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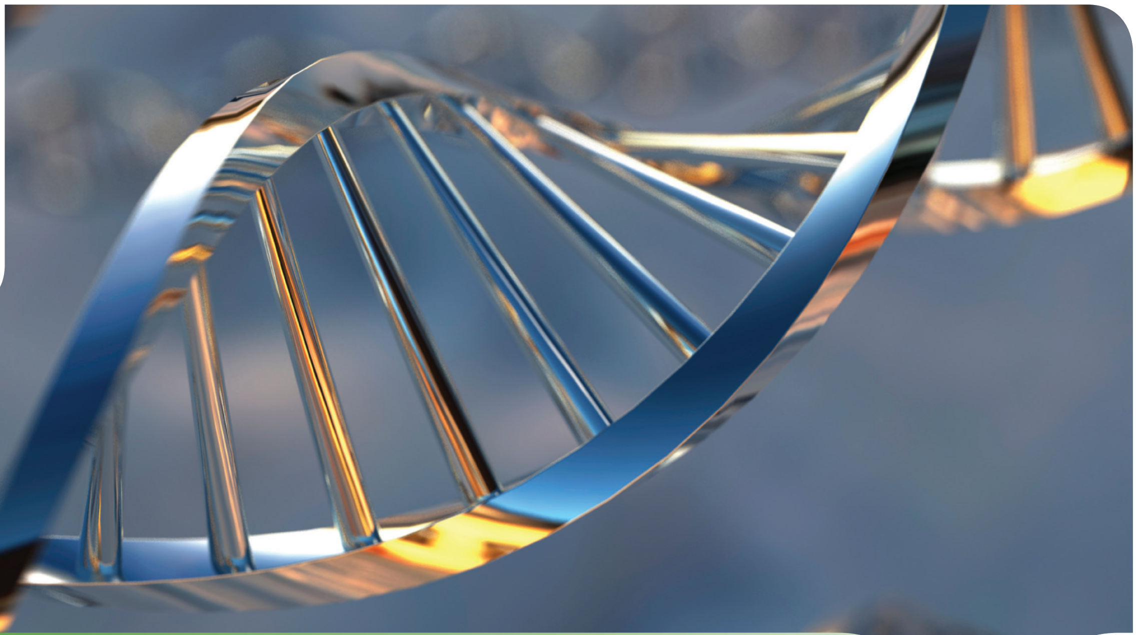

*Summary Report*

# Engaging Learners Effectively in Science, Technology and Engineering

## THE PATHWAY FROM SECONDARY TO UNIVERSITY EDUCATION

Tim J Parkinson, Helen Hughes, Dianne H Gardner,
Gordon T Suddaby, Marg Gilling & Bill R MacIntyre

AKO AOTEAROA
NATIONAL CENTRE FOR TERTIARY TEACHING EXCELLENCE

Massey University

# ENGAGING LEARNERS EFFECTIVELY IN SCIENCE, TECHNOLOGY AND ENGINEERING:
## The pathway from secondary to university education

Tim J Parkinson, Helen Hughes, Dianne H Gardner,
Gordon T Suddaby, Marg Gilling & Bill R MacIntyre

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PUBLISHED BY
Ako Aotearoa
P O Box 756
Wellington 6140

ISBN 978-0-473-18899-3 (print)
ISBN 978-0-473-18900-6 (online)

DESIGN AND LAYOUT: Fitzbeck Creative

JUNE 2011



To see the full report go to
http://akoaotearoa.ac.nz/

# Summary

This project was supported by the Ako Aotearoa National Project Fund 2008. To see the full report please go to http://akoaotearoa.ac.nz/


Considerable evidence exists of a world-wide trend of declining student numbers in school and university sciences. Much of the research evidence relating to student engagement in the sciences has focused on school students, with very little focusing on university students. Even less focuses on the transition and engagement of students from school to university science. This research seeks to understand how university students become or remain engaged in science during their transition from school to university. The aims of the project were to:

- improve student engagement in the study of science at university
- improve the transition from the school learning environment to that of university
- identify and promulgate pedagogical 'best practice' for science education in the first year at university.

Data were collected using a mixed-methods design that included a questionnaire and focus groups. Participants consisted of 421 secondary students, 630 first-year university science students, 33 school science teachers, and 69 university academic staff teaching in science-based programmes. Student engagement and transition were most strongly influenced by lecturers' style, personality, enthusiasm, and ability to place scientific knowledge into contexts that were relevant to the student, or which the students could construct for themselves. Lecturers' and teachers' perceptions of their teaching quality were significantly greater than those of their students and, conversely, students' perception of their engagement were significantly greater than those of their teachers/lecturers.

The findings provide clear evidence that more widespread use of best practice pedagogies and provision of relevant contexts would promote student engagement in the sciences at both secondary and tertiary education levels. Some key principles emerge from the study:

- Teachers and lecturers influence student engagement
- It is not what is taught, but how it is taught
- Science students want to be scientific
- Student engagement is not lost in transition
- Transition from school science to university science is a process
- There are different perceptions between students and lecturers/teachers.

Recommended responses to these findings are, first, to:

- assist lecturers and teachers to develop skills in the 'teacher efficacy' identified in this project
- ensure assessment practices at school and university reward critical thinking rather than reinforce low order learning
- ensure all content is delivered in a context that is immediately relevant to the learner.

Second, it is recommended that universities consider how to use most effectively the learning outcomes achieved by NCEA students in first year university study, by:

- building on the diversity of knowledge that results from the standards-based NCEA high school education
- guaranteeing liaison between universities and schools to ensure school leavers have the content knowledge needed to start their degrees.


University science students indicate higher levels of commitment to their studies than do school science students – does the university environment lever off this commitment as well as it could? [see results, page 9]

# Introduction

It seems to be getting harder to persuade people in New Zealand to study science. Getting students interested in science at school, getting them to choose science subjects at university, and keeping them interested in science through their tertiary studies is an increasingly serious problem in many western countries. These difficulties have led to concern in the governments of New Zealand and Australia about whether enough graduates are coming through the tertiary sector to maintain national development in the 'knowledge economy.'

Government initiatives have tried to understand the factors that promote students choosing 'the sciences' in their post-compulsory secondary education, as well as the factors that lead students to choose to study Science, Technology, Engineering and Mathematics (STEM) subjects at university. However, despite these efforts, there is substantial attrition of students in the transition between secondary and tertiary education, particularly during their first year of university study (Zepke et al., 2006; AUSSE, 2009; James et al., 2009). Some completely withdraw from university study, while others partially withdraw. More worryingly, even among those students who remain in university study, a significant proportion contemplates full or partial withdrawal from their studies.

This research project was undertaken to understand better how to engage learners in science so that more students would continue their university studies through to completion. This project sought to identify gaps between the science learning environments at high school and university, as well as identify the factors that promote (or inhibit) engagement with STEM at university.

Based on this information, a framework was designed to facilitate students' transition between the secondary and tertiary sectors. In the development of this framework close attention was paid to curricula and to the teaching methods in both sectors.

> This research seeks to better understand how university students become, or remain engaged in science during their transition from school to university.

Students and lecturers agreed that technology can contribute positively to a good learning environment, but cannot by itself turn a poor learning environment into a good one. [see results, page 7]

# *Methodology*

A mixed-methods approach, based on a quantitative survey and qualitative semi-structured focus groups was used in the research to ascertain the level of engagement in secondary and tertiary science courses. This approach was unique as it permitted comparisons within and between the two groups. An anonymous survey was used to collect questionnaire data. Massey University and five high schools in the Manawatu and Greater Wellington regions of New Zealand agreed to participate in the study. Four groups of people within these institutions were invited to participate: (i) Year 1 university students studying science, engineering or technology, (ii) university lecturers 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.

Questions, on 'Teacher Efficacy' and 'Student Engagement', were based on the research literature about student engagement in science (Hipkins et al., 2006; Lyons, 2006; Tytler, 2007; Osborne & Dillon, 2008), the nature of science and the pedagogy for teaching science effectively (Tytler, 2003). Questions addressed the following:

- The broad range of affective experiences (i.e., pertaining to motivation, attitudes, perceptions and values) that students/teachers might encounter in a secondary or tertiary setting.
- The declarative/procedural experiences (i.e., particularly relating to the 'know what' and 'know how' of knowledge) that students/teachers might encounter in a secondary or tertiary setting.
- Effective science teaching in classrooms.

Each group of participants received the same questions, with wording suited to their role (e.g., 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*). All items were on a scale of 1 to 5, where 1 = never; 2 = rarely; 3 = sometimes; 4 = often; 5 = always.

Questionnaire data were subjected to principal component analysis, analysis of variance and regression analysis. Focus groups were used to explore the questions in more detail. Focus groups were recorded, transcribed and subjected to 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).

Four hundred and twenty-one Year 12 school students, 630 Year 1 university students, 33 secondary school science teachers, and 69 university science lecturers participated in the survey. Forty-three Year 12 schools students, 46 first year university students, 30 school science teachers, and 49 university science lecturers participated in focus groups. Confidentiality precluded knowing whether those who participated in focus groups had also completed questionnaires (and vice versa).

# *Results*

## Scale Development

Initial analysis was undertaken to establish the factor structure of the scales using exploratory factor analysis. Principal component analysis of the 50 items relating to 'teacher efficacy' identified five scales with Eigenvalues >1.0 and Cronbach's alpha >0.70. These values were selected as an indication that the items that comprised the scales had reasonable internal consistency and reliability. Together, the five scales accounted for 41% of the variance in student responses. The labels given to these scales were: Lecturer Qualities (LQ), Relevant Contexts (RC), Scientific Method (SM), Self-directed Learning (SD) and Maximising Technology (MT).

Using the same criteria to analyse the 50 items related to 'student engagement', three scales were identified. Together, these three scales accounted for 39% of the variance in student responses. The labels given to these scales were: Commitment to Performance (CP), Learning with Excitement (LE), and Discovering Meaning (DM). Analysis of the qualitative data from focus groups mapped to very similar themes to those of the questionnaire data.

## Teacher efficacy scales

Mean scores for the teacher efficacy scales are summarised in Figure 1.

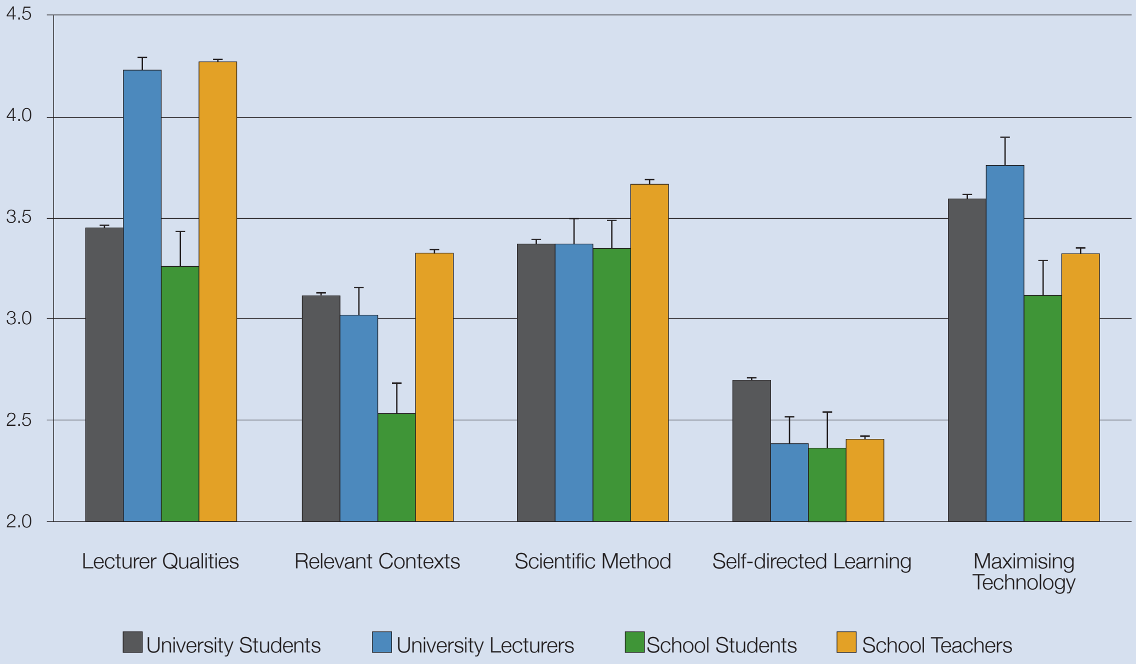


Figure 1: Mean (± SEM) scores for the five Teacher Efficacy scales.

## Lecturer Qualities

Lecturer Qualities was the most important of the scales of teacher efficacy (Tables 1 and 2, and see Figure 3), which encompassed many aspects of the persona, presentation skills, and quality of feedback of the teacher/lecturer. The items that comprised this scale included:

My lecturers inspire me with their enthusiasm

My lecturers stimulate me with the way they teach content

My lecturers use a variety of techniques to help me learn a topic

My lecturers relate science to things that interest me

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

My lecturers encourage me with their positive comments

Mean scores from university students (*M*=3.4, *SD*=0.6) and school students (*M*=3.3, *SD*=0.7) were significantly ($p<0.001$) lower than from university lecturers (*M*=4.2, *SD*=0.5) or school teachers (*M*=4.3, *SD*=0.3). There were small differences between school and university students, and between university lecturers and school teachers. These data show that school and university students thought less highly of the abilities of their teacher in this area than did the teachers and lecturers themselves. For example, university and school learners perceived their lecturers' qualities to be of a moderate standard, whereas lecturers themselves reported that their own lecturing qualities were of a high standard.

Qualitative data showed that students' engagement is stimulated by the enthusiasm of the lecturer or teacher: '*[I like it when] the lecturer is very enthusiastic – it keeps you interested and keeps you awake*'; and by teachers who use a range of teaching styles, media, humour or diagrams; who ask questions and who allow opportunities for students' participation. They value lecturers or teachers who relate material to the students' interests – particularly to their chosen degree speciality. Students are likely to become disengaged when lecturers or teachers are not enthusiastic: '*the voice is the same or varies a little. It is so boring. It seems like they are not enjoying it*', or who read their lectures (especially directly off PowerPoints). Students are also likely to become disengaged where material is not related to their specific interests: '*at the moment … I'm not really seeing any relevance to it so it's kind of like making me disengage*': this was particularly the case for courses that were generic across many degrees rather than being specific to the students' area of interest.

Lecturers also emphasised the importance of the 'lecturer qualities' scale. It is important to be enthusiastic: '*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*'. It is also important to be approachable.

Students value feedback on their learning, and want to clearly recognise the areas of knowledge in which they need improvement. School and university students value individual feedback from their lecturers, with several expressing a desire for more feedback on assessments. Typically, these students want to identify clearly the areas of knowledge in which they need to improve: '*They could give you feedback on... assignments and things... and see where you are and what you actually do need to focus more on.*'

## Relevant Contexts

This scale reflects the extent to which students perceive science to be meaningful in the context of their own experiences: whether this is the 'fundamental nature' of science, or the applicability of science to their everyday lives. The items that comprised this scale include:

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 learn about major 'break-throughs' in science

I am asked to learn how scientific ideas have developed over time

The mean scores for Relevant Contexts (Figure 1) were similar between university students and lecturers. However, scores given by school students (*M*=2.5, *SD*=0.7) were significantly ($p<0.001$) lower than those given by school teachers (*M*=3.3, *SD*=0.5) and lower than the scores given by university students ($p<0.001$). Overall, these data suggest that university learners, university lecturers, and school teachers believe that relevant contexts are only being included in learning sometimes, and school students felt that relevant contexts were being utilised even less.

Being taught science in an everyday meaningful context affects the engagement of both school and university students: '*I really like it when the teacher challenges me to apply the knowledge to real-life situations*', as do occasions when teachers explicitly connect science content to everyday life scenarios: '*I like it when you have a moment of realisation when you are going to be using that information they just told you about.*' Similarly, learning science in a contemporary context, especially in an area where '*new stuff is always coming out*' stimulates engagement, and students enjoy learning when it is combined with a sense of discovery.

Data from the focus groups illustrated that lecturers and teachers realise that students prefer to learn science in a meaningful context of 'real world' application: '*We should bring the real world into the classroom and connect chemistry or whatever it is to things that are going on...*' Nevertheless, a focus on context is not always easy to achieve because there is a tension between content and context in developing understanding of science: '*content is quite important because you have a certain amount of language ... in order to develop the more difficult concepts*'. On the other hand, teaching can be primarily driven by content per se, rather than focussing on the material the students need to be able to understand to utilise knowledge in an area. When this occurs, especially when combined with excessive assessment that focuses on minutiae, disengagement can readily ensue.

## Scientific Methods

This 'Scientific Methods' scale reflects the ability of students to personally engage with data as a source of scientific understanding. There were no statistically significant different responses between participant groups for mean scores for 'Scientific Methods.' Data for these scales are illustrated in Figure 1, and show that on average learners and teachers at both university and secondary school reported that learners are expected to use scientific approaches in their learning to moderate amounts. The items that comprised this scale included:

I am assessed on my ability to interpret scientific data

I am expected to evaluate then interpret scientific data/evidence for myself

I am expected to plan the investigations that I undertake

I am expected to use data/evidence to develop a logical scientific argument

## Self-directed Learning

The Self-directed Learning scale encompasses two main areas: the ability of students to choose what, and how, they are taught, and their ability to interact with a scientific community outside of their classroom:

I am given the opportunity to influence the way that I am taught

I am given the opportunity to influence what topics I am taught

I am given the opportunity to interact with the wider science community

Overall, Self-Directed Learning was reported as being utilised the least out of all of the teacher efficacy scales; for all four groups the mean reported frequency was between sometimes and rarely. Mean scores for Self-directed Learning were significantly ($p<0.01$) higher for university students

(*M*=2.7, *SD*=0.7) than for university lecturers (*M*=2.4, *SD*=0.9), but there were no significant differences between school students and school teachers.

Students reported that they have limited opportunities to affect how or what they are taught. As a consequence, most do not expect lecturers to take their personal learning preferences into account: '*you are only one person out of a hundred [i.e., in a lecture theatre] and everyone learns differently.*' Similarly, they feel they have limited ability to influence what they are taught, especially in terms of compulsory 100-level courses. Lecturers are in a difficult situation in relation to some compulsory papers with unpopular content. On one hand, they recognise that it can be difficult to maintain students' engagement in such papers. On the other hand, it is difficult to develop the content of these papers, given that students enter university with a highly variable level of content knowledge: '*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.*' Therefore, while lecturers recognise the need to 'stretch' able students, they also recognise the need to teach 'the basics' to students who were either less able or who had not encountered material during their school studies. Solutions to this problem suggested by many lecturers were (i) specifying individual NCEA units that were pre-requisites for entry to a degree or (ii) having pre-enrolment 'catch up' courses for students lacking those units.

## Maximising Technology

This scale reflects students' ability to interact with technology during teaching in the laboratory and during their personal study. The main focus is on IT, but also included laboratory equipment. The key items comprising this scale included:

> 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 develop my knowledge
>
> My lecturers use up-to-date technology for teaching

Overall, all groups reported that they used up-to-date technology at least sometimes. Mean scores for Maximising Technology (Figure 1) were significantly ($p$<0.001) higher for university students (*M*=3.6, *SD*=0.6) than for school students (*M*=3.1, *SD*=0.8). The difference between university lecturers (*M*=3.8, *SD*=1.0) and university students was not significant, nor was the difference between school teachers (*M*=3.3, *SD*=0.7) and school students.

University students like having access to teaching materials online, although largely as a convenience rather than as a key part of their learning. On the other hand, they are likely to be unimpressed by technology *per se*, especially if the lecturer or teacher is unfamiliar with its operation. Similarly, computer-aided learning packages are greatly valued by some lecturers and students as of value to students' learning, but '*It has to be in such a way that ... it facilitates students to independent thinking and problem solving.*' The consensus of students and lecturers was that technology can contribute positively to a good learning environment, but it cannot of itself turn a poor learning environment into a good one.

Additional problems faced some school students, who spoke of limitations to online learning when computers were not accessible or had broken down. Likewise, many reported that the equipment in science laboratories was not necessarily clean, up-to-date or in adequate supply.

## Student Engagement Scales

The Commitment to Performance scale reflected student' willingness to strive for understanding and excellence, particularly in terms of attendance and completion of assigned tasks:

- I strive to do my best in science
- I try to attend science classes
- I strive to get good grades in science
- I complete science assignments by their deadlines
- I strive to keep up to date with my science studies
- I intend to stay in science

The main components of the Learning with Excitement scale were:

- I tell other people how much I enjoy studying science
- I discuss science issues with other people
- I challenge myself to explore the 'deepest secrets' of science
- I get excited when I discover things about science
- I apply my knowledge of science to things in my life

Finally, the components of the Discovering Meaning scale were:

- I learn how science impacts people, society and technology
- I learn about major 'break-throughs' in science
- I consider ethical issues surrounding science
- I learn how scientific ideas have developed over time

Mean scores for Commitment to Performance, Learning with Excitement and Developing Meaning (Figure 2) all differed significantly (all $p<0.001$) between groups. University students' scores for Commitment to Performance ($M$=4.1, $SD$=0.6) and Learning with Excitement ($M$=3.4, $SD$=0.7) were significantly higher than those of university lecturers ($M$=3.5, $SD$=0.4 and $M$=2.9, $SD$=0.4, respectively) and school students ($M$=3.7, $SD$=0.8 and $M$=2.8, $SD$=0.8, respectively).

University learners reported feeling the most committed to their performance (they were often committed), compared with the other three groups who felt commitment to performance was evident between sometimes and often. All groups reported moderate levels of learning with excitement and discovering meaning.

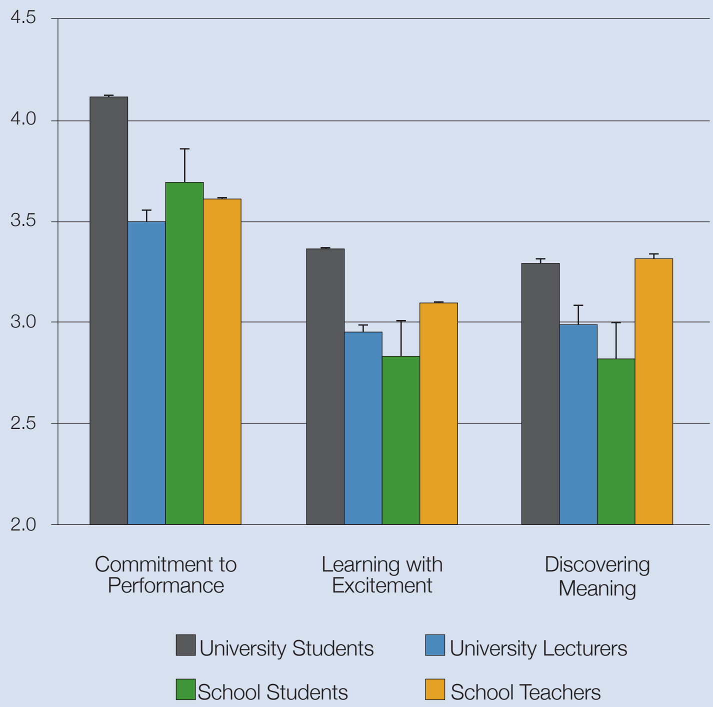


Figure 2: Mean scores for Commitment to Performance, Learning with Excitement and Developing Meaning.

The perceived level of motivation amongst first-year students was a recurring theme in discussions with university lecturers and school science teachers. School leavers often '*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...*', whereas older students, overseas students, and students with a career focus were considered to be more motivated. Moreover, lecturers thought the NCEA system had conditioned many students to develop an attitude about obtaining credits rather than learning for its own sake.

University science students indicate higher levels of commitment to their studies than do school science students – does the university environment lever off this commitment as well as it could?

Most university students recognised the need to study outside class, although some found 'keeping up to date with science studies' was challenging, particularly in the face of high contact hours, the need for part-time employment and the social distractions of their new life at university. The level of independence that students had been expected to develop at school was an important determinant of the effectiveness of their out-of-class study.

## Relationship between scales of Teacher Efficacy and Student Engagement

To examine the relationships between the five scales of Teacher Efficacy and the three scales of Student Engagement, multivariate regression analyses were conducted. Results for university and school students are presented in Tables 1 and 2. Overall, the results indicate that different facets of student engagement are predicted by different aspects of teacher performance. Relationships between Teacher Qualities and all three scales of Student Engagement were stronger for university students than for school students.

Table 1: Relationship between teacher efficacy scales and Student Engagement scales (β values) for first-year university students

| | Commitment to Performance | Learning with Excitement | Developing Meaning |
|---|---|---|---|
| Lecturer Qualities | 0.31 | 0.24 | 0.13 |
| Relevant Contexts | | 0.29 | 0.45 |
| Scientific Method | 0.21 | 0.20 | 0.23 |
| Self-directed Learning | –0.41 | | |
| Maximizing Technology | 0.18 | | |
| Adjusted $R^2$ | 0.29 | 0.28 | 0.44 |
| % variance explained by model | 46% | 42% | 85% |
| *p* (entire correlation) | $p<0.001$ | $p<0.001$ | $p<0.001$ |

*Only β values that made a significant (p<0.01) contribution to the overall regression are included in this table*

For University students (Table 1), the predictor of the scale Commitment to Performance were higher Lecturer Qualities, Scientific Methods and Maximising Technology; and lower Self-directed Learning. For the scales Learning with Excitement and Developing Meaning, the predictors were Lecturer Qualities, Relevant Contexts, and Scientific Method, but not Self-directed Learning or Maximizing Technology.

For school students (Table 2), only Lecturer Qualities and Scientific Method predicted Commitment to Performance. Lecturer Qualities, Scientific Method, and Self-directed Learning predicted Learning with Excitement. Developing Meaning was only related to Relevant Contexts.

Table 2: Relationship between teacher efficacy scales and Student Engagement scales (β values) for Year 12 school students

| | Commitment to Performance | Learning with Excitement | Developing Meaning |
|---|---|---|---|
| Lecturer Qualities | 0.47 | 0.21 | |
| Relevant Contexts | | | 0.59 |
| Scientific Method | 0.26 | 0.16 | |
| Self-directed Learning | | 0.21 | |
| Maximizing Technology | | | |
| Adjusted $R^2$ | 0.27 | 0.18 | 0.40 |
| % variance explained by model | 25% | 17% | 49% |
| *p* (entire correlation) | $p<0.001$ | $p<0.001$ | $p<0.001$ |

*Only β values that made a significant (p<0.01) contribution to the overall regression are included in this table.*

The interaction between the teacher/lecturer and the student is the most important single factor in determining student engagement. [see Implications for Teaching and Learning, page 13]

# *Discussion*

## *Key findings from this study*

### Teaching environment

#### Teachers/lecturers influence student engagement

Students' engagement at school and university is strongly influenced by the teaching environment. 'Lecturer/teacher qualities' are the most important aspect of the teaching environment, particularly the enthusiasm, commitment and teaching techniques of science teachers/lecturers. Other factors that affect engagement are the extent to which science content is taught in the context of career and individual interests. Also, the extent to which it promotes the development of students' scientific critical thinking skills, enables individual students to make choices regarding content, and is supported by appropriate technology. Conversely, a learning environment that is based primarily on the assimilation of 'science facts' is generally detrimental to student engagement (Ramsden, 1991; European Commission, 2004).

#### 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 and 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 engaged in learning.

### Transition

#### 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, indeed, their scores for Commitment to Performance and Learning with Excitement were significantly higher than for school students.

#### Transition from school science to university science is a process

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. 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 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 teaching to the 'lowest common denominator' or presenting material that 'goes over the heads' of a significant proportion of students in the class. Either of these situations impairs engagement. On the other hand, students have the potential to enter university with a broader repertoire of learning skills than under former school curricula, which provides universities with the opportunities to build upon these skills during the transition between educational sectors.

## Perceptions

### There are different perceptions between students and lecturers/teachers

University students' perceptions of their engagement were greater than that of their lecturers, while teachers' and lecturers' perceptions of their teaching qualities were greater than that of their (school or university) students.

This difference of perceptions creates the potential for a culture of mutual blame: 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. In other words, there is the risk that students and staff are more ready to attribute their short-falls to each other than they are to reflect on their own involvement.

> The pedagogical environment of science education needs to be redeveloped to promote students' attainment of intellectual independence and high order cognitive and non-cognitive skills, at all levels of their studies. *[see A Starting Point, page 15]*

# Implications for Teaching and Learning

The interaction between the teacher/lecturer and the student is the most important single factor in determining student engagement (Tables 1 and 2; and see Figure 3). Teachers may be effective because they create relevant contexts for information, promote Self-directed Learning and students' understanding of scientific method, and can also incorporate a range of technological innovations into their teaching. Alternatively, teachers/lecturers may be effective 'simply' by being passionate and interesting, and interested in their students. Data from focus groups as well as in the literature (e.g., Entwistle, 1997) emphasise that students' engagement is also 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.

The teaching effectiveness of individual lecturers and teachers is itself 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. In other words, the ability of teachers/lecturers to be effective is filtered through their perception of the institutional environment in which they operate, particularly with respect to workload and institutional values (i.e., what they perceive the institution will reward them for doing).

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.

Development of a teaching environment to support students' transition between educational sectors is undoubtedly challenging and complex. 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 (2010). The trouble is that there is content, often a great deal of content, that has to be mastered – both at secondary and tertiary levels – that is vital to the development of understanding and creativity. The challenge is therefore to develop curricula and a teaching environment in which content is so strongly anchored in contexts of both the 'real world' and of the students' career aspirations that engagement is not allowed to deteriorate. Curricula based on classical 'problem-based learning' are a largely successful (albeit often perceived as resource-intensive) solution to these problems (Albanese & Mitchell, 1993), but other methods have been developed that require less wholesale curricular change. The main issue seems to be that the learning is active: which can be achieved through many routes, such as that advocated through the Carl Wieman Science Education Initiative (Wieman et al., 2010), the 'invention' process of Taylor et al. (2010), the 'process-orientated guided enquiry' of Johnstone (1997), or simply implementing the precepts of active learning that have been described by many authors (e.g., Biggs, 2003).

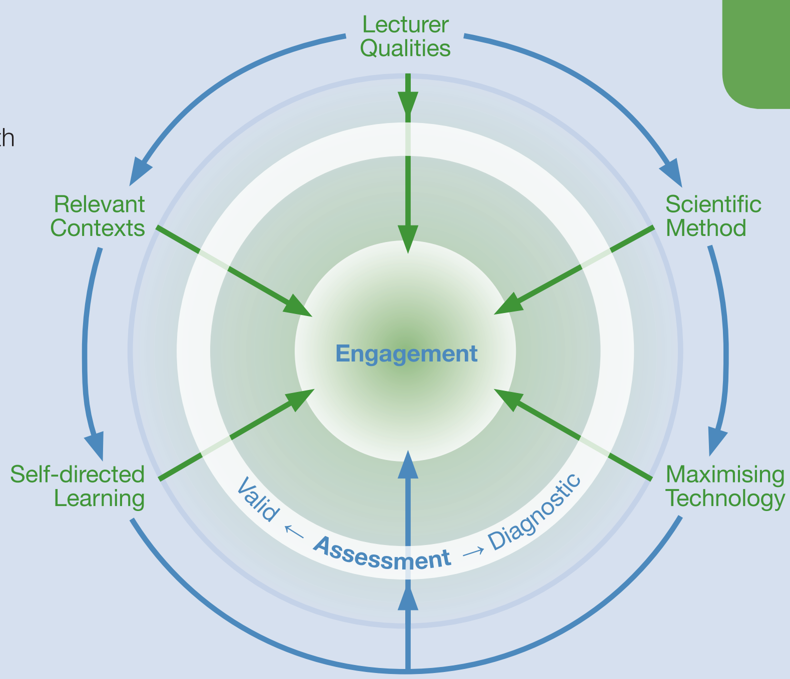


Figure 3: Relationship of aspects of 'teacher efficacy' with the engagement of their students.

Similarly, 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 others' processes for change.

A model for this dialogue is presented in Figure 4. 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 others' students
- between students and teachers/lecturers within a sector.

Dialogue also needs to take place within each sector, in order 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. The results of these dialogues, at the different levels, get communicated as explicit intentions to all.

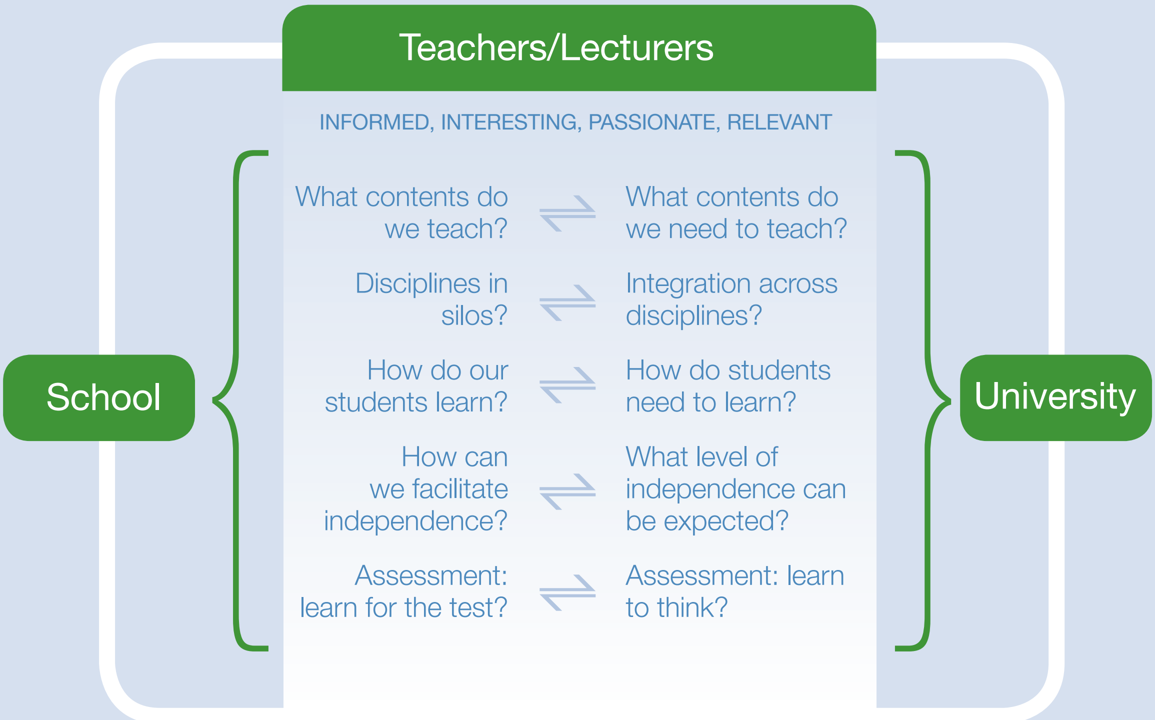


Figure 4: Dialogic framework for collaboration between and within the secondary and tertiary sectors to promote engagement and to facilitate students' transition.

The challenge is to develop curricula and a teaching environment in which content is so strongly anchored in contexts of both the ‘real world’ and of the students’ career aspirations that engagement is not allowed to deteriorate.

## *A Starting Point*

Critically, the pedagogical environment of science education needs to be redeveloped to promote students’ attainment of intellectual independence and high-order cognitive and non-cognitive skills, at all levels of their studies. Results from the present research suggest that the critical starting points are:

- Assisting lecturers and teachers to develop skills in the ‘teacher efficacy’ parameters that this project has identified as being pivotal to students’ engagement. Specifically, to promote independent learning and engagement by:
  - — ensuring assessment practices at school and university reward critical thinking rather than reinforce low-order learning
  - — ensuring all content is delivered in a context that is immediately relevant to the student.
- Effectively utilising the learning outcomes achieved by NCEA in first-year university study by:
  - — identifying how universities can build on the diversity of knowledge that results from the unit-based NCEA high school education
  - — ensuring liaison between universities and schools to make certain school leavers have the content knowledge that is needed to start their degrees.

# References


Albanese, M. A., & Mitchell, S. (1993). Problem-based learning: a review of literature on its outcomes and implementation issues. *Academic Medicine*, *68*, 52–81.

Australasian Survey of Student Engagement (AUSSE). (2009). *Engaging students for success: Australasian student engagement report*. Melbourne, Australia: Australian Council for Educational Research.

Biggs, J. (2003). *Teaching for quality learning at university*. Buckingham, England: Open University Press.

Braun, V., & Clarke, V. (2003). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*, 77–101.

Entwistle, N. (1997). Contrasting perspectives on learning. In F. Marton, D. Hounsell, & N. Entwistle (Eds.), *The experience of learning* (pp. 3–22). Edinburgh, Scotland: Scottish Academic Press.

European Commission. (2004). *Europe needs more scientists: Report by the high level group on increasing human resources for Science and Technology.* Brussels, Belgium: Author.

Hipkins, R., Roberts, J., Bolstad, R., & Ferral, H. (2006). *Staying in science 2: Transition to tertiary study from the perspectives of New Zealand Year 13 science students*. Wellington, New Zealand: New Zealand Council for Educational Research.

James, R., Krause, K.-L., & Jennings, C. (2009). *The first year experience in Australian universities: Findings from 1994 to 2009*. Melbourne, Australia: The University of Melbourne Centre for the Study of Higher Education.

Johnstone, A. H. (1997). Chemistry teaching – science or alchemy? *Journal of Chemical Education, 74*, 262–268.

Lyons, T. (2006). Different countries, same science classes: Students' experiences of school science in their own words. *International Journal of Science Education, 28*(6), 591–613.

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections*. London: Nuffield Foundation.

Ramsden, P. (1991). A performance indicator of teaching quality in higher education: The Course Experience Questionnaire. *Studies in Higher Education, 16*, 129–150.

Taylor, J. L., Smith, K. M., van Stolk, A. P., & Spiegelman, G. B. (2010). Using invention to change how students tackle problems. *CBE Life Sciences Education, 9*, 504–512.

Tytler, R. (2006). *Re-imagining science education: Engaging students in science for Australia's future*. Melbourne, Australia: Australian Council for Educational Research.

Tytler, R. (2007). School innovation in science: A model for supporting school and teacher development. *Research in Science Education, 37*(2), 189–216.

Wieman, C., Perkins, K., & Gilbert, S. (2010). Transforming science education at large research universities: a case study in progress. *Change, 42*(2), 9–15.

Zepke, N., Leach, L., & Prebble, T. (2006). Being learner centred: one way to improve student retention? *Studies in Higher Education, 31*(5), 587–600.

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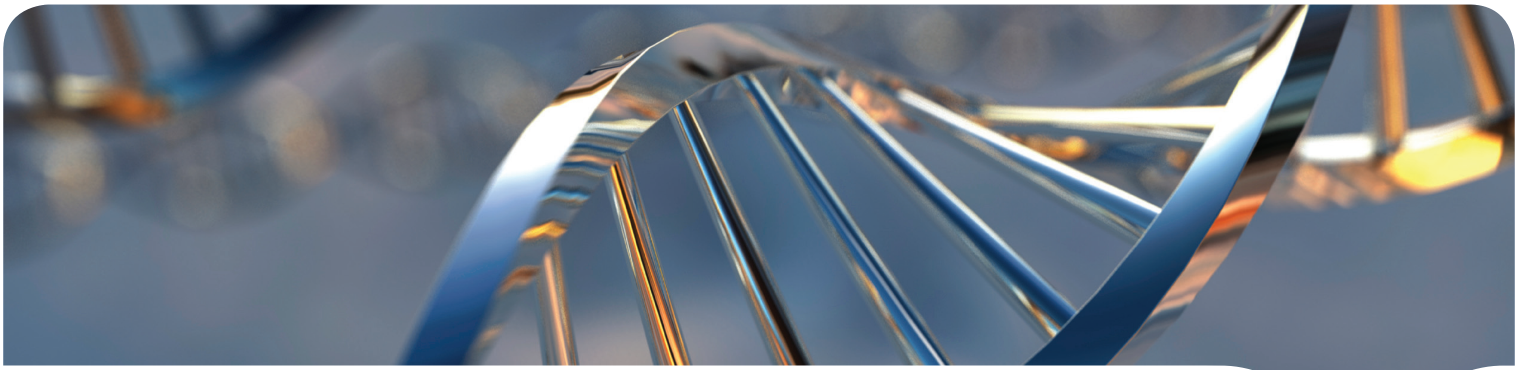

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ISBN 978-0-473-18899-3