typical New Zealand school leavers. Frequently cited exceptions were mature students (R1), second-year students (R2); overseas students (R3); students with career focus (R4); and veterinary students (R5):

> *R1: I don't know what other people think but anybody who arrives as a first-year student who's 20, anybody who is mature, is essentially a very good*

student. Because they are motivated and organized and all of those things 18-year-olds aren't.

R2: The first-years struggle but the ones that I get in the second year taking the first-year paper they are really, really good students and they interact and they get good grades.

R3: We are finding them [overseas students] an absolute joy – they are adding another dimension to the class, they are so enthusiastic.

R4: They [midwifery students] are all motivated because most of them are here with a set goal, i.e., the midwifery students are hugely motivated.

Veterinary students were described on numerous occasions as the epitome of students striving to do their best in science*, e.g., 'well, there are certainly not very many non-motivated students in the vet programme that's for sure.'* Many lecturers attributed the dedication of veterinary students to the competitive nature of the BVSc and were saddened that other majors could not provide a similar incentive:

R5: Well, they [veterinary students] work hard. That's a big difference. Because it's a competitive thing they know that only X number of students are going to be successful they have very good work ethic. If we could somehow have the same sort of carrot for other majors and say, look, we are only going to accept a certain number for chemistry.

Students themselves did not often speak explicitly about their level of commitment. From the examples available, one student reaffirmed lecturers' perception of the typical New Zealand school leaver:

R: It's just getting the motivation to do it [study]. Like, I suppose, the motivation's just not there. I don't know. I'm one of those people that need to be pushed. I know it's bad but...

On the other hand, a veterinary student in Semester 2 (post-selection) reaffirmed lecturers' perception of such students, even despite the alleviation of pressure upon them after the selection process:

R: Well, in the first semester we had to work hard, like it wasn't just personal pride that pushed us to work hard it was the need to work hard. I think like now though, at the moment, the second semester… it's so confusing because I know I don't have to get A pluses or whatever but I still want to do well.

Similar trends were seen among school students and their teachers. One teacher described how, *'there is always a proportion of boys that are in there because they have to be there – they, typically, are unmotivated, they will do as little as possible in order to fulfil the requirements of the school and they can become problematic.'* Several students supported this statement complaining about peers who were disruptive in class.

I try to attend science classes

Non-attendance at lectures was widely reported in focus group discussion with university lecturers. Some lecturers estimated that average attendance levels were 75–90%, although others reported that attendance levels could be as low as 50% by mid-semester. Non-attendance at lectures was undoubtedly a source of frustration to many lecturers: '*attending science class would be a step in the right direction for some students.'* One lecturer who had also taught in overseas universities attributed low attendance to a national trend, saying '*there seems to be a lot of skipping lectures in New Zealand anyway*'. Other accounts of low attendance tended to be associated with the negative perception that supplementary and online materials gave students the impression that they don't need to attend lectures. For example:

> *R: But we don't encourage that [class attendance] because I put all my notes on the web and there's all sorts of reasons why they can just not go to lectures and not be that badly affected.*

Where tutorials were concerned, lecturers reported that attendance of one-third or one-quarter of the class would be good. Students who attended tutorials were typically higher achieving students. Some lecturers described frustration because these students were not necessarily the ones who most needed extra tutoring. Other lecturers were positive about the opportunity to tutor an engaged audience.

School teachers did not comment about the attendance of their students, presumably because of the greater degree of compulsion regarding attendance at school than at university. One school teacher did recognise the issues created by non-attendance at university, however:

> *R '[students], actually told me that they don't even have to go to lectures next year at university because they will just get it off the internet.'*

I strive to get good grades in science

Several groups of lecturers discussed a common philosophy among first-year students was that '*C's get degrees*'. One lecturer reported a 10–20% difference between the grades achieved by first-year students taking 100-level papers and those achieved by second-year students in the same papers. It was suggested that one reason students do not strive for good grades is because, if they fail, they are entitled to re-enrol multiple times. The following conversation captured the essence of discussion:

> *R: It would be better for them [students] to get the idea that it's better to get As than just sneak through with a C. C really isn't wonderful.*
>
> *R: Yes, it's that little 'Cs get degrees'. Don't you hate it!*
>
> *R: Yes, 'I got a C+; I studied too hard.'*

One teacher admitted*, 'we do have a bit of a culture of running around after them, mothering them and I think that's going to have a huge impact.'* However, teachers reported that changing the culture might jeopardize grades, the subsequent reputation of the school *and* inflame parents who blame teachers when their children perform poorly.

Teachers also reported some resistance towards homework. According to one teacher, students frequently request revision periods because they do not understand that revision should be done at home. This teacher said, '*to them, learning is what you do at school'.* For some students, homework is a problem because they are engaged in part-time employment on school nights.

I set high performance standards for myself in science

Lecturers speculated that performance standards among students were heavily influenced by their experience of the NCEA system at high school. It was felt that the NCEA system had conditioned students to develop an attitude towards obtaining credits rather than learning per se.

> *R: That's a hangover from NCEA. Students are only motivated by assessment.*

A discussion about NCEA among one group of veterinary students confirmed the suspicions of lecturers that the typical New Zealand school leaver is predominantly motivated by assessment/credits:

> *R: They [i.e. peers who did not have veterinary school in focus] were just going to get the credits to pass – it was much easier for them. They just kind of had to get the 'achieved' to get the credits. We knew what subjects we had to take – they just took whatever they knew they were going to get credits in.*

Consequently, lecturers widely perceived that school leavers only undertake tasks that are directly associated with obtaining marks. For instance, one lecturer described a belief that students have forgotten the importance of a long-term performance focus:

> *R: If I say to them we have assessments; they might be worth 2%. First of all they'll say, this assessment should be worth 20%. When I say, no, it's worth 2% they will say, oh, well, I won't bother to do it and the argument is you should do it because it is actually to help you learn for your final exam… but they are just not interested in that. They are always focused on what's happening in the next 10 minutes.*

Similarly, school teachers warned that NCEA is credit-driven, which allowed students to '*pick and choose whether they are going to even bother with a particular assessment*'. This attitude seems to be particularly prevalent when students had already gained enough credits to pass or because students knew they would be given another chance to remedy a bad performance.

Furthermore, school teachers also said that students cannot fail NCEA. Instead, the worst performance grade is 'not achieved', which indicates, '*will achieve, just haven't done it yet*.' They considered that this situation was detrimental to students' learning and their motivation. Moreover, teachers were concerned about the differentiation between 'achieved' grades and 'merit' or 'excellent' grades. The excessive reliance on key words in the grading system meant that very able students (whose overall performance would be commensurate with 'merit' or 'excellent' grades) often ended up with 'achieved' grades due to the omission of some key word (often, in the view of the teachers, related to a trivial point). This, the teachers felt, was a substantial de-motivator to above average students: a series of 'achieved' grades when both student and teacher had expected much better results rapidly conditioned students towards doing as little as necessary to attain an 'achieved' grade, since extra effort was not rewarded with the appropriate higher grade.

I strive to keep up to date with my science studies/I work hard to understand things

Most university students recognized that ‘keeping up-to-date with science studies’ required them to study outside class. For example:

> *R: You go to a lecture and you kind of pick up on a few concepts but you have to go back and read over it so you understand it. It’s more like teach yourself – even though you are being taught in the lecture you really do teach yourself.*

However, a few students found it challenging to ‘keep up-to-date.’ One student (R1) described being unaccustomed to homework, which had never been a requirement at school. Another student (R2) perceived that contact hours did not leave much time for private study. A third student (R3) described how students are distracted by the social scene:

> *R1: Well, I wasn’t a big studier at school – my school didn’t even give me homework for 7th form, so after school was finished you didn’t do anything at night. Coming here you’ve actually got to do stuff and I did find that quite hard.*
>
> *R2: I mean if the university expects everyone to do like 12 hours [private study] per paper – I mean if you’ve got 3 hours [contact time] per paper [in science] – I’m finding I don’t have as much [time as BA students].*
>
> *R3: A lot of people focus more on the social side and forget that they’ve got all this work to do as well so they get really behind.*

A common message from lecturers was that students should consolidate information between lectures to avoid falling behind.

> *R: There are three lectures a week now – that’s going to present a lot of material – you don’t get a lot of chance to actually sort it out between times so a lot of people can get behind quite quickly and it’s very difficult to catch up.*

However, lecturers perceived a catalogue of reasons why many students struggled to keep up-to date. Categories of reasons included complacency (R1); poor time management (R2); paid employment (R3); social distractions (R4); ineffective study techniques (R5); school backgrounds (R6); NCEA variation (R7):

> *R1: They [students] clearly are reflecting on what they know and what they don’t know but they just don’t see any reason to go and fix it.*
>
> *R2: I had a student came and saw me today and said I wonder if you can help me with some questions. I said, this is the assignment that was due in last Friday.*
>
> *R3: I think a lot of it is students having part-time jobs and it’s almost as though they take a full-time university course and then try and do it as a part-time student. At that age they have rudimentary time management skills and so things just fall by the way.*
>
> *R4: They are learning all the things we learned as 18-19 year olds, which are huge distractions. Some of them need to be taught how to plan a diary so that they meet their deadlines – they don’t know how to do it.*

R5: I find a lot of them work very hard at home but don't have much to show for their effort. Most of them that come in, they don't know how to do the right type of work.

R6: Different schools certainly have different attributes. There are certain schools out there that do as part of their goal create more independent learners. There are other schools who will simply spoon-feed the students to pass the exams.

R7: Yes, the general physics knowledge of the students coming in straight from school, it really depends on the teacher and we have a number of students that have, in theory, done NCEA Level 3 and passed, yet if I asked them XXX, 50% of my class will get it wrong.

Again, there were very similar perceptions about the effort that students devoted to their studies among school teachers. One commented that '*today's generation – they don't want to do anything that's too hard*'. Another teacher reported that, when selecting subjects for Years 12 and 13, students and their parents are often concerned about whether science subjects are hard.

Learning with Excitement

Some evidence emerged from focus groups to support the notion that students learn about science with a degree of excitement. University students frequently commented on their excitement when discovering new things about science. When students were asked, 'what is your favourite thing about science', the following was typical of their responses:

R: A sense of discovery. Like, there's so much that's not discovered yet. You never know what diseases you might come across there to find new cures and treatments and stuff and prevention and medication.

In addition, students frequently described satisfaction when the knowledge of science could be applied to everyday life and used in conversation with other people. For example:

R: I didn't realize half the stuff that we learnt was quite so interesting to go away to the gym and put that into practice.

However, this enthusiasm for learning science is highly dependent upon prerequisites, such as being inspired by the enthusiasm of the *lecturer*. There were mixed opinions about whether learning science was, or was not, exciting. Some school students mirrored the views of university students, that they found new information exciting. On the other hand, another student admitted, '*I would rather not discover some new scientific miracle – I would rather just pass my exam*.'

In summary, the quantitative data identified eight key issues related to student engagement: five aspects of teacher performance and three aspects of student engagement. The qualitative data enabled deeper exploration of these issues, and sub-themes emerged. The strong parallels between the results of quantitative data derived from the statistical analysis of the questionnaires and the qualitative data derived from the thematic analysis of the focus group/interviews corroborate the validity of the groupings that were developed in the two strands of the data.

Although Year 1 university students identified lecturers’ enthusiasm, commitment, and teaching techniques as being important qualities, they also highlighted the need for science content to career and individual interests. Assessment and constructive feedback were seen as further ways in which teachers/lecturers could foster learning. With regard to Relevant Contexts, meaningfulness, and contemporary relevance while teaching staff indicated that they were aware of these issues and expressed some frustration with resource limitations that placed constraints on what they could do. Self-directed Learning, or students’ active roles in the learning process, was highlighted primarily in regard to student concerns about their limited opportunities to choose content and learning styles that interested them. The theme of Maximizing Technology focused on students’ use of available resources, the opportunities and limitations of technology in teaching, and the need for staff to be able to use them effectively.

With regard to student engagement, Commitment to Performance emerged as of greater concern to lecturers than to students, with lecturers recognising a wide range of student motivation and attributing this to a wide range of factors. Learning with Excitement was linked by students and staff to a sense of discovery and relevance that motivated students to engage with their science studies.

Discussion

This study aimed to explore the factors that promote students' transition from the study of science-related subjects at the secondary to the tertiary level; and to understand those factors likely to lead to students' completion of, or withdrawal from, such studies. No previous published studies in which responses of these two groups of students and their teachers could be directly compared were found. The goal was to understand how university students become, or remain, engaged in science during their transition from school to university, with the aims of:

- Improving student engagement in the study of science at high school and university
- Improving the transition from the school learning environment to that of university
- Identifying and promulgating pedagogical 'best practice' for science education in the first year at university
- Identifying those areas where dialogue between school and universities should occur

Although the discussions with teachers and school students were wide ranging, the main areas of interest during those discussions were to identify how high school students were engaged with science and what factors supported successful transition towards studying science at university.

Data showed that the engagement of students at high school and year 1 university was strongly influenced by factors related to the teaching environment, of which 'lecturer/teacher qualities' were the most important. Other factors were the extent to which material allowed the development of relevant contexts, supported individual students' choices regarding content, and was supported by appropriate technology. Students' opportunity to develop thinking skills in the area of scientific method (as opposed to the assimilation of 'science facts') was also related to engagement. Students' perception of their own engagement was greater than that of their lecturers/teachers, while teachers' and lecturers' perception of their own teaching qualities were greater than that of their students.

The key findings of this study were:

- Teachers / lecturers influence student engagement.
- There are different perceptions between students and lecturers.
- It's not so much *what* is taught, but *how* it is taught that affects engagement.
- Science students want to be scientific.
- Student engagement is not lost in transition.

Teacher efficacy and student engagement

Teachers and lecturers influence student engagement

The scales of 'teacher efficacy' were highly correlated with those of 'student engagement', while the qualitative data strongly supported these statistical associations. Together these data sets made it clear that the interaction between teacher and student, both at school and university, in the context of the material that was being taught, was the pivotal factor that promoted or inhibited students' engagement. Overall, teachers/lecturers who were perceived as being enthusiastic, able to communicate, able to create relevant contexts, and able to clarify rather than obfuscate concepts, were more likely to result in students becoming engaged with their learning than were those who were perceived as lacking those abilities.

Neither school nor university students gave scores for Learning with Excitement and Developing Meaning that were as high as their scores for Commitment to Performance. It is intriguing to speculate about reasons for the different responses to these three scales. Perhaps, in this context, Commitment to Performance should be considered to represent students' potential commitment, whereas Learning with Excitement and Developing Meaning represent the authentic level of excitement for learning science that students displayed. If this is the case, it would align with the dearth of strongly affirmative responses to items in the Developing Meaning scale, which suggests there is a relative failure (particularly at school, and especially for students studying only a single science subject (Appendix 2.3), to contextualize the material in the students' personal experience. Qualitative data support this notion, since teachers and lecturers who provide 'real-life' examples or draw upon students' experience are perceived as creating context within which personal engagement can be developed (Wenger, 1998; Aikenhead, 2005).

There are different perceptions between students and lecturers

University students had significantly lower (p<0.001) perception of Teacher Qualities than lecturers, and lecturers had significantly lower (p<0.001) perceptions of Student Engagement scales than did university students. The gap between university students and their lecturers for the Student Engagement scales was substantial, as was that between school students and their teachers. These differences in perception reflect a similar trend reported for university students (AUSSE, 2010), in which students considered themselves less engaged than did their lecturers, and in which lecturers overestimated the proportion of students who were very satisfied with their learning environment. Data also showed that the mean scores for Lecturer Qualities given by school and university students were lower than those given by teachers and lecturers.

Focus group discussions revealed a culture in which students and staff were more ready to attribute short-fallings to each other than they were to reflect on their own involvement. University lecturers similarly blamed high-school science education, particularly the unit/assessment structure of NCEA, for the shortcomings of Year 1 science students. Biggs (1999) labelled this the 'blame-the-student' theory of teaching and notes as characteristic of a teacher-centred, transmission-based, contents-based learning environment: *'blame-the-student' is a comfortable theory of teaching. If students don't learn, it's not that there is anything wrong with the teaching, but that they are incapable, unmotivated or otherwise not doing what they are supposed to be doing. The presumed deficit is not the teacher's responsibility to correct (p. 22).*

Perhaps the most important aspect of a 'blame-the-student' attitude is that, by absolving the teacher/lecturer from responsibility for students' learning, it risks instilling an expectation of failure into students. Moreover, the culture of blaming NCEA means that lecturers teaching introductory papers seem to display little confidence in either the breadth or depth of students' knowledge so may gear their teaching towards the lowest common denominator. Where failure is attributed to a lack of (intrinsic) ability on the part of the student, loss of motivation is likely. But equally, where failure occurs despite significant effort to understand material (e.g., where faced with impossible memorisation tasks, or material that has been explained in a way that renders it incomprehensible), loss of motivation and engagement with the subject is likely (Biggs, 1999).

It's not what is taught, but how it is taught

Where the teaching environment is student-focused and fosters active learning, it is likely that there will be deep learning, good retention of knowledge and an improved recognition of the value of information (e.g., Meyers & Jones, 1993). Hence, for example, Zepke et al. (2006) advocated a shift from lecturer-centred teaching to student-centred teaching, which would also see the lecturer becoming a greater provider of clarity, feedback, and encouragement for students. In the focus groups, students indicated that they thought lecturers relied on transmission methods of instruction in an environment that was teacher-focused and did not stimulate active learning. The association between the pedagogical environment and students' engagement with learning is well known, but it appears that some lecturers and teachers may have yet to develop their teaching practice in accordance with this knowledge.

The role of technology in teaching has been the subject of debate. While technology can provide opportunities, it must be used in the context of appropriate pedagogies and learning design principles (Stefani, 2010). Results from the present study support this view. Thus, although Year 1 university students indicated that they considered their lecturers to be leveraging up-to-date teaching technologies, the relationship between the Maximizing Technology scale and student engagement was weak. Furthermore, focus group discussions emphasised that while the use of 'teaching technology' was not necessarily associated with greater engagement or better learning, the absence of reasonably up-to-date technologies was likely to be met with dissatisfaction.

Tytler (2003) suggested that online systems that merely manage teaching have little impact on learning, whereas when students can use computers to undertake/submit assignments, follow planned work schedules, contact experts via web quests, or use data loggers attached to computers to record on-going data from an investigation are more likely to improve engagement. Technology per se may not have a great effect on student engagement unless it is an integral part of the teaching and learning environment. Specifically, the use of technology does not provide a 'fix' if a learning environment is fundamentally inimical to the principles of good adult learning.

The Self-directed Learning scale referred to the scope for students to direct their own learning. The scores, by staff and students alike, at the secondary and tertiary levels, showed that such scope was limited. Focus groups with university students indicated that while they found this situation unfavourable, they were more-or-less resigned to homogeneity in their tertiary education, citing large class sizes as being inimical to students' ability to make significant choices. It was therefore surprising to see that the

Self-directed Learning scale was negatively related to Commitment to Performance in the multivariate analysis. Perhaps this should be interpreted to mean that students know their own preference for learning in their first year at university, but engagement may be reduced when lecturers are unable to provide opportunities for them to engage with science using their preferred style.

Science students want to be scientific

Both school and university students gave low mean scores for Relevant Contexts. The scores given by students were substantially lower than those given by their teachers/lecturers. However, relevance and context are important to students, and focus groups emphasised that the initial attraction of many students towards the sciences is because they consider them to be contemporary and meaningful to people, society and technology. Conversely, where science is not presented in relevant contexts, students are unlikely to be excited about their learning. The higher scores for this scale given by university compared with school students may imply that university lecturers find more opportunities than school teachers to show that science is meaningful to people, society and technology, but it could equally indicate that, by entry into university, students have more life-experience on which to create context.

The importance of developing relevant contexts in an adult learning environment has been previously highlighted (e.g., Knowles et al., 1998; Biggs, 1999; Wlodskowski, 1999), particularly as a means of providing a point of personal reference upon which students can embed conceptual material. In other words, where students are given opportunities to develop a personal connection to science and or recognise its societal worth, they have a greater ability to develop understanding. This may explain the observation of the European Commission (2004) that the initial cause of disaffection among many students on their entry to university is that they typically feel themselves to be *'plunged into novel seas of abstract thought and expected to swim for themselves'* (p. 106). This problem is not, however, unique to university. Osborne and Dillon (2008) showed that school science is often presented as a set of stepping-stones across the scientific landscape and lacks sufficient exemplars to illustrate the application of science in context. The need for exemplars, context, and opportunity to establish personal reference points seems to be an important aspect of the learning environment for the development of conceptual frameworks and the comprehension of factual material that fits within these frameworks.

One of the most remarkable findings of this study was that the scores given by both school and university students for Scientific Methods indicated that the concepts of the scientific method were not well embedded in their science education.

From the qualitative data, it was clear that school and university students both value and enjoy planning and undertaking their own investigations. Unfortunately, it was also clear that while university students enjoyed 'hands-on work', they felt that laboratory classes were more likely to require following a prescribed set of instructions to achieve pre-determined findings that provided little intellectual engagement with the subject, or the concepts that underpin it, or the nature of science itself. Some university students also reported in focus groups that 'laboratory classes' were often little more than supplementary lectures, with negligible opportunity for active learning. On the other hand, there were individual university lecturers who had put a great deal of thought and effort into designing laboratory classes and, in some cases, lectures that gave students opportunities for the generation and testing of hypotheses, and these classes were highly engaging. Moreover, the level of teaching practice represented by these lecturers was, in many cases, outstanding – to the extent that some had earned prestigious teaching awards at a university and/or national level. What appeared to be lacking were mechanisms at an institutional level that would encourage and promulgate such practice.

In the secondary sector, the ability to provide practical instruction could be limited by laboratory facilities where these were inadequate. More universally, teachers identified the need to cover curricular content and time constraints as the main issues for not engaging with laboratory practicals. This was exacerbated in schools that lacked discipline specialists to teach students in each subject and curriculum design of the NCEA Achievement Standards. In these situations some students were unable to study the 'investigation' Achievement Standards [AS 2.1 and AS 3.1] in Years 12 and 13, to bring this area forward into tertiary study.

Student engagement is not lost in transition

Using the Commitment to Performance scale as the primary measure of students' engagement, it was clear that many first-year university students perceived themselves to be committed to a high standard of performance in their science studies. Curiously, although the mean scores given by school students for this scale were similar to those of university students, significantly fewer gave scores ≥4 (57% vs. 38%: 1–5 scale), especially where less than three sciences were being studied. It might seem logical that school students who were studying fewer science subjects would be less engaged than those who were studying more subjects (although, conversely, it would not be difficult to argue that students who had chosen a single science had done so because they were particularly interested in it). Similarly, Hipkins et al. (2006) reported better engagement among school students in New Zealand students taking three core science subjects and/or mathematics in Year 13 than in those taking a single subject. In the face of the steady decline in numbers of students taking more than one science subject in the final year of school (Australia: Fullarton, 2003; New Zealand: Hipkins & Bolstad, 2005) it seems clear that there is need to support the science learning of those students who are not 'specialising' in the sciences during their later years in secondary school.

The transition from school to university

The transition from school to university should be characterised by a change in teaching and learning environments from a more to a less dependent mode. It was clear from both students' and staff commentary that understanding the difference between school and university is pivotal to understanding how students make the transition between the sectors. At school, subjects are generally taught by one teacher who is responsible for 'teaching' the contents, and also has a 'pastoral oversight' of how/whether the student is engaging with the subject. At university, a subject is likely to be taught by multiple staff with very limited responsibility for 'pastoral oversight' of the student's progress. Some students can cope with this transition but, judging by fall-out rates of school-leaver entrants to university, many cannot. These differences appear to represent key areas in which secondary and tertiary institutions need to work together to help students make the transition between sectors.

It was clear from the data that student engagement was strongly influenced by factors related to the teaching environment, of which Lecturer Qualities were the most important. Other factors with a significant impact on engagement were the extent to which material allowed the development of relevant contexts, supported individual students' choices regarding content, and was supported by appropriate technology. Fostering students' engagement with science is well within the means of New Zealand's schools and universities.

Nonetheless, it was also clear that most teachers and lecturers genuinely want students to be engaged with science for its own sake, and to develop a depth of understanding that will allow them to become innovative thinkers – as in the strategic priorities of MoRST. The trouble is that there is content, often a great deal of content, that has to be mastered – at secondary and tertiary levels – that is vital to the development of understanding and creativity. This raises the question: should content knowledge be given pre-eminence at the risk of losing interest (i.e., engagement), or, as argued by many lecturers, should students *'attempt to apply imperfect knowledge to scientific problems at the risk of forming invalid thought patterns'?* It appears from the data that emphasising content knowledge at the expense of context and application of that knowledge reduces engagement. Consequently, knowledge needs to be presented in ways that emphasise its relevance to the personal, career, and educational aspirations of the students. This presents a conundrum for universities, because on one hand, present circumstances dictate that the most cost-effective way to teach introductory material is in generic units that can accommodate students from a wide range of subjects, while on the other hand, if such generic units are not seen to be relevant to the subject which the student actually wants to study, engagement and retention can be reduced.

One result of the aforegoing appears to be the development of a culture of mutual blame and recrimination. The data showed strong evidence of academics 'blaming-the-students' for poor outcomes, while students 'blamed the teachers' for not motivating them. Likewise, lecturers 'blamed the schools' for not providing key [assumed] knowledge, while teachers 'blamed the universities' for failing to keep abreast of changes in high school science curricula.

The solution to the outward-looking problem (i.e., blaming another party) is actually an inward-looking process of reflection (i.e., what do 'we' rather than 'they' need to do better). Pivotal to this process is dialogue between the parties, to understand what limitations and opportunities constrain or facilitate each other's processes for change.

Dialogue between and within schools and universities

Identification of key factors that affect engagement in sciences allows for the development of a framework for nurturing students' engagement during their transitions between secondary and tertiary education.

Pivotal to this framework is dialogue between the sectors. Dialogue is needed so that the tertiary sector knows what and how students have learnt in the secondary sector. It is needed so that the secondary sector understands what and how students are expected to learn when they enter tertiary sector. It is needed to ensure that pedagogical best practices are implemented across both sectors, and that the approach during the transition is characterised by continuity and planned progress. Dialogue is needed to replace a culture of blame with a culture of cooperation and collaboration.

A model for this dialogue is presented in Figure 5.1. This figure should be interpreted as a framework that nurtures and enhances the dialogue between the secondary and tertiary sectors. The 'school' must be looked at through a generic lens representing the teachers, the educational and organisational structures, and the complex interactions that occur within the 'school'. A similar lens should be used with the university sector.

Key questions about engagement and transition that have been identified from the evidence of the current research are represented by the text between the 'school' and 'university' boxes. For each of these, dialogue should focus on what is needed between, and within, educational sectors to promote engagement and to optimise transition. Such dialogue needs to occur at different levels: between sectors at the levels of qualifications frameworks; within disciplines across sectors; between schools and universities who cater for each other's students; and between students and teachers/lecturers within a sector. Dialogue also needs to take place within each sector to develop institutional cultures that ensure promulgation of best practices in terms of pedagogy and structures (e.g., units of study, programme design) that emerge from these dialogues.

What is taught?

The first questions relate to 'what is taught.' In the present context, this will be largely equated with content and, although the interactions between content and delivery are inescapable, delivery will largely be considered under later headings.

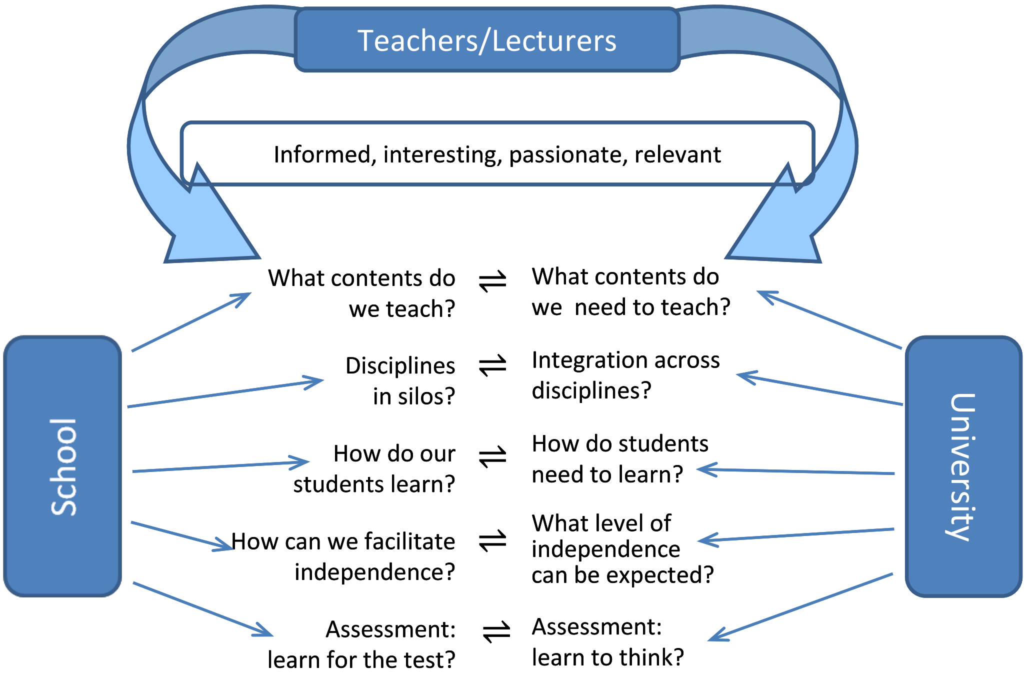

Figure 5.1: Dialogic framework for collaboration between and within the secondary and tertiary sectors to promote engagement and to facilitate transition of students between sectors.

Questions regarding 'what contents do we teach?/what contents do we need to teach?' provide possibilities on various levels. They open a dialogue between schools and universities on the pre-entry/entry content requirements for studying sciences at a tertiary level. On another level they provide opportunities for school teachers and lecturers to evaluate the content requirements, while within the university they open a dialogue between lecturers and curriculum managers about degree structures. The results of these dialogues, at the different levels, get communicated as explicit intentions to all.

Lecturers, teachers, and school and university students all noted that heterogeneity of attainments between students on entry to university created difficulties in managing content during the first year at university. Resolution of these difficulties, while maintaining the undoubted advantages of student choice within the secondary sector, could be achieved through questions such as:

- What core content is essential for entry to a given discipline at university? How is this mirrored in the units that school students should study?
    - What units should science students study at school? How should universities communicate to schools which NCEA units are required knowledge for entry to specific degree programmes?
    - How should the liaison between university programmes and school syllabuses take place, to ensure that the pre-requisite requirements (in terms of content knowledge) of the former are met?

- How should the balance between ‘easy’ and ‘hard’ NCEA credits be managed at schools, to the benefit of those students who are, as well as those who are not, intending to undertake post-secondary science study?
- How should universities best build upon the diversity of knowledge that results from the unit-based NCEA high school education? Do universities need entry-level programmes to accommodate this diversity? Is there a need for pre-entry ‘catch up’ courses to ensure that any pivotal material that has not been taught at school is covered before entry to the degree programme?

Students, particularly those at university, may find it difficult to make connections between material in which the content is taught on a discipline basis. This approach can fail to develop context and hence can exacerbate low engagement. Conversely, lecturers may believe that students cannot make meaningful links between disciplines until they have achieved a degree of mastery of the ‘core contents’ of each individual subject. On the other hand, while the literature (e.g., Harden et al., 1984) argues that integration of content results in better learning outcomes than discipline-based delivery of content, programme structures, and departmental structures are often poorly compatible with such delivery. Again, questions that might help resolve such issues could include:

- How can the pedagogical advantages of integration between disciplines be achieved in institutions that are largely organised into discipline-based ‘silos’?
    - How can degrees be structured to promote integration? How can foundation information (where this is unavoidably discipline-based) be contextualised for the subject that students have actually come to study?
    - How can integration be promoted within degrees, in situations where considerations of cost-effectiveness may suggest that ‘generic’ discipline-based foundation papers should be taught across many degrees?
    - At a more basic level, is the model of [3 years x 8 papers = 1 degree] still a valid way of delivering tertiary science education? Is such a model compatible with, and does it build on, the structures to which students have been exposed in NCEA?

As a result of these dialogues, it should be possible to determine how and whether the content that is taught to Year 12/13 school students and to Year 1 university students should be modified.

How do students learn?

Questions of how students learn appear to be harder to unravel than those about content, despite the plethora of literature on children’s and adults’ learning. Nonetheless, questions regarding how students learn require a careful scrutiny of the teaching and learning environments in which students study science, in both the secondary and tertiary sectors, particularly as these are closely related to the issues of engagement that were the focus of the present research. Moreover, the ‘how’ of learning is closely intertwined with the ‘what’ (content] that is to be learnt, especially where learning objectives for content are framed in terms that promote shallow or passive learning rather than deep or active learning. Indeed, it could be argued that questions about ‘how students learn’ are perhaps the pivotal issue we have been addressing in this research – namely, whether science education in New Zealand is educating scientists.

Questions that will help resolve issues surrounding how students learn are often explored via learning outcomes. Relevant questions include:

- Does the pedagogical environment of science education promote students' attainment of intellectual independence and development of high order cognitive and non-cognitive learning outcomes?
    - Are the explicit (i.e., stated) learning outcomes of secondary and tertiary science education compatible with these aims? Are they couched in terms that emphasise lower order outcomes, or limited to the cognitive domain?
    - Are the implicit learning outcomes (i.e., those that are reflected in the teaching environment and assessment methods) also compatible with these aims? Are they compatible with the explicit outcomes?
    - Are there mechanisms by which institutions can ensure that there is alignment of implicit and explicit learning outcomes, and alignment of both with an overall aim of effective education as scientists?

Many of these questions need to be answered via internal dialogues, particularly within tertiary institutions since these have more autonomy in determining curricula than do secondary schools. Each level at which the dialogue can take place (for example, administration with academic directors, faculty with degree coordinators, lecturers with their peers) seems to present valid opportunities for the positive development of the pedagogical environment.

Questions that could facilitate a useful dialogue to address the transition between secondary and tertiary sectors include:

- How do schools and universities provide opportunities for students to become engaged with science? What relevant context and opportunities are provided (in both sectors) to nurture engagement and independence?
    - How do schools foster a culture of independence in their senior students? How do they help students to start to develop critical thinking skills?
    - How do universities recognise and build on the independent learning skills that students have developed at school? How can universities best nurture incoming students during the development of their independent learning skills?
    - How do universities (and schools) ensure that high-order learning outcomes and independent learning do not become swamped by demands to acquire large amounts of 'basic' factual information? How do they support and develop engagement while students acquire essential factual information?

The third issue linked to 'how students learn', which would form the basis of valuable dialogues, is that of relationship between assessment and learning. Again, there is an extensive literature on this subject, yet the results of the present research indicate that these issues are by no means resolved in science education. Without revisiting the entire subject of assessment, some questions that might bring about useful dialogues that are relevant to the present results include:

- How is learning assessed (at school and university)? Does assessment reinforce low order learning or reward critical thinking?
    - How is feedback on assessment given – is there a dialogue between teacher/lecturer and student on their attainment of expectations?

- How can students' abilities as independent learners be assessed? What opportunities are there for early remediation where these are deemed inadequate?
- Do students 'learn to the test' or do assessment practices encourage critical thinking? Do assessment practices encourage extrinsic or intrinsic motivation?

Effective teaching

The key finding of the present research is that the interaction between the teacher/lecturer and the student is the most important single factor in determining student engagement.

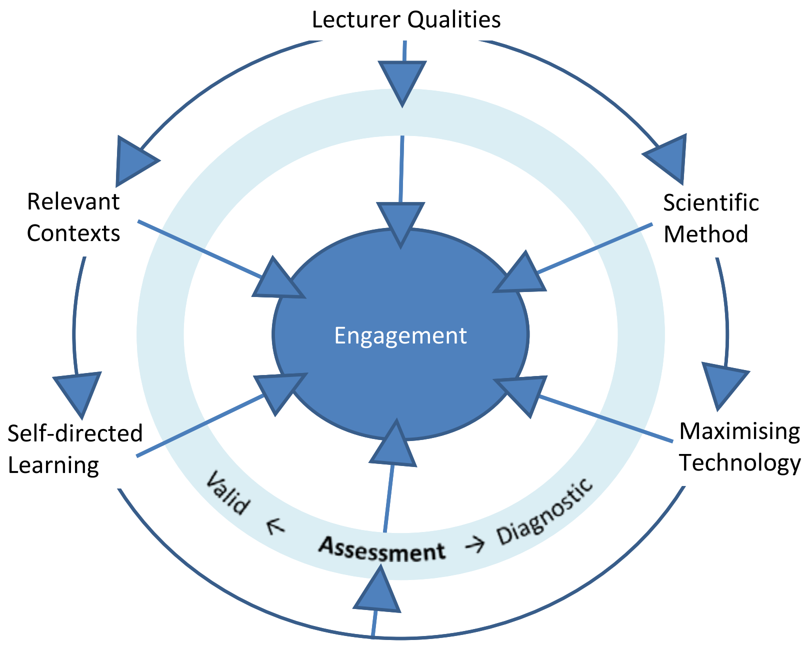

Figure 5.2: Relationship of aspects of 'teacher efficacy' with the engagement of their students.

The relationship between the teacher efficacy scales and students' engagement is summarised in Figure 5.2. While the Teacher Qualities scale was the most important in the quantitative data, both qualitative and quantitative data showed that effective teachers also created relevant contexts for information, promoted self-directed learning and students' understanding of scientific method, and could also incorporate a range of technological innovations into their teaching.

Alternatively, teachers/lecturers may 'simply' be passionate and interesting, and interested in their students – and those factors seem to be enough to engender engagement. Regardless, students' engagement is affected by the magnitude of the factual load and the assessment methods that are used to evaluate their learning. Thus, assessment practice seems to be a 'filter' through which everything else a teacher/lecturer does is ultimately judged.

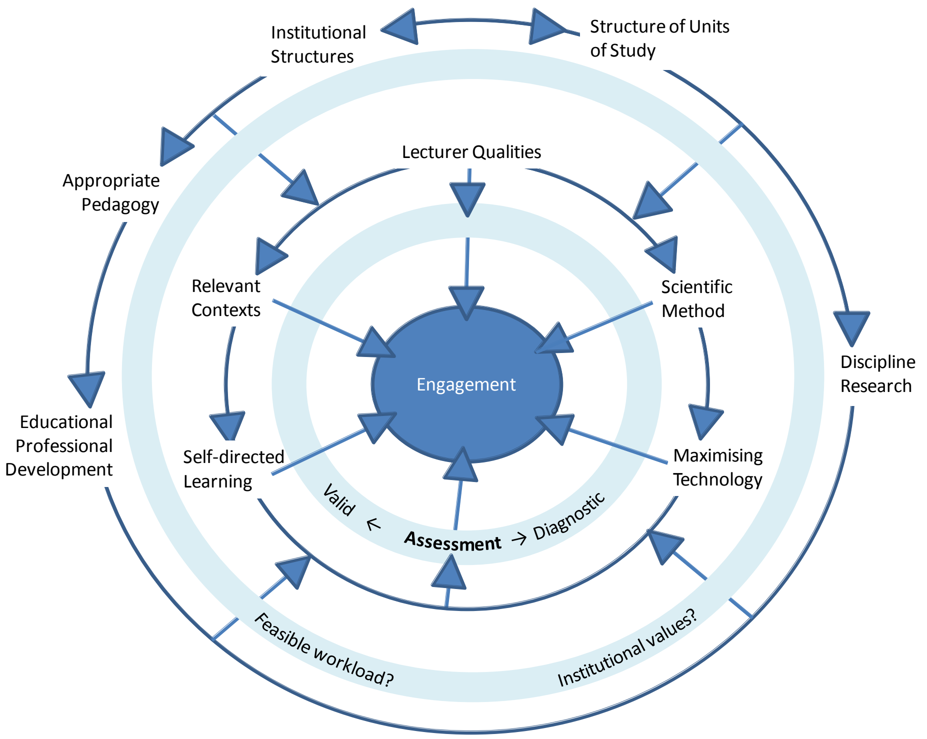

Figure 5.3: External influences on the relationship between teacher efficacy and student engagement.

The teaching effectiveness of individual lecturers and teachers, however, is constrained by the institutional environment in which they work. For example, it is of limited value if an individual teacher attempts to promote integrative or critical thinking where the structure of units of study enshrines discipline-based teaching or replicative learning. During the present research, the factors placed in the outer ring of Figure 5.3 were all cited as significantly affecting the effectiveness of individuals' teaching and, as with students who view teacher efficacy through a filter of the assessment environment, so teachers/lecturers view their ability to be effective through filters of workload and institutional values (i.e., what they perceive that the institution will reward them for doing). Research is of particular importance in this regard. Research activity that is rewarded at the expense of teaching activity will lead staff to concentrate on the former and neglect the latter, yet universities are mandated to develop and reward the teaching-research nexus. In terms of the dialogues that are needed to promote high quality teaching, this seems to be an area that is overdue for action.

Limitations of the study

Further research is required in a range of issues. School students' engagement with science earlier in their high school years deserves further investigation, as the present study focused on students in their next to last year of school. An additional limitation of the study is that it included only learners who were engaged in science, and omitted those who had already discontinued their science studies. It is also worth exploring the value that science education in schools may have beyond preparing students for university: skills in critical thinking, for instance, have broader applicability as life skills.

Conclusions

Key findings

Teachers/lecturers influence student engagement.

Students' engagement, both at school and university, is strongly influenced by the teaching environment.

'Lecturer/teacher qualities' are the most important aspect of teaching environment. Other factors that affect engagement are the extent to which material allows the development of relevant contexts, development of students' scientific critical thinking skills, supports individual students' choices regarding content, and is supported by appropriate technology. An environment based primarily on the assimilation of 'science facts' is detrimental to engagement.

There are different perceptions between students and lecturers.

Students' perception of their engagement was greater than that of their lecturers/teachers, while teachers' and lecturers' perception of their teaching qualities were greater than that of their students.

Consequently, there appears to be a culture in which students and staff are more ready to attribute their short-fallings to each other than they are to reflect on their own involvement.

It's not *what* is taught, but *how* it is taught.

Science teaching at school and university is generally based on transmission methods of instruction in an environment that is discipline-based, teacher-focused, and does not stimulate active learning. Teaching that is integrative, student-focused, stimulates active learning and allows some student choice in content promotes engagement. Technology is only an effective aid to teaching when it is use as part of an active learning environment.

Science students want to be scientific.

Relevance and context are important to students, many students are attracted to the sciences is because they consider them to be contemporary and meaningful to people, society and technology. Similarly, students enjoy the ability to explore scientific methods by generating and testing hypotheses in practical classes. Students considered these concepts were weakly embedded in their science teaching. Where they are not duly emphasized, students are unlikely to be excited about their learning.

Student engagement is not lost in transition.

First-year university students consider themselves to be committed to a high standard of performance in their science studies, and are no less committed than are senior high-school students.

The process of transition.

Key differences between the university and school environments are that at school one teacher usually teaches all of a subject and has a considerable pastoral oversight of the progress of the student. Whereas at university subjects are usually taught by many lecturers, each of whom has very limited pastoral oversight of an individual student's progress.

Ideally, university teaching should place greater emphasis upon independent learning and critical thinking than that of school. Yet the results of the present study showed that this progress was not necessarily evident during the first year of study at university.

Heterogeneity of study at school means that universities cannot accurately predict the knowledge with which a student will enter university study. Early units of study therefore run risks of either (i) teaching to the 'lowest common denominator' or (ii) presenting material that 'goes over the heads' of a significant proportion of students in the class. Either of these situations impairs engagement.

Resolving these issues

This study recommends a series of dialogues within and between the secondary and tertiary education sectors. Some of these dialogues refer to content and curriculum process:

- Universities need to identify what core content is essential for entry to tertiary study in a given discipline. Universities and schools need to liaise to ensure that this core content is met by the units that school students study.
- Universities need to determine how to best build upon the diversity of knowledge that results from the unit-based NCEA high school education. Universities need to liaise with schools to ensure they are conversant with the content and process knowledge students have attained at the end of secondary education, and tailor their entry-level programmes accordingly.
- Universities should consider how best to promote integration in first-year tertiary study, particularly with respect to determining how the pedagogical advantages of integration between disciplines can best be achieved in institutions that are largely organised into discipline-based 'silos'.

Underpinning such questions is the need for a more fundamental dialogue about the pedagogical environment in which science education takes place:

- The pedagogical environment of science education needs to be developed to promote students' attainment of intellectual independence and high-order cognitive and non-cognitive skills, at all levels of their studies.
- Assessment practices at school and university need to promote engagement, particularly by rewarding critical thinking rather than reinforcing low-order learning.
- Lecturers, and perhaps teachers, need to be assisted to development skills in the 'teacher efficacy' parameters identified by the present research as being critical for students' engagement.

- Consideration needs to be given to the structures and systems that are needed to create institutional environments that are favourable for such developments to occur.

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Appendix 1: Questionnaire and focus group questions

Appendix 1.1 Questionnaire questions.

The first 50 items refer to 'teacher efficacy' and the second 50 to 'student engagement' Questions were randomised through the questionnaire

I am asked to learn how scientific ideas have developed over time
I am asked to learn about major 'breakthroughs' in science
I am asked to learn how science impacts people, society and technology
I am asked to learn about how science relates to contemporary issues
I am asked to consider ethical issues surrounding science
My lecturers explain science in the context of real-life examples
My lecturers relate science to things that interest me
My lecturers use a variety of techniques to help me learn a topic
My lecturers teach content directly out of a textbook / written notes
My lecturers explain the principles of a topic before teaching me detailed facts
My lecturers use my existing knowledge of science as a starting point
My lecturers use my questions as a springboard for the next step
I am expected to apply my previous science knowledge to new topics
I am expected to integrate knowledge across different sciences
I am expected to develop my knowledge through class discussion
I am expected to contribute my knowledge to team projects
I am given the opportunity to reflect on which tasks helped me learn most effectively
I am given the opportunity to seek clarification on things I am trying to learn
I am expected to undertake practical science investigations
I am expected to plan the investigations that I undertake
I am expected to evaluate then interpret scientific data/evidence for myself
I am expected to use data/evidence to solve scientific problems
I am expected to use data/evidence to develop a logical scientific argument
I am given the opportunity to influence what topics I am taught
I am given the opportunity to influence the way that I am taught
I am given the opportunity to learn at my own pace
I am given the opportunity to collaborate with other people
The criteria on which I will be assessed have been made clear to me
I am assessed using a variety of methods
Assessment is embedded throughout my course
Assessment tasks allow me to demonstrate what I have learned from a topic
My lecturers give me feedback on my performance in assessment tasks
I am assessed on my ability to memorise scientific facts
I am assessed on my ability to interpret scientific data
I am assessed on my ability to discuss scientific concepts
My lecturers use up-to-date technology for teaching
I am given the opportunity to use up-to-date technology during investigations
I am given the opportunity to use up-to-date technology to complete assignments
I am given the opportunity to use up-to-date technology to develop my knowledge
I am given the opportunity to interact with the wider science community
I am given the opportunity to study science outside the classroom / laboratory
I am given the opportunity to listen to external people talk about science
My lecturers inspire me with their enthusiasm
My lecturers encourage me with their positive comments
My lecturers support me with constructive feedback to go forward
My lecturers empower me with useful resources
My lecturers stimulate me with the way they teach content
My lecturers reward me with fair grades
My lecturers value my contribution in class
My lecturers care for me by creating a class environment that protects my individuality
I learn how scientific ideas have developed over time
I learn about major 'breakthroughs' in science

I learn how science impacts people, society and technology
I learn about how science relates to contemporary issues
I consider ethical issues surrounding science
I apply my previous science knowledge to new topics
I integrate knowledge across different sciences
I develop my knowledge through class discussion
I contribute my knowledge to team projects
I reflect on which tasks helped me learn most effectively
I seek clarification on things I am trying to learn
I undertake practical science investigations
I plan the investigations that I undertake
I evaluate then interpret scientific data/evidence for myself
I use data/evidence to solve scientific problems
I use data/evidence to develop a logical scientific argument
I take the opportunities that are given to listen to external people talk about science
I take opportunities to influence what topics I am taught
I learn at my own pace
I chose to collaborate with other people when I am given the opportunity
I learn by memorising scientific facts
I learn by interpreting scientific data
I learn by discussing scientific concepts
I use technology to develop my knowledge
I interact with the wider science community
I ask questions in science class
I take the opportunities that are given to me to study science outside the classroom / lab
I strive to get good grades in science
I set high performance standards for myself in science
I tell other people how much I enjoy studying science
I get excited when I discover things about science
I apply my knowledge of science to things in my life
I discuss science issues with other people
I strive to do my best in science
I use resources in addition to the set text to study science
I use the set texts and study guides to study science
After science class, I reflect on what I've learned
I do more science study than is required just to complete assignments
I ask for help from my science lecturers
I challenge myself to explore the 'deepest secrets' of science
Before I start a science assignment, I plan how I am going to do it
I complete science assignments by their deadlines
I take opportunities to influence the way that I am taught
It takes me no longer to complete science assignments than the hours suggested
If I can, I study in an environment that is free from distraction
I balance social activities / employment so it doesn’t distract me from studying science
I try to attend science classes
I work hard to understand things I find confusing about science
I strive to keep up to date with my science studies
I intend to stay in science

Appendix 1.2 Demographic questions of different participant groups

All groups:

- Gender (male/female)
- Ethnicity (European-Pakeha, Māori, Pacific Islander, Other)

University students

- Degree programme
- Prior school science curriculum (NCEA, A-level, International Baccalaureate)
- Year of leaving school (enrolment validation question)

School students

- School science curriculum (NCEA, A-level, International Baccalaureate)
- What sciences subjects are being studied (1, 2, or 3 sciences, biology, chemistry, physics, mathematics)
- Intention to study science at University (yes, no, maybe)

University lecturers

- Title (professor, associate professor, etc.)
- Paper coordinator (yes, no)
- Number of hours teaching each semester
- Full time/part time
- Academic preference (do you prefer disseminating information or discovering information?)

School science teachers

- How many years teaching senior high school science
- Where primary teaching training occurred (NZ, overseas)

Appendix 1.3 Focus group and interview questions

Participant Group	Questions
University Students	What is your favourite thing about Science? Please complete these statements: In science class, I really like it when... In science class, I really *don't* like it when... In science class, I would really like it if... What is the biggest difference between Science at school and university?
University Lecturers	What three things engage your students in your Science papers? What knowledge and skills do students have when they enter your class; and what do you want them to have by the end of the year? What can students do to help themselves? What can lecturers do to help students engage with their learning? If you could 'blue sky' your area of science teaching, what would you do?
University Programme Directors	What knowledge and skills do students have when they enter your programme; and what do you want them to have by the end of the year? How well prepared are school-leavers for entrance to tertiary science study? What are the major issues that your programme faces in teaching students who have just completed high school?
School Students	What is your favourite thing about Science? Please complete these statements: In science class, I really like it when... In science class, I really *don't* like it when... In science class, I would really like it if... What are your plans for the future?
School Teachers	What three things engage your students in your Science classes? What knowledge and skills do students have when they enter your class; and what do you want them to have by the end of the year? What can students do to help themselves? What can the school do to help students engage with their learning? If you could give one piece of advice to university teachers, what would it be?

Appendix 2: Relationship between demographic data and questionnaire responses

In each of the tables in this appendix, data are presented as the arithmetic mean (1–5 scales, in which 1 = never and 5 = always) for the individual items making up each scale (See Table 2.5 and 2.6 for details). *p* values are the significance of overall differences within a column (univariate ANOVA). Post hoc analyses are not shown.

Appendix 2.1: Relationship between gender and questionnaire scales of teacher efficacy and student engagement

Gender		Teacher efficacy					Student engagement		
		Lecturer Qualities	Relevant Contexts	Scientific Methods	Self-directed Learning	Maximizing Technology	Commitment to Performance	Learning with Excitement	Developing Meaning
University students	Male	3.4	3.1	3.4	2.8	3.5	4.0	3.4	3.4
	Female	3.4	3.1	3.3	2.6	3.6	4.2	3.3	3.2
	p	0.53	0.20	0.50	0.20	0.41	0.31	0.99	0.09
University lecturers	Male	4.3	3.2	3.4	2.3	3.7	3.5	3.0	3.1
	Female	4.0	3.0	3.1	2.3	3.5	3.4	2.9	2.8
	p	0.02	0.55	0.49	0.75	0.31	0.18	0.35	0.94
School students	Male	3.2	2.5	3.3	2.4	3.1	3.6	2.8	2.8
	Female	3.3	2.6	3.3	2.3	3.1	3.9	2.9	2.8
	p	0.66	0.70	0.60	0.71	0.62	0.17	0.70	0.59
School teachers	Male	4.3	3.3	3.5	2.5	3.5	3.8	3.1	3.3
	Female	4.3	3.2	3.6	2.5	3.3	3.6	3.1	3.2
	p	0.55	0.90	0.76	0.17	0.49	0.84	0.75	0.72

Boxes with a double outline are significantly higher (p<0.05) than other boxes in the column

Appendix 2.2: Relationship between ethnicity, and of whether English is the first language, with questionnaire scales of teacher efficacy and student engagement, for school and university students

Ethnicity		Teacher efficacy					Student engagement		
		Lecturer Qualities	Relevant Contexts	Scientific Methods	Self-directed Learning	Maximizing Technology	Commitment to Performance	Learning with Excitement	Developing Meaning
University students	Pakeha-European	3.4	3.1	3.3	2.6	3.6	4.1	3.3	3.3
	Māori	3.5	3.2	3.4	3.1	3.4	3.8	3.4	3.2
	Pasifika	3.7	3.3	3.6	3.2	3.8	3.9	3.7	3.4
	Other	3.4	3.1	3.4	2.9	3.5	4.1	3.4	3.4
	NZ Mix	3.5	3.1	3.6	3.0	3.8	4.0	3.3	3.3
	p	0.82	0.40	0.01	0.01	0.85	0.38	0.26	0.83
School students	Pakeha-European	3.2	2.5	3.4	2.2	3.0	3.7	2.7	2.8
	Māori	2.9	2.3	3.2	2.4	2.9	3.2	2.6	2.6
	Pasifika	4.0	3.3	3.7	3.1	3.8	3.8	3.1	3.4
	Other	3.4	2.6	3.3	2.6	3.3	3.8	2.9	2.9
	NZ Mix	3.2	2.5	3.2	2.1	3.0	3.6	2.8	2.9
	p	0.01	0.01	0.16	0.01	0.07	0.10	0.08	0.04
School students	Yes	3.2	2.5	3.3	2.3	3.0	3.7	2.8	2.8
English as 1st language	No	3.5	2.9	3.2	2.8	3.3	3.7	3.0	3.1
	p	0.95	0.01	0.16	0.01	0.08	0.32	0.91	0.03

Boxes outline in solid black are significantly lower ($p<0.05$) than other boxes in the column. Boxes with a double outline are significantly higher ($p<0.05$) than other boxes in the column. Boxes outlines with a thin black line tend ($0.10>p>0.05$) to differ from other boxes in the column. *p*: significance of univariate ANOVA within column

Appendix 2.3: Relationship between programmes of study and programme of study at school for university students, and of programme of study and future study intentions with questionnaire scales of teacher efficacy and student engagement

Studies		Teacher efficacy					Student engagement		
		Lecturer Qualities	Relevant Contexts	Scientific Methods	Self-directed Learning	Maximizing Technology	Commitment to Performance	Learning with Excitement	Developing Meaning
University students degree	BSc	3.4	3.2	3.4	2.7	3.5	4.1	3.4	3.4
	BVSc	3.5	3.2	3.4	2.5	3.7	4.5	3.5	3.3
	BEng	3.5	3.1	3.5	2.8	3.6	3.9	3.2	3.3
	BInfSci	3.5	3.1	3.4	2.9	3.5	3.8	3.3	3.4
	Other	3.5	3.0	3.2	2.6	3.6	4.0	3.1	3.1
	p	0.45	0.21	0.23	0.53	0.09	0.01	0.05	0.11
University students school curriculum	NCEA	3.4	3.1	3.4	2.7	3.6	4.1	3.3	3.3
	A-Level	3.4	3.0	3.3	2.4	3.2	4.1	3.5	3.3
	International Baccalaureate	3.5	3.1	3.2	2.8	3.4	4.1	3.5	3.4
	Other	3.5	3.1	3.3	2.6	3.5	4.2	3.4	3.3
	p	0.34	0.79	0.41	0.69	0.49	0.71	0.15	0.21

Appendix 2.3 (contd)

Studies		Teacher efficacy					Student engagement		
		Lecturer Qualities	Relevant Contexts	Scientific Methods	Self-directed Learning	Maximizing Technology	Commitment to Performance	Learning with Excitement	Developing Meaning
School students	3 Core Sciences	3.4	2.6	3.4	2.5	3.1	4.2	3.2	2.9
	Chemistry & Biology	3.3	2.8	3.6	2.4	3.1	4.0	3.0	3.0
	Chemistry & Physics	3.5	2.5	3.3	2.4	3.1	3.8	2.9	2.7
	Biology & Physics	3.5	2.8	3.2	2.1	3.0	3.7	2.5	2.8
	Chemistry only	3.3	2.1	3.3	2.2	3.3	3.5	2.6	2.5
	Biology Only	3.3	2.7	3.3	2.4	3.3	3.5	2.6	3.0
	Physics Only	3.0	2.3	3.3	2.2	2.9	3.5	2.6	2.5
	p	0.42	0.41	0.28	0.69	0.35	0.45	0.03	0.81
School students science at university?	Yes	3.4	2.6	3.4	2.4	3.1	4.1	3.2	3.0
	No	3.0	2.4	3.2	2.3	3.0	3.1	2.4	2.6
	Maybe	3.3	2.5	3.3	2.4	3.1	3.7	2.7	2.8
	p	0.40	0.47	0.30	0.47	0.48	0.01	0.01	0.13

Boxes outline in solid black are significantly lower ($p<0.05$) than other boxes in the column. Boxes with a double outline are significantly higher ($p<0.05$) than other boxes in the column. Boxes outlines with a thin black line tend ($0.10>p>0.05$) to differ from other boxes in the column. *p*: significance of univariate ANOVA within column

Appendix 2.4: Relationship between lecturer appointment and hours of teaching with questionnaire scales of teacher efficacy and student engagement

University lecturers		Teacher efficacy					Student engagement		
		Lecturer Qualities	Relevant Contexts	Scientific Methods	Self-directed Learning	Maximizing Technology	Commitment to Performance	Learning with Excitement	Developing Meaning
Paper coordinator	Yes	4.2	3.1	3.4	2.3	3.8	3.5	3.0	3.0
	No	4.3	3.0	3.0	2.3	3.3	3.5	2.8	3.0
	p	0.85	0.20	0.02	0.89	0.27	0.79	0.31	0.68
Title	Professor	4.3	3.4	3.3	2.1	3.7	3.6	3.0	3.5
	Ass Prof	4.6	3.3	3.7	2.8	4.3	3.8	3.1	3.3
	Senior Lecturer	4.1	3.1	3.3	2.2	3.7	3.5	2.9	2.8
	Lecturer	4.2	3.0	3.2	2.3	3.6	3.3	2.8	2.8
	Other	4.4	3.2	3.5	2.4	3.6	3.6	3.1	3.4
	p	0.74	0.25	0.62	0.85	0.45	0.57	0.03	0.47
Appointment	Full Time	4.2	3.1	3.3	2.3	3.7	3.5	2.9	3.0
	Part Time	4.3	3.2	3.5	2.4	3.4	3.3	3.0	3.1
	p	0.95	0.76	0.88	0.94	0.69	0.01	0.11	0.97

Appendix 2.4 (contd)

University lecturers		Teacher efficacy					Student engagement		
		Lecturer Qualities	Relevant Contexts	Scientific Methods	Self-directed Learning	Maximizing Technology	Commitment to Performance	Learning with Excitement	Developing Meaning
Teaching Semester 1	0.5 h	4.2	3.3	3.1	2.1	3.6	3.5	2.9	3.1
	6-10 h	4.2	2.9	3.4	2.3	3.9	3.5	3.0	2.9
	11-15 h	4.3	3.1	3.5	2.3	3.7	3.6	2.8	3.0
	≥16 h	4.3	3.2	3.6	2.9	3.8	3.5	3.1	3.1
	p	0.90	0.65	0.62	0.01	0.34	0.72	0.70	0.36
Semester 2	0.5 h	4.2	3.3	3.2	2.3	3.7	3.5	2.9	3.2
	6-10 h	4.2	3.0	3.3	2.1	3.7	3.6	3.0	3.0
	11-15 h	4.3	3.2	3.7	2.3	3.6	3.5	2.7	2.8
	≥16 h	4.4	3.3	3.3	2.6	4.0	3.3	3.1	3.0
	p	0.92	0.80	0.71	0.07	0.39	0.65	0.53	0.66
Information preference	Discovering	4.0	3.1	3.3	2.3	3.7	3.5	2.9	2.9
	Disseminating	4.3	3.0	3.2	2.3	3.7	3.4	2.9	3.0
	p	0.07	0.45	0.23	0.79	0.52	0.72	0.57	0.97

Boxes with a double outline are significantly higher ($p<0.05$) than other boxes in the column. Boxes outlines with a thin black line tend ($0.10>p>0.05$) to differ from other boxes in the column. *p*: significance of univariate ANOVA within column

Appendix 2.5: Relationship between school teacher appointment and training with questionnaire scales of teacher efficacy and student engagement

University lecturers		Teacher efficacy					Student engagement		
		Lecturer Qualities	Relevant Contexts	Scientific Methods	Self-directed Learning	Maximizing Technology	Commitment to Performance	Learning with Excitement	Developing Meaning
Teacher training	NZ	4.3	3.2	3.5	2.5	3.4	3.6	3.0	3.2
	Other	4.4	3.5	3.8	2.6	3.1	4.0	3.3	3.4
	p	0.12	0.89	0.66	0.44	0.92	0.02	0.66	0.03
Teaching time	0-3 y	4.4	3.1	3.8	2.6	4.0	3.6	2.9	2.9
	4-7 y	4.0	3.1	3.1	2.2	3.2	3.5	3.0	3.4
	8-12 y	4.5	3.3	3.8	2.5	3.1	3.8	3.3	3.3
	13-20 y	4.0	3.3	3.2	2.8	3.1	3.3	3.0	3.0
	≥20 y	4.4	3.4	3.6	2.5	3.4	4.0	3.1	3.3
	p	0.65	0.51	0.47	0.13	0.75	0.74	0.72	0.48

Boxes with a double outline are significantly higher (*p*<0.05) than other boxes in the column.

Appendix 3: Means, standard deviations and frequency of scores for teacher performance and student engagement scales

Table A3.1

Lecturer Qualities

Mean score	University students		University lecturers		School students		School teachers	
Mean (± *SD*)	3.44 (0.57)		4.22 (0.46)		3.27 (0.74)		4.29 (0.34)	
Mean score	*N*	%	*N*	%	*N*	%	*N*	%
1.0 - 2.0	7	1.2	0	0.0	24	6.1	0	0.0
2.1 - 3.0	140	23.8	1	1.8	118	30.1	0	0.0
3.1 - 4.0	363	61.6	14	25.5	189	48.2	5	20.0
4.1 - 5.0	79	13.4	40	72.7	61	15.6	20	80.0

Table A3.2

Relevant Contexts

Mean score	University students		University lecturers		School students		School teachers	
Mean (± *SD*)	3.11 (0.58)		3.11 (0.83)		2.54 (0.69)		3.24 (0.64)	
Mean score	*N*	%	*N*	%	*N*	%	*N*	%
1.0 - 2.0	21	3.4	6	9.5	112	27.7	2	6.7
2.1 - 3.0	283	46.5	24	38.1	208	51.5	10	33.3
3.1 - 4.0	276	45.3	27	42.9	78	19.3	18	60.0
4.1 - 5.0	29	4.8	6	9.5	6	1.5	3	10.0

Table A3.3

Scientific Methods

Mean score	University students		University lecturers		School students		School teachers	
Mean (± *SD*)	3.33 (0.59)		3.32 (0.84)		3.32 (0.62)		3.55 (0.69)	
Mean score	*N*	%	*N*	%	*N*	%	*N*	%
1.0 - 2.0	12	2.0	6	9.4	10	2.5	0	0.0
2.1 - 3.0	175	29.1	22	34.4	128	32.3	7	23.3
3.1 - 4.0	354	58.9	23	35.9	215	54.3	15	50.0
4.1 - 5.0	60	10.0	13	20.3	43	10.9	8	26.7

Table A 3.4

Self-directed Learning

Mean score	University students		University lecturers		School students		School teachers	
Mean (± *SD*)	2.69 (0.75)		2.28 (0.87)		2.37 (0.76)		2.48 (0.64)	
Mean score	*N*	%	*N*	%	*N*	%	*N*	%
1.0 - 2.0	138	22.4	29	46.0	167	41.1	12	38.7
2.1 - 3.0	313	50.9	22	34.9	174	42.9	15	48.4
3.1 - 4.0	137	22.3	11	17.5	55	13.5	3	9.7
4.1 - 5.0	27	4.4	1	1.6	10	2.5	1	3.2

Table A3.5

Maximising Technology

Mean score	University students		University lecturers		School students		School teachers	
Mean (± *SD*)	3.57 (0.65)		3.63 (0.91)		3.09 (0.76)		3.38 (0.70)	
Mean score	*N*	%	*N*	%	*N*	%	*N*	%
1.0 - 2.0	13	2.1	5	8.3	48	11.8	0	0.0
2.1 - 3.0	134	21.9	10	16.7	157	38.6	9	28.1
3.1 - 4.0	348	56.9	24	40.0	169	41.5	20	62.5
4.1 - 5.0	117	19.1	21	35.0	33	8.1	1	3.1

Table A3.6

Commitment to Performance

Mean score	University students		University lecturers		School students		School teachers	
Mean (± *SD*)	4.09 (0.60)		3.51 (0.41)		3.71 (0.77)		3.67 (0.42)	
Mean score	*N*	%	*N*	%	*N*	%	*N*	%
1.0 - 2.0	1	0.2	0	0.0	14	3.6	0	0.0
2.1 - 3.0	37	6.2	7	14.9	59	15.3	0	0.0
3.1 - 4.0	218	36.3	38	80.9	168	43.5	18	78.3
4.1 - 5.0	345	57.4	2	4.3	145	37.6	5	21.7

Table A3.7

Learning with Excitement

Mean score	University students		University lecturers		School students		School teachers	
Mean (± *SD*)	3.33 (0.65)		2.95 (0.35)		2.82 (0.81)		3.07 (0.40)	
Mean score	*N*	%	*N*	%	*N*	%	*N*	%
1.0 - 2.0	15	2.5	1	2.1	83	20.6	0	0.0
2.1 - 3.0	198	32.7	30	62.5	168	41.7	13	52.0
3.1 - 4.0	312	51.5	17	35.4	127	31.5	11	44.0
4.1 - 5.0	81	13.4	0	0.0	25	6.2	1	4.0

Table A3.8

Developing Meaning

Mean score	University students		University lecturers		School students		School teachers	
Mean (± *SD*)	3.29 (0.63)		3.00 (0.70)		2.82 (0.75)		3.22 (0.72)	
Mean score	*N*	%	*N*	%	*N*	%	*N*	%
1.0 - 2.0	20	3.3	5	9.6	74	18.2	2	6.7
2.1 - 3.0	212	34.6	20	38.5	192	47.3	13	43.3
3.1 - 4.0	317	51.7	24	46.2	127	31.3	12	40.0
4.1 - 5.0	64	10.4	3	5.8	13	3.2	3	10.0

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