Staying in Science

Students' participation in secondary education and on transition to tertiary studies

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Executive summary

In recent years there has been concern that declining numbers of young people are choosing a tertiary education in the sciences, with a view to taking up science careers. This background paper examines the view that the "problem" may begin at secondary school, with fewer and fewer students choosing to study the science disciplines once these become optional (typically at Year 12 in New Zealand), or choosing to continue with science on transition from secondary to tertiary study.

Science participation in the senior secondary school

Does the evidence support claims of a steady decline in numbers of students taking science at secondary school? This question is more difficult to answer than it may first appear, as there are many different ways to collect and analyse data about students' participation in science education. Section 2 outlines seven different methods for describing trends in science participation in the secondary school. These are:

1. Participation in science subjects as a percentage of final year [of secondary school] enrolments.
2. "Curriculum share" of all science subject enrolments.
3. Participation as a percentage of the whole cohort who enrolled in secondary school.
4. Participation as actual numbers enrolled.
5. Student- or school-specific participation trends.
6. Combinations of science subjects taken by students.
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The advantages and disadvantages of each measure are discussed, and each method is illustrated with national trend data from Australia. For New Zealand, where similar national data has yet to be fully researched, small-scale case studies are used to illustrate participation patterns in local school contexts.

The seven measures reported here illustrate the contextual complexities of trying to determine and interpret overall participation trends in the senior sciences at secondary school. Great care is needed in deciphering exactly what story the data tell, particularly if comparing measures proposed by different research groups. However, across the range of measures it does seem that there has been a decline in participation in recent years. It may be of a smaller magnitude than those who pick the most negative measures would suggest but it definitely exists in Australia, and seemingly on the evidence available, in New Zealand.

What influences students' choices? Insights from related research

The transition from secondary to tertiary level studies is another potential point at which students might choose to opt out of sciences. Section 3 reports on research that has investigated factors that influence the tertiary study choices made by students who are nearing the end of secondary school.

Although this background paper focuses mainly on the decision making of "science-able" secondary students at the transition point from senior secondary to tertiary education, it is important to recognise that there are numerous points on either side of the secondary-tertiary transition at which students may "decide" to continue (or discontinue) science study, including:

- the transition from the compulsory to the post-compulsory school curriculum, at which point science subjects usually become optional;
- the transitions between each of the years of the post-compulsory school curriculum (i.e. from Year 11 to Year 12, and Year 12 to Year 13), at which times students may decide to discontinue with sciences;
- the transition from senior secondary to the first year of tertiary study; and
- the transition between each of the subsequent years of tertiary study.

This background paper draws on a wide spectrum of research that, collectively, provides information about subject choices and decision making for students across all these educational stages. This includes studies that have focused specifically on students' choices in relation to science, and research which has focused more generally on students' decision-making and educational pathways through secondary and tertiary school. The latter research reveals interesting data (and raises even more interesting questions) about students' educational decision making. For example, when are students' decisions and choices actually made? Are there less visible influences (e.g. cultural or socioeconomic) that shape, constrain, or encourage certain kinds of choices/pathways of certain types of students? Finally, what can educators and policy makers do to support or influence young people's choices and pathways?

International studies of students' subject choice decisions in the last few years of secondary school suggest first, that there is a great deal of variation in how young people make their subject choices and educational decisions. Secondly, they also suggest that these decisions involve a complex mix of psychological and social factors, and often it is the *interaction between* these factors that is important in shaping students' choices and decisions. Thirdly, students' personal and family worlds seem to be an important influence on their choices. Notwithstanding these complexities, existing research suggests two areas that seem to be particularly important in students' choice to continue or not to continue with science. These are: students' experiences with school science; and their knowledge and awareness of the range of study and career options that involve science.

Many students, including those who choose to *continue* with science, describe school science teaching as sometimes boring, irrelevant, not people-focused, lacking in practical work, or requiring too much content coverage. However, research suggests that there are some students who would continue with science regardless of their perceptions of the quality of their school science learning. Internal motivation, for example, a keen interest in science, or a career orientation towards science, thus seem to be important motivators for continuing in science.

How important is students' knowledge (or lack of knowledge) about the range of science-related study and career options in their decisions about continuing to study senior secondary or tertiary science? In some cases, it seems as though career aspirations are a key factor in students' decision making. In other cases, it seems that an interest in science, or encouragement to continue in science, matters more than specific career aspirations—at least in students' initial decisions to enrol in tertiary-level science. New Zealand and international studies suggest that many students enrol in tertiary science without a clear career aspiration in mind. However, on balance, the existing research literature suggests two things: first, that careers advice and information *do* make a difference to students, and second, that many students feel they do not get enough personalised advice and information.

The review and discussion of existing research shows that there is still a great deal we don't yet know about students' decision making in relation to science study. That contextual factors such as family background have an impact seems clear, but we have yet to find out whether the SES effects, and the role of parental support, are as evident in New Zealand students' decisions. It is also clear that there is no single way to explain choice patterns. Students have different reasons, in different circumstances, and according to their personal dispositions, interests, future plans, and choice-making experiences. Understanding the complexity of choice making should help inform any future careers and transition guidance strategies that Ministry of Research, Science and Technology (MoRST) may wish to undertake. We aim to contribute valuable New Zealand data from both the focus groups and the survey stages of this research.

1. Introduction

In recent years there has been concern that declining numbers of young people are choosing a tertiary education in the sciences, with a view to taking up science careers. This paper examines the view that the "problem" begins at secondary school, with fewer and fewer students choosing to study the science disciplines once these become optional (typically at Year 12 in New Zealand).

The paper begins by outlining seven different methods for describing trends in science participation in the secondary school. Each method is illustrated with national trend data from Australia. For New Zealand, where similar data has yet to be fully researched, small-scale case studies are used to illustrate participation patterns in local school contexts.

The transition from secondary to tertiary level studies is another potential point at which students might choose to opt out of sciences. The second part of this paper reports on research that has investigated factors that influence the tertiary study choices made by students nearing the end of secondary school. In a subsequent phase of the research, New Zealand students' choices will be further investigated.

2. Science participation in the senior secondary school

Does the evidence support claims of a steady decline in numbers of students taking science at secondary school, and if so should policy makers be concerned about this? This section discusses the different ways such a question might be addressed. Care is needed in reading statistics related to participation because different methods of composition portray different aspects of a complex situation. It will be evident that no one measure can tell the full story.

While there is little systematically *published* evidence available to inform trends in New Zealand, there is rather more evidence available concerning trends in science participation in secondary schools in Australia. With the assumption that what is happening across the Tasman is likely to be mirrored by similar trends in New Zealand, this section discusses the Australian situation, and makes comparisons with any available New Zealand data where possible.

Three main sources of Australian data are used in this section.

- A report prepared for the Australian federal government (Committee for the Review of Teaching and Teacher Education, 2003).

With a focus on the future supply of teachers to maintain high standards of mathematics, science, and technology teaching, this report sketches data pertaining to student participation in all these areas from the 1970s until 2002. This is referred to as the "Committee" report.

- A report prepared for the Australian Council of Deans of Science (Dobson, 2003).

The primary focus is on university participation, but this report includes a chapter that outlines some school participation trends from 1989–2002. While the timeframe is narrower, the data are more comprehensively reported. It is referred to as the "Dobson" report.

- A longitudinal study of trends in educational participation for a large sample of Australian Youth—around 14,000 students from 300 schools (Fullarton, Walker, Ainley, & Hillman, 2003).

Data from this often-quoted research were used in the preparation of the Committee report. It has the advantage of providing student-specific trend data and is referred to here as the "LSAY" report.

The NZCER research project *Learning Curves: Meeting students' learning needs in an evolving qualifications regime* has been used as a source of case study data to illustrate the wider trends with reference to the complexities of school-specific dynamics in six medium-sized New Zealand secondary schools (Hipkins & Vaughan, 2002).

Measure One: Participation as a percentage of final year enrolments

The first measure discussed determines student *enrolment* in a science subject as a percentage of overall student numbers at this year level. This provides a picture of the relative *popularity* of that subject choice, compared to other subjects that could have been chosen.

An advantage of this measure is that, being a percentage, it is independent of overall cohort size, which tends to fluctuate across time. Availability of data is another advantage. Australian states all collect data on student subject enrolments by year level, albeit with some differences of interpretation (Dobson, 2003). New Zealand collects subject enrolment data as part of schools' annual returns. This data is available electronically from 1994 onwards. However, like Dobson in Australia, the MOE has reservations about its use because each school employed its own methods of subject collation, which compromises comparability [1].

This measure has some other disadvantages. It assumes that each enrolment represents a full-year course of equivalent value in terms of effort and study time (Dobson, 2003). In New Zealand, this assumption may no longer apply. Since the NCEA introduction some secondary schools have introduced, or are actively considering the introduction of, a semester structure. This allows students to try subjects in the first half of the year and make changes in the second half if they feel they want or need to do so (Hipkins, Vaughan, Beals, & Ferral, 2004). And as already noted, the way in which "science" subjects are counted may be open to interpretation. In the post-NCEA environment this issue has become even more complex. This will be further discussed below.

A related issue is that this measure assumes students make the same total number of course choices, and that this has not changed over time, or does not change between schools. If, for example, most students took four subjects in their final year in the 1980s, but most now take six, direct comparison of enrolment trends becomes problematic. The Dobson report notes that there was a 51 percent increase in the secondary school student population from 1997 to 2002, but in the same time period there was a 57 percent increase in total subject enrolments (Dobson, 2003, p. 77). This suggests that at least some students are indeed taking more subjects now than in the past. The LSAY report notes that, whereas the average number of subjects taken in Australia is five, 63 percent of students in Queensland take six subjects and 52 percent of students in Tasmania take four, spending more time on each (Fullarton et al., 2003, p. 24). While we do not have the data to

1 Jacinta Dalgety, MOE, personal conversation.

support this, our instinct is that New Zealand schools may well have different policies about students' subject totals, and that these may differ for different types of students within each school.

Science enrolment trends in Australia

Australia's overall national pattern for this measure shows a steady decline in enrolments in all three traditional science disciplines (biology, chemistry, physics) from the late 1970s to 2002, the last year for which data were available for the Committee and LSAY reports. Biology enrolments peaked at 58 percent in 1977, declining to 25 percent in 2002. Chemistry peaked at 33 percent in 1980 and declined to 17 percent in 2002. Physics peaked at 29 percent in 1980 and declined to 16 percent in 2002 (Committee for the Review of Teaching and Teacher Education, 2003).

The Committee report pointed out, however, that across the same period enrolments in some other science subjects increased, partially offsetting this pattern of falling enrolments. For example psychology enrolments grew from its 1992 emergence as a "significant subject" (p. 4) to reach 8 percent in 2002. Across the same time period enrolments in "multi-strand science" remained reasonably steady on 4 percent. Interestingly, while the Committee report classified subjects such as food technology within the technology cluster, other researchers have counted these as alternative science subjects.

Dekkers and De Laeter (1997) asserted that a 20 percent decline in Australian senior school students' enrolments in the three traditional science subjects in the first half of the 1990s was matched by an increase in enrolment in alternative science subjects with a multidisciplinary focus. Food technology and science for life in New South Wales, health education in Victoria, and marine studies in Queensland accounted for 96 percent of these enrolments in alternative subjects. They said, "of the 15 [alternative] subjects listed, three are involved with food, three with health, three with rural studies and two with marine studies" (p. 39). They predicted that on trends as at the mid-1990s the combined enrolments in these alternative subjects would soon outnumber enrolments in chemistry—the least often chosen of the three traditional sciences.

The Committee report also noted an increase in the range of technology subjects across the 1990s. For example, enrolments in information technology stood at just 8 percent in 1991, but reached 25 percent in 2001 before declining slightly in 2002. Other technology enrolments also stood at 8 percent in 1991 and peaked at 16 percent in 2001. The committee reported that "increases in these subject areas were greater than declines in physics and chemistry" (Committee for the Review of Teaching and Teacher Education, 2003, p. 19).

Science enrolment trends in New Zealand

While psychology has not been taught in New Zealand secondary schools in the past, the increase in enrolments in alternative science subjects almost certainly does explain at least some of the perceived decline in traditional science participation here. During the early 1990s "science" was developed as a multi-strand Year 12 and 13 subject, based on the newly mandated *Science in the New Zealand Curriculum* (Ministry of Education, 1993). It was examined as a Bursary subject from 1995 until the Bursary examination was replaced by Level 3 of the National Certificate in Educational Achievement (NCEA) in 2004. (Examination enrolment as a measure of participation is further discussed below.)

New subjects have been introduced into New Zealand's overall curriculum in the last decade, for example in the technology and arts curriculum areas, and these are obviously also in competition with the traditional sciences. Furthermore, with the introduction of a "seamless" National Qualifications Framework (NQF) in the early 1990s, and initiatives such as STAR[2] funding, new subjects aligned to transition to work were introduced into the senior secondary school curriculum. These quickly became popular for meeting the needs of certain groups of students who were now staying longer at secondary school (Vaughan & Kenneally, 2003).

The Learning Curves case studies document an opening up of multiple possible pathways, both through the traditional and newer school subjects, since the NCEA was introduced (Hipkins & Vaughan, 2002; Hipkins et al., 2004). To illustrate, one of these schools, "Town School E", offered students eight Year 12 science options in 2002, combining agriculture and horticulture to reduce the number to seven options in 2003[3]. The following table, based on data from these case studies, illustrates the extent of choices on offer to students in just five curriculum areas[4] and the variations that exist between schools.

Table 1 **Summary of Year 12 subject choice numbers in five curriculum areas**

	School					
Curriculum area	**A**	**B**	**C**	**D**	**E**	**F**
Mathematics	3	2	2	2	2	2
English	2	4	3	3	3	2
Sciences	3	4	3	5	7	4
Arts	5	8	3	4	3	3
Technology	6	10	4	7	8	7

Source: Hipkins and Beals, 2004.

This situation effectively creates a "popularity contest" between subjects. Are the sciences holding their own? The next table shows all those Year 13 subjects being taken by 10 percent or more of the responding Year 13 students in 2004 in the Learning Curves schools (Hipkins,

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2 Secondary Tertiary Alliance Resource.

3 Year 13 data were not collected because NCEA implementation at that level did not begin until the next year.

4 Other curriculum areas such as the social sciences and languages other than English were not included in the case studies and so no data were available for them. Their inclusion would expand the available choices considerably.

Vaughan, Beals, Ferral, & Gardiner, in press). The second column compares the participation rates in these six schools with national data from the 2004 MOE roll returns. Where the Learning Curves analysis aggregated subjects (for example all the variations of the visual arts) we have been unable to use national data to make a direct comparison because we cannot account for students who took more than one of these variations. Nevertheless, the comparison shows clearly that, for the sciences, the patterns of participation in the Learning Curves schools are very similar to the overall national pattern. This should be borne in mind when other aspects of the Learning Curves study are being considered.

Table 2 **Most popular Year 13 subjects in New Zealand schools in 2004**

Subject	**% of students taking**	
	L Curves schools	Nationally
Traditional English	45	57
Statistics	33	37
Biology	25	25
Calculus	25	26
Physics	23	23
Chemistry	20	21
Visual Arts	18	
Other Year English	18	
Physical Education	16	20
Vocational Pathways	15	
Economics	14	17
History	13	15
Geography	13	19
Graphics	10	6
Classics/Latin	10	

Note: There are 1 percent differences between these and aggregated subject-combination data presented below because of rounding effects.

It is evident that sciences are holding their own with other traditional curriculum subjects such as English and mathematics. The potential for mutli-levelling of courses since the NCEA was introduced is reflected in the 18 percent of Learning Curves students who were taking English at a lower year level.[5] Some of them would doubtless have been seeking to achieve the NCEA Level 2 literacy credits that are now needed for entry to New Zealand's universities.

The widening of curriculum choices is also reflected in the popularity of vocational courses (the Learning Curves data here represent an aggregate of all courses offering vocational pathways

[5] Note that aggregated national data do not allow this distinction to be made

rather than a single subject) and physical education, which was first introduced as a Bursary subject early in the 1990s.

The snapshot presented here suggests the trend to declining science enrolments should not necessarily be read as a negative choice against science participation, but may equally well represent a positive choice of some other study pathway.

Measure Two: Curriculum share

One way to avoid a potentially misleading emphasis on the three traditional sciences is to aggregate all enrolments within the *learning area*. Fullarton et al. call this measure "curriculum share" (2003, p. 8). For clarity, however, it is important to state which subjects are counted in and which are not. The LSAY report specifies that biology, chemistry, physics, multi-strand science, psychology, and other science subjects are all included in the curriculum share data presented. The next table shows the LSAY analysis (p. 52) of the science subjects' curriculum share across a decade.

Table 3 **Trends in science subjects' share of the Australian curriculum, 1990–2001 (LSAY report)**

Subject area	1990	1993	1998	2001
All sciences	17.0	17.2	15.2	14.1
Physical sciences	8.1	7.7	7.5	6.5
Biological and other sciences	8.9	9.5	7.7	7.7

Note: Physical sciences are physics and chemistry. Other sciences include psychology, environmental studies, earth science (Fullarton et al., 2003, p. 25) .

The Dobson report compares mathematics and science enrolments for curriculum share (p. 77). Note that there is a break of 10 years between the second and third data columns of the table.

Table 4 **A comparison of trends in science and mathematics curriculum share (Dobson report)**

Learning area	1986	1987	1997	1998	1999	2000	2001	2002
Science	21.6	20.9	17.3	17.1	16.8	16.3	15.5	15.2
Mathematics	17.4	17.2	18.1	18.2	18.1	18.0	18.5	18.5

The LSAY data is based on a large national sample of around 14,000 actual student records. The Dobson data is based on national enrolment statistics. While they show the same trend, there are differences in equivalent columns for 1998 and 2001, with the LSAY data showing lower enrolment rates. This suggests that great care needs to be taken if reading meaning into "trends" that move by only 1–2 percentage points.

Nevertheless, neither data set shows the balancing out effect claimed by Dekkers and De Laeter. Science enrolments have declined even when all science subjects are taken into account. However, technology subjects have their own “key learning area” and are not included in either of these reports. The relatively steady pattern of mathematics enrolments shown in Table 4 provides an interesting contrast.

The LSAY report proposes three curriculum-share measures that can be used as indicators of broadening subject selections. These are:

- distribution of enrolments across the traditional learning areas (for example English, mathematics, science, and social science together made up 76 percent of Australian final year enrolments in the early 1990s, but had reduced to 71 percent by 2001);
- increasing enrolments in vocational subjects; and
- decline in numbers of students taking at least two subjects from the same curriculum area (for example physics and chemistry).

The third of these measures will be further discussed shortly.

Discipline share

Curriculum share data can also be analysed *within* the whole science learning area to show a measure that we have coined “curriculum share”. For example, the Dobson report compares science participation across the 1990s by this method (p. 79). The data for either end of the range (1992 and 2002) are shown in the next table, along with data for the mid-point year, 1996. Numbers have been rounded and so may not add to 100 down each column.

Table 5 **Percentages of all science students taking each discipline (Australian data)**

Discipline	1992	1996	2002
Biology	38	36	35
Chemistry	24	24	23
Physics	22	22	22
Science—other	9	10	9
Psychology	5	8	11
Geology	1	1	1

Note: Based on data drawn from the Dobson report (2003).

The increase in the popularity of psychology has already been noted, and it appears that its increased subject “share” has been drawn mainly from biology. We could speculate that the impact of this type of switch on subsequent tertiary enrolment in the sciences might be minimal. Where biology might have been chosen as an “interest” or “filler” subject with no intention to progress it to tertiary level, psychology may well fulfil the same purpose.

Measure Three: Participation as a percentage of the whole cohort

The numbers of students enrolled in a final year subject can be expressed as a percentage of the total cohort on entry to secondary school. This measure draws on the data used to construct enrolment trends, and so is open to the issues of interpretation of what counts as a science subject, as already described for Measures One and Two above. Another disadvantage is that this measure cannot account for students who repeat a year, or who are enrolled on a part-time basis (Fullarton et al., 2003). In Australia, movement between states over the course of schooling creates another potential source of error for this measure.

Cohort retention data add an interesting new perspective to possible interpretations of trends. The Committee report noted that in 1982 just 35 percent of the Australian cohort continued to the final year of secondary school. This figure rose sharply across the 1980s to peak at 77 percent in 1992 and in 2002 stood at 75 percent[6].

Dobson and LSAY both report a continuing pattern of higher retention rates for female students (82 percent for females, 72 percent for males in 2002, for example). LSAY further reports that staying at school longer is associated with coming from a higher socioeconomic background, a non-English speaking background, having better earlier school achievement, attending school in a metropolitan area, and attending a private school (Fullarton et al., 2003). While some of these factors may seem self-evident, this is an important reminder that the nature of the cohort at secondary school in the final year is not fully representative of all students who *could* still be at school, and will have impacts on reported choice trends.

A snapshot of New Zealand data shows some similarities, with final year retention rates rising from 18 percent in 1984 to 48 percent in 1995. Retention rates show demographic differences, with Mäori students staying at school for an average of 4.1 years in 1997, compared to 4.6 years for Päkehä students (Bolstad, in press)[7].

Changes in the size and composition of the final year student cohort must be taken into account when participation trends are discussed. Notwithstanding the factors reported above, learning abilities must span a wider range when far more of the cohort is still in school. This has been reflected in the opening up of a much wider variety of subject choice, as briefly outlined above.

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[6] Dobson's report puts the 2002 retention rate at 77 percent, suggesting that minor differences of interpretation are an issue whatever statistical measure is used. (He specifies that students were "full time", for example.)

[7] This "snapshot" relies on secondary data, with the original analysis of MOE statistics carried out by two other research teams. It is not possible to access comparative data systematically collated across multiple years, in ready-published form.

Participation trends by cohort retention in Australia

When retention rates are taken into account, interesting differences in participation patterns over time emerge. The following data, summarised from the Committee report (2003), illustrate the different measures for participation in biology. Note that the years used in the two tables do not coincide exactly because only exact data reported in the text of the discussion have been used[8].

Table 6 **Enrolment as a measure of participation in biology (Australian data)**

Year	% of final year enrolled biology
1977	58
1990	30
2002	19

Table 7 **A participation measure that takes Australian school retention rates into account**

Year	% of original cohort taking biology
1981	18
1992	30
2002	19

While Table 7 does show a decline in numbers enrolled in biology across the 1990s, the pattern of steady decline since the early 1980s, as shown by the enrolment measure (Table 6), is not as evident. As a percentage of the original secondary school cohort, as many students continued to take biology in the final year of school in 2002 as did so in the early 1980s. For this measure, the peak in the early 1990s doubtless reflects the situation when more students were staying at school, but subject choices had not yet opened up. For some of these students biology may well have been a default choice, taken because there were few other suitable options available. As noted above, such students have access to a much wider range of choices now.

A similar pattern was found for chemistry and physics. As the next table shows, expressed as a percentage of the original cohort, 2002 participation rates in these two subjects are also seen to be similar to those of the early 1980s, after having peaked in the early 1990s.

8 Comparisons for the same years could be extrapolated from the graphs provided, but would not be as accurate.

Table 8 **Participation trends in chemistry and physics expressed as a percentage of cohort at start of secondary school (Australian data)**

	Physics (% original cohort)	Chemistry (% original cohort)
1981	11	10
1992	18	17
2002	13	12

Participation trends by cohort retention in New Zealand

While the data have not been published in this form, it would be possible to collate patterns pertaining to changes in the size of the beginning cohort still at school in Year 13, at least from 1994 on. Comparisons of science participation based on this measure do not currently exist.

Measure Four: Participation as actual numbers enrolled

Participation can be reported as actual numbers of students enrolled in the three traditional sciences in different years. Fluctuations in enrolment numbers will obviously reflect fluctuations in the size of the cohort as a whole. This measure could be useful if data is needed to make planning decisions—for example, to ascertain how many students are likely to be seeking tertiary enrolments in any one year.

The Australian situation

Dobson (2003) reports that the Australian "student aged population increased between 1986 and 1991, declined to 1996, but at the time of the 2001 Census of Population and Housing had increased" (p. 75). There is clearly some instability in cohort size over time, as there is in New Zealand (see below).

The Committee report (2003) found that, when collated on total student numbers per subject, the Australian participation data showed a "steady and cumulative" decline in numbers enrolled in each of the three sciences across the 1990s. That is, the actual numbers of students choosing these options in their final year of school have steadily declined.

The New Zealand situation

According to demographer Ian Pool, New Zealand has a pattern of "disordered cohort flows" that produce wave-like patterns of increases and decreases in various sectors of the population, making educational planning a considerable challenge. The numbers of young people in the 15–24 age group are predicted to rise from 534,000 in 2001 to 640,000 in 2011 as the "baby-blippers" move through their secondary and tertiary education years. Yet at the same time, numbers in the

5–14 age group are expected to drop because of the decline in fertility rates in New Zealand (Pool, 2004). This current increase in cohort size needs to be taken into account if participation is reported as actual enrolment numbers per subject.

The MOE currently collects data on actual numbers of students enrolled in all subjects[9] at all secondary year levels. This data is recorded by gender, and the numbers of schools offering each subject are recorded. To illustrate what is available, the 2004 data for the sciences are shown in the table on the next page.

In view of concerns about participation, it is interesting to note that not all secondary schools offer any or all of the three traditional sciences. Smaller schools, which are more likely to be found in rural areas, struggle to offer a wide range of curriculum choices at the senior level. This seems a likely explanation for this pattern. It would be possible to investigate this possibility by cross-tabulating this data set with school size and school type.

The relative popularity of physics for male students and biology for female students is also apparent, and is further discussed below.

[9] What "counts" as a subject is specified in the data return forms. Where unusual subjects are offered, schools would need to allocate students to the nearest equivalent subject on the provided list.

Table 9 **MOE enrolment data for science subjects in 2004**

Subject		Zone Year 9		Zone Year 10		Zone Year 11		Zone Year 12		Zone Year 13		TOTAL			Number of schools offering the subject
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Total	
Science	Agriculture/Horticulture	1250	720	2307	1046	2403	995	1415	543	461	234	7836	3538	11374	202
	Biology/Biological Science	298	1	382	40	1301	1857	5062	8807	3118	5386	10161	16091	26252	397
	Chemistry	326	43	343	33	1268	1040	5718	6067	3620	3675	11275	10858	22133	371
	Earth Science/Astronomy	33	10	68	98	340	1456	65	335	11	51	517	1950	2467	74
	Physics	311	18	327	13	1858	863	7521	4097	5200	2783	15217	7774	22991	365
	Science	32789	31203	31126	30003	23651	23571	1579	1118	542	591	89687	86486	176173	480

Measure Five: Student- or school-specific participation trends

This measure, along with Measure Six, turns attention away from broad demographic data to consider the nature of choices made by individual students in different schools. These measures require a different type of data, with all the choices made by each student able to be collated.

In Australia, data gathered in the LSAY project shows that 55 percent of the final year cohort studied at least one science subject in 2001. This represented a decline from 1993 (68 percent) and 1998 (60 percent). However, as we have seen, across this time period the number of available subject choices increased considerably, and would differ across schools. The LSAY analysis also reports "strong gender differences in the type of sciences studied" (p. 29). Sixty-four percent of physical sciences students were males, while 60 percent of biological and other sciences students were females (Fullarton et al., 2003).

Illustrative data from the Learning Curves case studies

Data from NZCER's Learning Curves research also provides a snapshot of students' subject choice combinations in the six participating schools. Year 12 students' choices were documented for the years 2003 and 2004, and Year 13 students' choices for 2004. While the sample is not comparable to the LSAY sample in Australia, this data does show some interesting similarities to the Australian trends. The Learning Curves data show that 56 percent of Year 12 students were taking at least one science subject in 2004, compared with 54 percent in 2003. This is very similar to the Australian participation rate in 2001. In the six Learning Curves schools there was an apparent[10] drop in participation for the final year of school, with just 45 percent of the responding Year 13 students taking at least one science subject in 2004. As in the LSAY study, girls were more likely to be taking biology, and boys were more likely to be taking physics. By contrast gender differences in chemistry participation were insignificant.

Within any one school setting, the types of *pathways* through science subjects that are open to students also influence choices, and provide another dimension to considerations of participation patterns. The following data from the Learning Curves project illustrate this. The next figure shows enrolment data for all the Year 12 sciences (Measure One) for 2003 and 2004. Note that the small differences between these two years are not significant (Hipkins et al., in press). As in the enrolment data reported above, biology is the most popular of the three traditional sciences, but only by a small margin.

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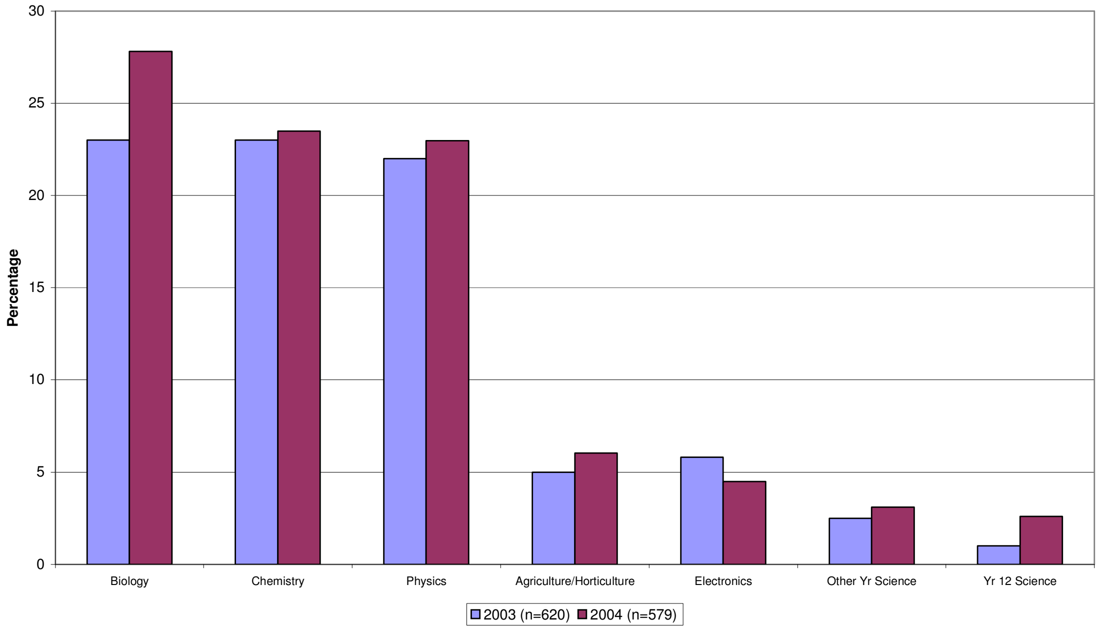
[10] A smaller percentage of the cohort responded to the 2004 survey, when they were in Year 13, than to the 2003 survey when they were in Year 12. Although some would have left school, others may have felt they had already contributed to this research in previous years, or to the focus groups that were also carried out in 2004.

Figure 1 **Enrolment data for Year 12 students in six New Zealand schools (2003/2004)**



This figure also shows that, in these six schools, a combination of agriculture/horticulture and electronics were the two most popular "alternative" Year 12 science choices[11], despite only being offered in four of the six schools. However it seems some alternative pathways peter out at the end of Year 12. In 2004 electronics was not offered by any of the six Learning Curves schools at Year 13 and one school no longer offered a combination of agriculture and horticulture at this year level. The apparent fall in numbers of students studying sciences in Year 13 may partially reflect the loss of students taking these types of options. While this is only a snapshot of what may be happening nationally, this trend bears further investigation, and highlights the impact of school-specific factors on students' choices.

Measure Six: Combinations of science subjects

Where data for individual students' subject combinations are available, participation can also be described in terms of combinations of science subjects taken. As the Australian Committee report noted "it is the package of subjects taken in combinations that provides an indication of students' orientations and which influences their future options, choices and pathways" (Committee for the Review of Teaching and Teacher Education, 2003, p. 8). They also noted that the combination of two physical sciences—i.e. chemistry and physics—is of particular interest because these subjects are a "foundation for further science-based studies" (p. 8).

[11] Electronics is often recorded as a technology subject in New Zealand, including in MOE statistics.

Australian trends in combining sciences

As the next table shows, the LSAY study has found a steady decline across the last decade in participation in more than one science subject in the final year of school (Fullarton et al., 2003, p. 51). In 2001, just 2 percent of final year LSAY students took all three traditional science subjects.

Table 10 **Percentage of final year Australian students taking more than one science subject**

Possible combinations	1990 %	1993 %	1998 %	2001 %
Physics/chemistry	15	13	11	10
Biology/other sciences	3	5	3	3

Fullarton et al. (2003) note that the overall decline in numbers of students taking biology across the 1990s was primarily for students who took *only* biology, whereas the decline in the physical sciences was mainly for students taking a combination of physics and chemistry. This may be a telling difference, given the implications of taking the physical sciences for keeping a wider range of university pathways open.

Again, care is needed because the trend may not be all that is seems. In recent years it has become increasingly common for students to multi-level—for example, to take at least one Year 13 subject in Year 12. While the subject most often “accelerated” like this is mathematics, this practice may have particular appeal for able science students who also wish to keep other types of subjects in their Year 13 courses. By taking either Year 13 chemistry or physics in Year 12, they keep one more timetable slot open in Year 13.

New Zealand trends in combining sciences

Rather more of the responding Year 13 Learning Curves students took three science subjects, usually but not always biology, chemistry, and physics (Hipkins et al., in press). The next two figures show the ways Years 12 and 13 students in the Learning Curves schools combined the three traditional science disciplines in 2004.

Figure 2 **Year 12 science combinations (n=579)**

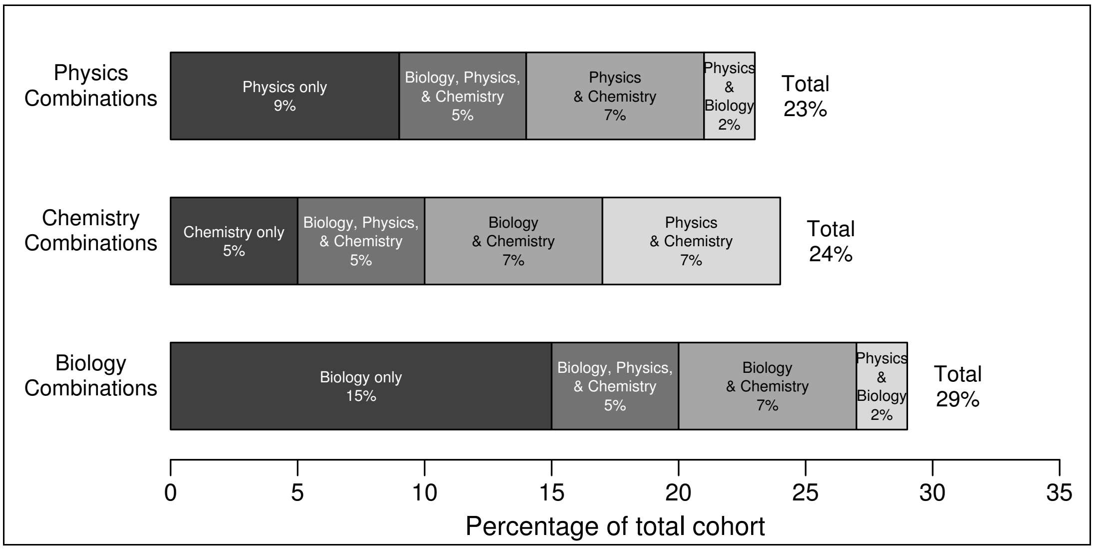
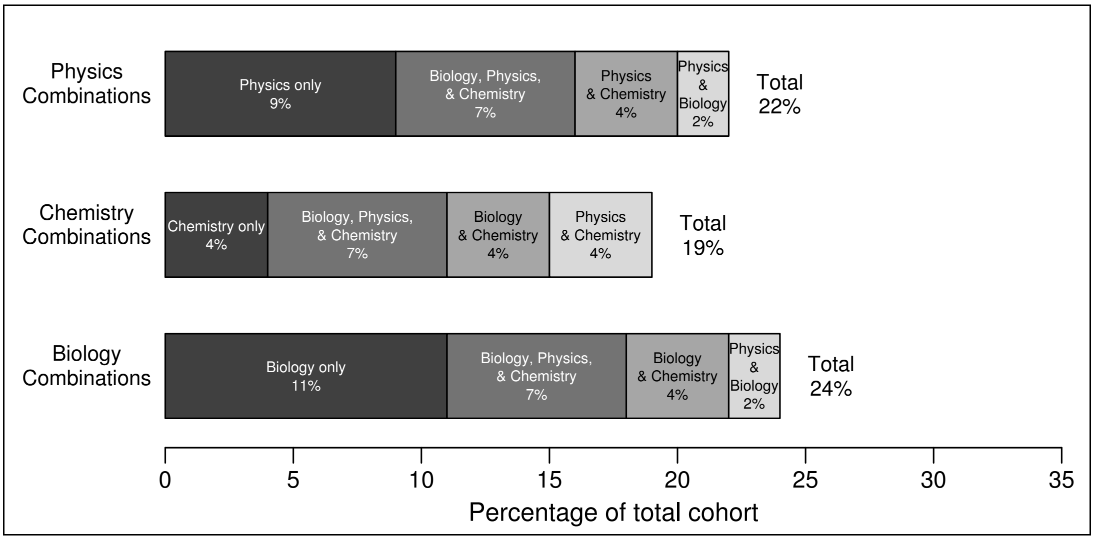


Figure 3 **Year 13 science combinations (n=358)**

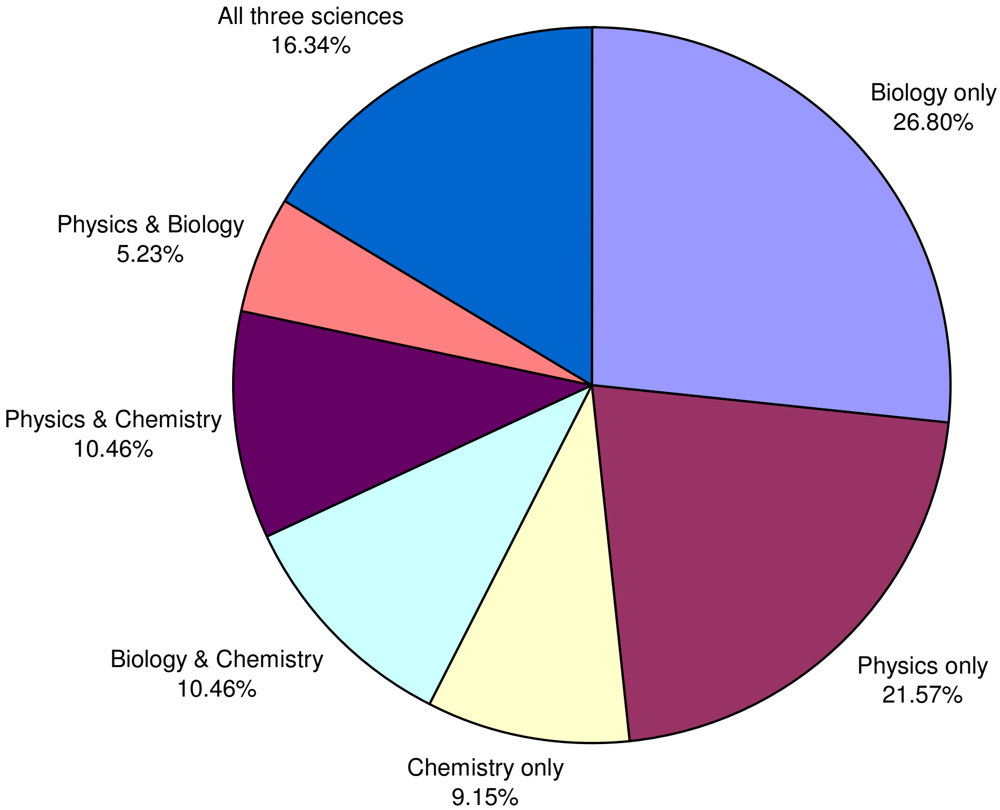


While the sample size is very much smaller, there are again similarities between the Learning Curves and LSAY patterns of science subject combinations. A slightly greater percentage of these New Zealand students combined all three sciences (7 percent at Year 13, 5 percent at Year 12 compared with 2 percent of Australian students in their final year). But as we have seen, differences of several percentage points are quite likely to result from differences in the way data are gathered and processed, even in the very large samples. What the New Zealand data does illuminate is the apparent drop in biology participation from Year 12 to Year 13. As in Australia, this occurs amongst the students who are only taking biology, not those who are combining it with other sciences—that is, amongst students who, we could speculate, would be less likely to be seeking to study sciences at tertiary level.

Discipline share by combinations

The next figure shows the percentages of all Year 13 science students taking each of the various science discipline combinations in the Learning Curves schools in 2004 (Hipkins et al., in press).

Figure 4 **Distribution of choice combinations amongst Year 13 traditional science disciplines**



Taking biology as the only science subject chosen is the most popular option. We could speculate that this is because more girls stay at school into Year 13, and biology is chosen more often by girls. Taking physics as the only science option comes next, and taking all three sciences is the third most popular of the combinations. Taking physics and biology together is the least common combination (5 percent of all science students, 2 percent of students in whole responding cohort). Given the increasing emphasis on fields of scientific research that cross discipline boundaries, this is food for thought.

Subject cluster analyses

Moving beyond a focus on only science subjects, choices can also by analysed by statistical techniques that cluster the most commonly occurring combinations. Such an analysis has been carried out at each of Years 11, 12, and 13 for the 2004 Learning Curves data (Hipkins et al., in press, provides an explanation of how this was done). The next two tables show how the sciences were distributed through the five clusters at Year 12 and four clusters at Year 13.

Table 11 **Cluster analysis of Year 12 students' 2004 subject combinations in the Learning Curves schools**

Cluster One	Traditional English	Media Studies	Alternative Maths
(n=165)	**Agriculture/Horticulture**	Physical Education	Health & Lifeskills
	Sports	Geography	History
	Tourism & Hospitality	Classics/Latin	Te Reo Mäori
	Information Management	Drama	Visual Arts
	Photography	Transition	Vocational
	Comment: This cluster combines traditional social sciences and English with a range of newer subject choices in the arts and in transition to work areas. The only science subject represented is agriculture/horticulture.		
Cluster Two	Traditional English	Traditional Mathematics	
(n=91)	**Biology**	**Chemistry**	**Physics**
	Geography	History	European Languages
	Computer Studies		
	Comment: Here the three traditional science disciplines all appear in a cluster with other "academic" subjects, drawing choices across a relatively narrow range. This is the only cluster in which biology appears.		
Cluster Three	Alternative English	Alternative Maths	**Agriculture/Horticulture**
(n=77)	**Electronics**	Physical Education	Sports
	Tourism & Hospitality	Te Reo Mäori	Practical Technology
	Computer Studies	Music	Transition
	Vocational		
	Comment: There are some similarities here to the first cluster, but these students are taking an alternative version of English, which suggests they may be contending with learning difficulties. The subjects have a noticeably practical orientation. Pasifika and Mäori students are over-represented in this cluster.		
Cluster Four	Alternative English	ESOL	Traditional Mathematics
(n=62)	Accounting	**Chemistry**	**Electronics**
	Physics	Health & Lifeskills	Economics
	Computer Studies		
	Comment: While these students may struggle with their English, the other choices reflect the appeal of more mathematically orientated subjects, including the physical sciences. Asian students are over-represented in this cluster.		
Cluster Five	Traditional English	Media Studies	Traditional Mathematics
(n=163)	Accounting	**Chemistry**	**Physics**
	History	Economics	Classics/Latin
	European Languages	Practical Technology	Graphics and Design
	Information Management	Visual Arts	
	Comment: This cluster has some similarities to Cluster Two, but represents a wider and more eclectic combination of other subjects with the physical sciences.		

For Year 13, the final year of secondary school, four main subject clusters were found. The traditional sciences appear in two of these clusters.

Table 12 **Cluster analysis of Year 13 students' 2004 subject combinations in the Learning Curves schools**

Cluster One	Alternative English	Media Studies	**Agriculture/Horticulture**
(n=100)	Sports	Geography	Tourism & Hospitality
	Information Management	Computer Studies	Music
	Transition	Vocational	
	Comment: Agriculture/Horticulture is clustered here with a small range of subjects with a more "alternative" feel. This may, however, represent its availability as a continuing pathway in just three of the six schools. Mäori and Pasifika students are over-represented in this cluster.		
Cluster Two	Traditional English	Accounting	Calculus
(n=80)	Statistics	**Biology**	**Chemistry**
	Physics	History	Economics
	Graphics and Design		
	Comment: As at Year 12 three traditional science disciplines all appear in a cluster with other "academic" subjects, drawing choices across a relatively narrow range.		
Cluster Three	ESOL	Calculus	Statistics
(n=66)	**Biology**	**Chemistry**	**Physics**
	Economics	Computer Studies	
	Comment: This is very similar to Cluster Four at Year 12, except that biology appears alongside the physical sciences and English has been dropped. Again, Asian students are over-represented in this cluster.		
Cluster Four	Traditional English	Physical Education	Geography
(n=80)	History	Classics/Latin	Graphics and Design
	Music	Drama	Visual Arts
	Photography	Art History	Correspondence Subject
	Vocational		
	Comment: In this cluster the arts are strongly represented, but no sciences, nor either of the mathematics subjects. Female students are over-represented in this cluster.		

While this data shows very interesting trends in choice combinations that include the sciences, it should not be read as other than indicative of what could be achieved with larger and more representative samples. There were strong school, ethnicity, and gender effects that cannot be disentangled with the small data pool available. These effects are likely to be related to the clustering of Mäori, Pasifika, and Asian students in several of the schools, and to the patchy student response rate, especially at Year 13, in several of the schools.

These caveats notwithstanding, the data do raise questions about how widely science subjects are actually combined with the wide range of other subjects available. In its first year, the Learning Curves study described ways that school timetabling practices constrain the combinations that are actually possible (Hipkins & Vaughan, 2002). In the second year it discussed advice from deans as a conservative influence on students' choices (Hipkins et al., 2004). These school effects compound any other clustering effects related to the nature of the community on which the school draws and so on.

The clusters suggest that some students, if they turn away from the traditional sciences in their final 2 years, may do so completely. Whether or not this is cause for concern is an interesting question that bears further debate.

Measure Seven: Examination enrolments

Participation in science subjects in the senior secondary school can also be analysed in terms of enrolment in assessments that lead to qualifications. Such data applies only to those students who enrol, participate, and complete their courses, giving it some advantages over other measures if likelihood of ongoing participation in the sciences post-school is the question at issue. NZQA holds participation data for the former School Certificate and Bursary examinations, and now for NCEA enrolments at Year 11/Level 1, Year 12/Level 2, and Year 13/Level 3. School Certificate and Bursary were examined by one examination per subject, making for a relatively straightforward comparison with other enrolment data, should this be desired. However, with the inception of the NCEA, participation patterns are more difficult to determine easily or simply.

The unit of assessment for the NCEA is not a full examination but rather the "achievement standard" or "unit standard" in some cases. Full year courses are assessed by different standards, some assessed internally as the year progresses, and others collected together in subject examinations at the end of the year. Students may use the examination time to sit any number of the achievement standards being tested. Students who opt to complete the questions for just one standard will have the full examination time to do this (but obviously risk gaining no or few credits towards their qualification). Students who complete all the questions may be providing evidence of their achievement in as many as six standards, all within the same timeframe. Students' achievement will then be reported for individual standards, albeit clustered into subjects on their record of learning. Controversially, standards that students had entered but failed to achieve were not mentioned on their records of learning in 2004.

All this data is available from NZQA aggregated on a per-standard basis. Enrolment levels in different standards within a subject area vary widely because it is up to schools to determine how they put assessment combinations together. There is no guarantee that all students taking the same "subject" will in fact be studying much the same course. While this sounds very uncertain, the Learning Curves research has shown that, so far, science teachers in the six schools have been cautious about taking advantage of the flexibility offered, at least for their able students. The traditional science courses they offer differ very little from the intention of the standards developers because they cover most, or all, of the full suite of achievement standards on offer at any one level.

The next table illustrates this for Year 11 science courses offered in the six Learning Curves schools in 2003 (Hipkins et al., 2004). Ticks indicate an intention to teach and assess the topic covered by the standard of that number. For example, the science standard AS 1.3 was a biology topic: “Describe uses and effects of micro-organisms and the transfer of genetic information”. It was worth 5 credits. Some teachers opted for biology unit standards from the wide range available, reasoning that students would be better assured of gaining credits if the two aspects were assessed separately. Adding to the complications for making comparisons, this standard has been revised and is now called “Describe aspects of biology” although it arguably covers much the same content.

Another issue to bear in mind is that these are the types of courses offered to those students considered “able”. Other students may be studying “science” courses of entirely different composition—perhaps assessed with the suite of unit standards developed for the NZASE “Certificate in Science” course, for example (Hipkins et al., 2004).

Table 13 **Composition of the Year 11 traditional-discipline science course assessment in the six Learning Curves schools**

	Science achievement standards offered							Other standards offered
School	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**	**1.7**	
City School A 26 credits	✓	✓		✓		✓		2 unit standards Biology achievement standards 1.3 and 1.8
City School B 25 credits	✓	✓	✓	✓		✓		Biology achievement standard 1.1
City School C 24 credits	✓		✓	✓	✓	✓	✓	
Town School D 24 credits	✓		✓	✓	✓	✓	✓	
Town School E 34 credits	✓	✓	✓	✓	✓	✓	✓	3 unit standards
Town School F 27 credits	✓	✓		✓		✓		3 unit standards Biology achievement standards 1.3 and 1.8

Note: Grey-shaded columns are internally assessed standards.

Clearly it would be difficult and complicated to determine the level of students’ ongoing participation in science by using *only* NZQA’s examination enrolment data as a measure. However, great care also needs to be taken when interpreting the meaning of a “subject” now—as in enrolment data provided by schools to the MOE. While uncertainty in this measure has always existed, the NCEA must have exacerbated it. However it would be possible, given the necessary resources, to work with individual schools to determine the nature of their science subjects, and also to carry out the types of cluster analyses described above. Each school is required to keep detailed electronic records of student participation and this data is potentially a very rich source for such analysis.

Despite this complexity, one new measure has greatly increased potential for rich analysis of participation based on students' qualifications entries. All Year 11 students, on entry to Level 1 of the qualifications framework, are now assigned a "national student identity number" that is used to record all their subsequent educational assessment at both secondary and tertiary levels. While this system was initiated for tertiary study in the mid-1990s, it was not implemented at the secondary school level until 2002. With the caveats on this measure outlined above, this unique number has made it possible to begin at either end of the participation spectrum to track students' choices of science subjects—or not. Such an analysis would potentially yield data concerning some of the patterns that can be read from the LSAY data in Australia, because students' combinations of choices, both within a year and across time, could potentially[12] be tracked. Cluster analyses, such as the pilot study described above, would also be possible.

Concluding comment

The measures reported here illustrate the contextual complexities of trying to determine and interpret overall participation trends in the senior sciences at secondary school. Great care is needed in deciphering exactly what story the data tells, particularly if comparing measures proposed by different research groups.

However, across the range of measures it does seem that there has been a decline in participation in recent years. It may be of a smaller magnitude than those who pick the most negative measures would suggest but it definitely exists in Australia, and seemingly on the evidence available, in New Zealand. Whether this is read as a negative choice against science, or a positive choice for one of the many new subjects now on offer, is a matter of perspective. This question should be illuminated by the empirical component of this project, and will be further discussed in the following literature review.

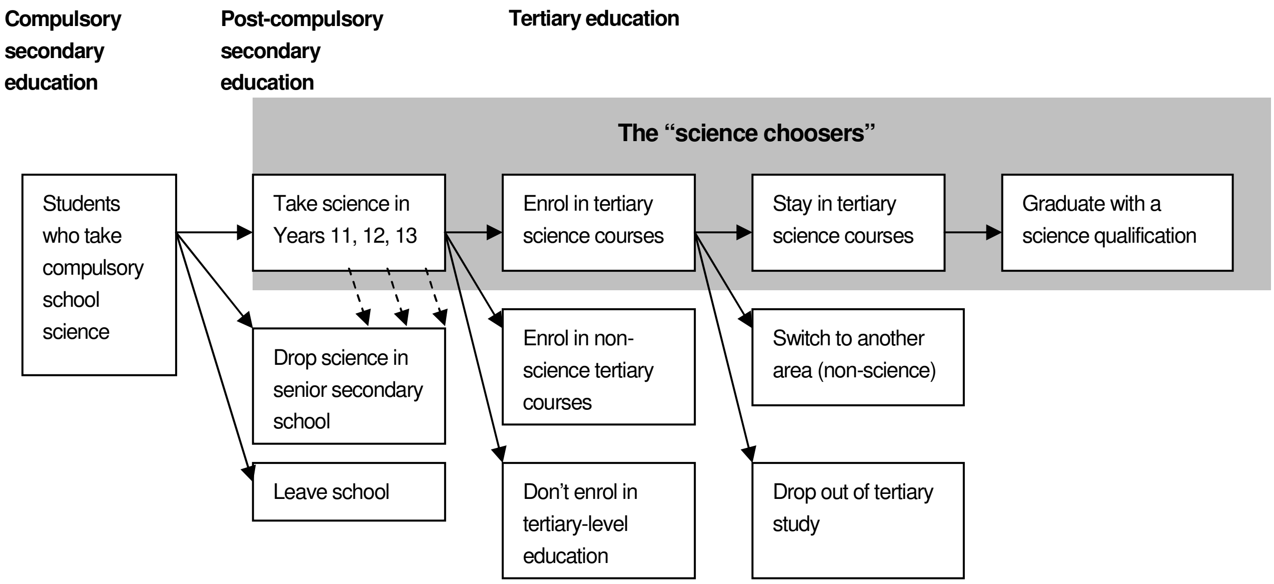
[12] There would be ethical issues to address if data were disaggregated in a way that allowed identification of individual students.

3. What influences students' choices? Insights from related research

Why do students decide to continue, or not to continue, with science as they move into upper secondary school, and as they move from secondary to tertiary study? This section reviews existing research to provide some insights into this question.

This part of the background paper, and the larger research project which it informs[13], focuses mainly on the decision making of "science-able" secondary students at the transition point from senior secondary to tertiary education. However, it is important to recognise that there are numerous points on either side of the secondary-tertiary transition at which students may "decide" to continue (or discontinue) science study. For example, Figure 5 represents one simple model for the pathway students might take between Year 10 of secondary school, to graduating with a tertiary science degree.

Figure 5 **The pathway from compulsory school science to tertiary science graduate**



[13] NZCER's research for MoRST on students' subject choices on transition to tertiary study.

Research about why learners choose to continue or discontinue science study has been undertaken at or across all of the transition stages shown in Figure 5, including:

- the transition from the compulsory to the post-compulsory school curriculum, at which point science subjects usually become optional[14];
- the transitions between each of the years of the post-compulsory school curriculum (i.e. from Year 11 to Year 12, and Year 12 to Year 13), at which times students may decide to discontinue with sciences;
- the transition from senior secondary to the first year of tertiary study; and
- the transition between each of the subsequent years of tertiary study.

There are at least two ways to approach research about students' decision making in relation to science study. The first approach is to identify students who have *already* chosen to continue or discontinue studying science, and to investigate *post hoc* why they have made those decisions (e.g. Brown, Koutoulis, & Jones, 2005; Koslow, 2005; Lyons, 2004; Stewart, 1998; Worthley, 1992). The second approach is to collect longitudinal data as students progress through secondary or tertiary science education, and to investigate what underlies students' decisions to continue or discontinue with science *as these decisions occur* (e.g. Cleaves, 2005; Dalgety & Coll, in press; Johnstone, Haines, & Wallace, 2001). In either case, the first challenge for any researcher is to decide on their target population for research. Will they study only those students who *have* chosen to continue to study science? Will they study those who have chosen *not* to continue with science? Or will they study both kinds of student, and try to understand the differences between them?

Research that focuses on the "science choosers", whether at secondary or tertiary level, tends to ask questions such as: Why were these students attracted to science in the first place? Why do they remain in science? Does it have anything to do with their personal characteristics, views about themselves, previous educational experiences, social backgrounds, or future aspirations? Previous research seems to have devoted substantial attention to the difference(s) in science participation between male and females students (e.g. Brown et al., 2005; Erwin & Maurutto, 1998; Stewart, 1998; Worthley, 1992). What other factors might influence students' participation or non-participation in science education? Similarly, research that investigates those who do *not* continue with science study asks questions like: Why aren't these students attracted to science? When did they decide not to pursue science? Could anything have been done to encourage them to stay in science? Are there ways they might be attracted *back* into science study?

In preparing this background paper we have drawn on a wide spectrum of research that, collectively, provides information about subject choices and decision making for students across all the educational stages shown in Figure 5. This includes studies that have focused specifically

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[14] In New Zealand schools, this usually occurs at Year 11 or Year 12. There is no national requirement for Year 11 students to study science. However, most schools require their students to take science at least until Year 11.

on students' choices in relation to science, and research which has focused more generally on students' decision making and educational pathways through secondary and tertiary school (e.g. Furlong, 2005; Leach & Zepke, 2005; Vaughan, 2005). The latter research reveals interesting data (and raises even more interesting questions) about students' educational decision making. For example, when are students' decisions and choices actually made? Are there less visible influences (e.g. cultural or socioeconomic) that shape, constrain, or encourage certain kinds of choices/pathways of certain types of students? Finally, what can educators and policy makers do to support or influences young peoples' choices and pathways?

For MoRST, a key question is: Are there ways to support or influence young peoples' choices and pathways so that they continue to participate in science at least to tertiary level education, and perhaps into their careers? In order to inform this policy question, the background paper next outlines our findings in relation to the wide range of questions posed above.

What accounts for secondary students' decisions to study science?

As outlined in the first part of this paper, science education actually encompasses a broad range of learning areas. Beyond Year 10 of secondary school, "science" shifts from being a single subject, to an increasingly differentiated range of specialist subjects. In Years 11–13, these include: science, biology, chemistry, physics, earth sciences, astronomy, agriculture, and horticulture; as well as other subjects classified in the "technology" domain, such as biotechnology, computer science/ICT, structures and mechanisms, or electronics and control. The choices students make about *which* sciences to study in senior secondary school have implications for the branches of science that students can easily move into in their tertiary study. Thus, much research about students' science subject choices has focused on students' particular choices *within* the sciences. For example, why students choose *biological* but not *physical* sciences, or vice versa.

Existing research suggests that students' subject choices in senior secondary school involve a complex interplay of personal, social, and structural factors. Below, we discuss findings from three international studies. Two of these studies investigated, *post hoc*, why students chose to take physical science subjects in their final 2 years of high school (Lyons, 2004; Stewart, 1998). The third was a longitudinal study which tracked the science and non-science subject choices of 69 science-able students between the ages of 13 and 16 in six English schools (Cleaves, 2005).

Stewart (1998) surveyed 128 A-level (senior secondary) physics students (93 male and 35 female) to explore reasons for the under-representation of girls in physics courses in England and Wales. A range of theories has been put forward to explain why girls and women are often under-represented in physics. For example, is it due to a lack of opportunities for girls to study physics? Can it be attributed to biological differences, or children's early socialisation or gender identity? Does the school environment make a difference? The students in Stewart's study had all made a positive choice to study physics beyond the compulsory minimum level. Therefore, one might expect them to have similar attitudes towards the subject, perhaps be of similar academic ability, and have similar aspirations and motivations for choosing physics. However, Stewart's small study identified a few interesting differences between the male and female students in the sample. For example, the females tended to be of higher academic ability than the males (measured on their GCSE[15] results), and were more likely to choose physics as their favourite subject. The female students also seemed to prefer physics teaching and learning to be "contextualised", often with a people-oriented focus. Males tended to think there should be more mathematical input into their physics teaching, and females thought there should be more input of sociological examples. In terms of future career aspirations, medicine was a popular higher education choice, particularly for females (who were also more likely to be taking biology alongside physics), while engineering or computing were more popular with males.

Leaving gender issues aside for a moment, Stewart's findings highlight the fact that different students bring their own, perhaps very different, attitudes and interests to their decisions to study (or not to study) science. Some researchers have taken a "deeper" look at what lies underneath these decisions. For example, Lyons (2004) used surveys (n=196) and in-depth interviews (n=37) to explore high achieving students' decisions about enrolling in physical science courses in New South Wales. Like Stewart's study, the students in Lyons' study were aged 15–16 and had recently chosen their courses for the final 2 years of high school. However, Lyons' sample included some students who chose physical science, and some who did not. Lyons used a theoretical model of students' "multiple social worlds", to look at whether the congruence or lack of congruence between these worlds might help to account for students' choices regarding physical science. These "multiple worlds" were: school science, self, family, peers, and mass media.

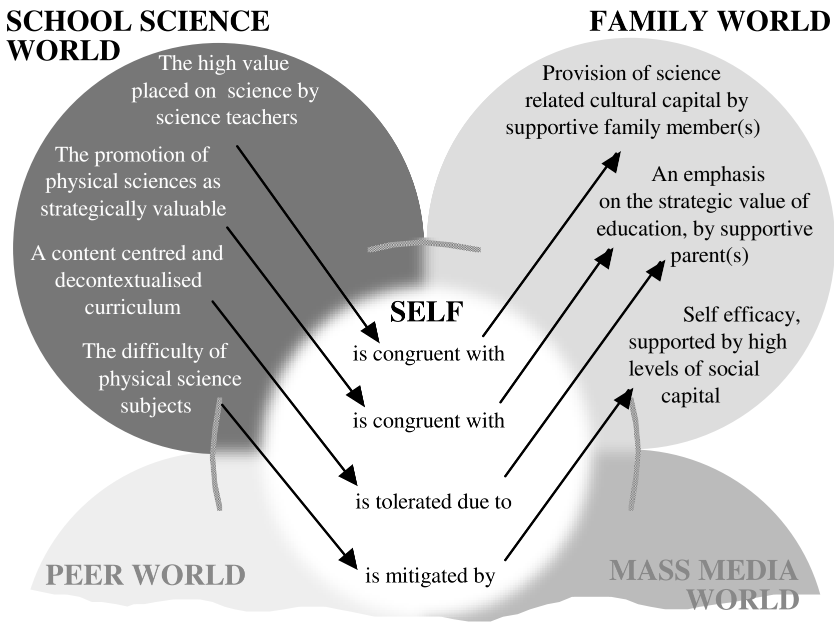
Lyons found that the characteristics most closely associated with decisions about taking physical science were found within students' worlds of school science and family. Interestingly, Lyons found it was decidedly *not* the case that students who chose physics and chemistry courses, or indeed other science courses, described a more, or less, attractive picture of their school science experiences than did those choosing not to continue with science study. Whether or not they chose to continue with physical science, students tended to describe school science as a subject that was focused on "facts", transmitted from expert sources, to relatively passive recipients. Students felt that curriculum content was usually presented in a decontextualised manner, leading many to consider school science irrelevant and boring. The students who opted to take physics and chemistry tended to see these subjects as having primary *strategic value* in terms of the students' future study and work options. Physics and chemistry were also considered to be the most difficult of science courses, and generally more difficult than most other subjects. Thus, the combination of the difficulty of these subjects, and their strategic value, imbued them with a certain level of prestige for the students.

[15] General Certificate of Educational Achievement.

Lyons also found several aspects of the students' "family worlds" which were associated with their decisions about choosing physical science. These included their families' attitudes to formal education, and their attitudes towards science. Almost 80 percent of the interviewees who chose physical science felt their parents were oriented towards the strategic importance of formal education for university or career paths. By contrast, the parents of students *not* taking physical science tended to encourage students to take subjects they enjoyed or were good at, rather than basing their decisions on the subjects' strategic value. About 71 percent of the students choosing physical science described parents or other family members who advocated or encouraged an interest in science. Overall, it appeared that the most important thing was whether or not families' attitudes were aligned with students' *own* attitudes. With the exception of one case, *all* of the interviewees who chose physical science subjects described supportive relationships with a parent or family member whose attitudes to education, or science, favoured such a choice. The quality of the relationships between the students and their families was also implicated in students' levels of confidence and academic self-efficacy, and in some cases, affected the role-modelling dynamics within families.

Lyons developed the following working model as a framework for further research (see Figure 6).

Figure 6 **A model illustrating the congruence between characteristics of family and school science worlds found among science proficient students choosing physical science subjects (Lyons, 2003)**



Lyons' model suggests that:

- Science proficient students are more likely to choose physical science courses when the importance attributed to science by teachers is congruent with the advocacy for science of a significant, and supportive, family member.

- Enrolment in physical science subjects is more likely where the perception that they are primarily of strategic value resonates with students' recognition that such a quality is highly valued within the family.
- For some students, the perception that school science is a content-centred subject, presented in a transmissive, decontextualised, and often personally irrelevant way, is offset by the short- and long-term strategic value of taking physics and chemistry.
- The perception that physics and chemistry are the most difficult of science courses may be less daunting for some students because they possess high levels of confidence, optimism, and self-efficacy. Such qualities are associated with the high levels of social capital inhering in their relationships with one or more significant family members, usually a parent.

Lyons concludes that:

> Statistical factors relating to enrolment decisions, such as socioeconomic status, parental education or ethnic background, may only be indicators of the more directly influential characteristics of students' worlds, such as the resources of cultural capital[16] made available by families (Lyons, 2004, p. 9).

A third study, by Cleaves (2005), suggests that investigating students' subject choices and decisions *over time* provides an even more complex picture of how and why these decisions are made. Cleaves' study tracked 69 science-able students from six schools in England between the ages of 13 and 16, to investigate how, when, and why students decided upon their post-16 subjects. Cleaves' data suggested five types of student "choice trajectories", which she labelled and described as follows:

1. **"Directed"**. These students had already chosen a career by Year 9, and they chose to continue or discontinue with science based on whether or not it would contribute to their specific career ambition. The careers to which these students aspired tended to be "high visibility occupations" such as teacher, lawyer, caterer, or beauty therapist. The "directed" trajectory students tended to have a limited awareness of the range of occupations and careers involving science.
2. **"Partially resolved"**. These students chose a wide range of subjects through school, with the view that this would keep open a wider range of options. Such students were receptive to a variety of career possibilities, and were proactive and analytical in making subject choices that would provide them with versatile tertiary study and career options in the areas that interested them. If they were interested in some aspect(s) of science, these students kept these subjects in combination with mathematics for strategic reasons.

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[16] **Cultural capital** (*le capital culturel*) is a sociological term first used by Pierre Bourdieu. It can be defined as: forms of knowledge; skill; education; any advantages a person has which give them a higher status in society, including high expectations. Parents provide children with cultural capital, the attitudes and knowledge that make the educational system a comfortable familiar place in which they can succeed easily (see http://en.wikipedia.org/wiki/Cultural_capital).

3. **“Funnelling identifier”**. Like the students in the “partially resolved” category, the “funnelling identifier” students began by keeping their subject choices broad, but gradually funnelled their choices towards a career across the years of secondary school. Most of these eliminated science by “negative selection”. That is, their decision to drop science reflected an increasing antipathy to science over time. Negative attitudes were associated with not doing well in science, finding it boring or irrelevant, and being unaware of the scope of science knowledge. Some students did not have an accurate perception of their science potential—that is, they saw themselves as “not good enough”, despite assessment results to the contrary.
4. **“Precipitating”**. Students in this category were aware of their breadth of choices, and considered these all in a mature way before deciding. All the “precipitating” students who eventually chose science deliberately kept a broad combination of science and non-science subjects right up to A-levels. They were different from the other students in that they had “a deeper appreciation of what one might expect in a science career, despite evidence that such understanding had not been acquired in the science classroom”.
5. **“Multiple projection”**. These students juggled images of themselves in various career roles, including science-related roles, but seldom ended up choosing science because they developed “stronger tastes in other directions”. For these students, discontinuing science was not “negative selection”, but a positive choice to follow interests other than science.

What do these studies tell us?

The three studies discussed above present a range of interesting information and ideas about students’ subject choices and decision making during, and leading up to, the point of transition from secondary to tertiary study. We have grouped these ideas into two thematic clusters:

- those related to students’ “transition” decision making in general; and
- those specifically related to students’ decision making in relation to science.

We discuss both clusters of ideas below, in the context of other relevant literature.

Students’ “transition” decision making

The studies above all suggest that there is a great deal of variation in how young people make their subject choices and educational decisions. Secondly, they also suggest that these decisions involve a complex mix of psychological and social factors, and often it is the *interaction between* these factors that is important in shaping students’ choices and decisions. Thirdly, students’ personal and family worlds seem to be an important influence on their choices. These findings are consistent with other research about the decisions, choices, and pathways of young people who are preparing to leave, or have recently left school (Leach & Zepke, 2005; Vaughan, 2005).

Cleaves’ research is particularly interesting, since it highlights a range of different orientations or “choice trajectories” that young people may have towards making decisions about their education and career post-school. This suggests that it may be important for anyone seeking to support or influence young peoples' choices, including with respect to science study and career pathways, to recognise this diversity of orientations towards decision making. Provision of individualised or tailor-made approaches that recognise these differences may be more appropriate than one-size-fits-all initiatives. Indeed, a one-size-fits-all approach may be impossible given the complexity of the transition[17] environment that young people are faced with today. Vaughan's longitudinal New Zealand study of 114 young people's pathways from school has found that young people are "engaged in a complex interplay of identity and lifestyle establishment, on the one hand, and negotiation of transition-to-work policies and institutional practices on the other". Vaughan's advice is that:

> For New Zealand careers teachers and policy officials, it might mean supporting young people *through* apparent indecision and changes of heart rather than eradicating those things because they are how young people make sense of the complex transition environment (p. 184, emphasis in original).

It is important, however, not to assume that all young people have the same degree of choice and opportunity available to them. Other international and New Zealand research supports the idea that socioeconomic status is an important variable in determining students' participation in upper secondary and tertiary education (Furlong, 2005; Leach & Zepke, 2005). Furlong (2005) drew on three different UK studies to look at the educational orientations and educational decisions made by 16–18-year-olds. Furlong found that students' decisions at age 16 seemed to be strongly affected by the resources young people were able to access—including qualifications, teacher support, and encouragement from their families. Where these were present, they opened up a clear route for young people to progress to upper secondary and higher education. However, decisions at age 18 and beyond regarding tertiary institutions were strongly affected by financial concerns, with many lower-SES students choosing an institution close to home to minimise travel costs. The effects of SES in New Zealand are visible in one study identified by Leach and Zepke (2005), which showed students from deciles 9 and 10 schools were five times more likely to go to university than students from a decile 1 or 2 school,

Reviewing 57 previous studies about students' decision making in the transition from secondary to tertiary education, Leach and Zepke (2005) comment once again on the complexity and lack of theoretical agreement about how to characterise or understand these decision-making processes. Given this situation, can the decision-making process be usefully explained at all? Leach and Zepke believe that it can. They favour a decision-making model that is based on a person's lifespan yet is independent of time; that recognises different decision-making variables, yet does not theorise them as occurring in set sequences; that recognises that choice is part of the decision-making process but does not burden it with neo-liberal economic assumptions. This model has three stages. First, the *predisposition* stage considers the family background, parental disposition to tertiary education, degree of self-belief, and nature of the school attended. The second, the

[17] Meaning transition from school, to post-school education and work.

search stage, occurs when the person is searching out post-school options based on variables such as career aspirations, interest in a field of study, academic achievement, access to information, and contact with tertiary institutions. At the third stage, *choices* to pursue specific tertiary programmes at certain providers are made. These are based on whether admission is achieved, whether the right courses in a preferred field of study are available, and whether costs and rewards are in balance.

Given this level of complexity, and the likely interaction of many background variables when study choices are being made, it would appear unwise to design solutions or interventions into the "problem" of lack of science participation without a deeper understanding the contexts of relevance in New Zealand. The factors discussed above all seem to be important parts of the "backdrop" of students' choices and decisions, which interact with more specific factors to do with choosing science (discussed next).

Students' decision making in relation to continuing with science study

Leaving aside the complex web of issues discussed above for a moment, Stewart's, Lyons', and Cleaves' studies of secondary students' science subject choices suggest two areas that seem to be particularly important in students' choice to continue or not to continue with science. These are students' experiences with school science and their knowledge and awareness of the range of study and career options that involve science. Lyons' and Cleaves' studies both suggest there are some students who, for whatever reason, would continue with science regardless of their perceptions of the quality of their school science learning. However, Cleaves (2005) identifies three powerful factors that, for other students, mitigated against deciding to continue in science. These were:

1. disappointment with school science: finding it boring, irrelevant, not people-focused, lacking in practical work, or requiring too much content coverage;
2. a lack of knowledge about the range of science occupations and science work available; and
3. students underestimating their own science ability, carrying a "deflated self-esteem with respect to science achievement".

Regarding the first of these points, Lyons (2004) reached similar conclusions, commenting that:

> …the most cogent single force acting against the choice of physical science courses was not external, but rather the culture of school science itself. While emphasising its status and strategic utility, high school science was considered by students in this study, and others (Osborne & Collins 2001; Lindahl 2003), to have fewer intrinsically satisfying characteristics than it might have, even for many students who had achieved well in the subject.

Speculating about the decline in physical science enrolments in Australia, Lyons wonders whether the recent decrease in the strategic value of such courses, as universities offer more flexible options and lower entry criteria for science courses, has simply highlighted to students the lack of intrinsic benefits of school science, as it is conventionally taught.

Is better science teaching the answer?

Dalgety and Coll (in press) suggest that science teaching needs to be more engaging for students. There is a considerable literature that advocates for change in science teaching and explores much that could be "better". This literature was recently comprehensively reviewed in the New Zealand context (Hipkins et al., 2002). One finding of relevance to this background paper was that narrative materials, telling stories about "real" science done by real people, have the potential to engage more students in science learning.

Picking up on the idea that engaging science learning needs to be better connected to "real" science, Tytler and Symington (2005) report on focus group discussions with top scientists from six different areas that are Australian Government research priorities. These discussions canvassed the manner in which science currently operates in each of these areas, how it might change over the coming decade, and the implications these scientists saw for effective science education. A common theme was that science is now practised in multidisciplinary teams. The scientists therefore saw a need for science education to be taught in multidisciplinary frameworks within strong social contexts that allowed for discussion of social and ethical issues. They were less concerned with the preparation of future scientists as an outcome of science education than with maintaining all students' interest in science and a willingness to continue to engage with science issues as citizens.

Drawing these various discussions together, Tytler and Symington recommend that science education should convey "a much greater and more realistic representation of contemporary science". They suggest the use of narrative curriculum materials that "represent science in all its richness", closer links between community science, industry, and schools, and a restructuring of the curriculum around meaningful problems. Since such materials could only be produced with the active collaboration of the scientists who are in a position to tell such stories, this might be an area of policy interest to MoRST.

Do students need better information and advice about science-related study and career options?

How important is students' knowledge (or lack of knowledge) about the range of science-related study and career options in their decisions about continuing to study senior secondary or tertiary science? In some cases, it seems as if career aspirations are a key factor in students' decision making. For example, the students who Cleaves (2005) described as having a "directed" subject choice trajectory appeared to decide very early on what kind of career they were interested in, and chose their senior school subjects accordingly. However, these students often chose "high visibility" occupations, and many had a limited awareness of the range of science-related work.

Would such students make different choices if they were introduced to a wider range of study pathways and career options? Conversely, the students whom Cleaves described as having "partially resolved", "funnelling identifier", "precipitating", or "multiple projection" choice trajectories were concerned about keeping their options open. They made calculated decisions over time based on their developing interests, career information and advice, and the experiences they were having in their senior secondary subjects. Would the right kinds of information and advice, given at the right times, encourage more of these students to see a future for themselves in science-related study and work?

Better careers advice and guidance may also be important for students who have *already* opted to continue with science at tertiary level, as several studies suggest that many who enrol in tertiary science do not do so with clear career aspirations in mind. For example, Koslow (2005) recently surveyed over 1,400 recent science graduates from all eight New Zealand universities. The survey asked the graduates why they decided to do science in the first place, what their current jobs were, and how these related to their science education. The survey suggested that most graduates did science degrees first and foremost because they were genuinely interested in science. They appeared more ambivalent/less certain about where science could take them, and what it was exactly that they liked about science.

International studies also support the idea that an interest in science, or encouragement to continue in science, might matter more than specific career aspirations—at least in students' initial decisions to enrol in tertiary-level science. Erwin and Maurutto (1998) used longitudinal in-depth interviews with 91 female university science students in a Canadian university, over a 3-year period. Parental occupation and support, and teachers' encouragement, influenced the women's career and academic choices as first-year students. They often mentioned initiatives encouraging "high ability" girls to pursue a scientific career. However, it became apparent during the interviews how little the majority of these women knew about postgraduate programmes or career requirements. "Indeed most had a very narrow conception of career choices, or had given little thought to alternative occupations if their first choice was not possible" (Erwin & Maurutto, 1998). Another study (Brown et al., 2005), which surveyed 179 students enrolled in various levels of life sciences courses at one Australian university found that "interest in science" rated much more highly than "career intentions" as a reason for choosing to enter first-year life science courses.

Koslow's survey of 1,400 recent New Zealand science graduates found that the graduates' current employment did not always match their area of study, and just over one-quarter of the scientists did not end up in science-oriented jobs. However, many were apparently happy in these non-science careers. Koslow speculates:

> If current science graduates felt so ambivalent toward science careers, then there might be many others who were also internally motivated to do science but who make the decision to go into another area (Koslow, 2005, p. 17).

There is some speculation that many "science-able" students may choose to go in other directions before, or shortly after, beginning their tertiary studies, believing that they will not have good career prospects in science. This view underpinned a recent MoRST and Careers Services Rapuara initiative called *The Business of Science*, conceived to target Year 13 students who have taken sciences at high school, but may intend to drop science to study law or business degrees. The aim of the initiative was to encourage these students to retain some science papers in their law or business degree, or to consider doing a conjoint degree in science and business/law. In presenting this message to students, MoRST and Careers Services Rapuara developed a careers expo seminar and a "roadshow" which visited schools to showcase examples of New Zealand businesses and individuals who have successfully coupled science with other disciplines. An evaluation of the initiative[18] (Bolstad, 2003) found that students liked seeing examples of successful New Zealand companies, and enjoyed hearing "real people" talk about their own educational and career pathways. However, it was less clear whether the initiative had an effect on the students' tertiary enrolment choices. Some students felt the seminars had given them useful information/ideas for planning their tertiary study, or had confirmed their existing ideas about what to do in their future study/careers. Other students were not sure yet, or said the seminar had "not really" had any impact on their plans and ideas for future study[19].

As an exploratory initiative, one aim of the *Business of Science* initiative was to establish a better understanding of the influences behind Year 13 students' degree course choices, and to see if the extra information on what a future, rather than present, New Zealand will look like, might change their views on subject choice (Meylan, cited in Evans, 2003, p. 5). The evaluation of the initiative suggested that the seminars attracted several different "sub-populations" of students, including:

1. students who were already firmly convinced that they want to combine science/technology with business or management at tertiary level;
2. students who definitely intended to study "science/technology/mathematics"[20] at tertiary level, but were open to ideas and options for "adding value" to their education by taking business/law/other subjects;
3. students who were weighing up whether to do "science/technology" OR another area, but were open to ideas and options for doing both; and
4. students who were heading towards business/law, but had not taken science to Year 13, or were "just not interested" in science.

Students in any of these groups might have benefited from the *Business of Science* message that it is viable and useful to combine science studies with studies in other areas. However, each sub-

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[18] Data collected for the evaluation included surveys of 303 students who attended seminars, and follow-up telephone interviews with 33 of these students.

[19] Data on students' actual tertiary enrolment choices could not be collected in the scope of the evaluation.

[20] That is, they were interested in one or more of the following areas: science or environmental studies; engineering or architecture; computer science/IT; medicine, health, nursing, or veterinary studies; technology; or mathematics or statistics.

group may need different kinds of additional information or advice in order to see how they connect this idea with their own personal circumstances. For example, students in the second category may have taken science subjects at school with the view that they would enter science at tertiary level. These students may not have taken senior secondary business subjects and may want to know how (or whether) they can "pick up" these areas at first-year university level. Students in the second and third category may need advice on how to act on their intention to combine science/technology with business/law, and/or reassurance on why it might be to their advantage to do so. Finally, some students in the fourth category might decide after seeing the presentation that, even without a previous background in science, it still may be possible for them to become "science-savvy" business people or lawyers. These students may want to know whether it is possible for them to "pick up" science at tertiary level, and if so, what sort of science(s) they could pick up.

The *Business of Science* did not give students specific details about which institutions they could study at, or the kind of degrees/papers they could enrol in, presumably because this fell beyond the remit of the initiative. However, some students in the evaluation said they wanted more information about university courses and programmes of study that they could do (Bolstad, 2003). Students thought it would be good to have access to people/role models whom they could talk to, to find out more about study pathways and career prospects that were available in the areas they were interested in, including those not covered in the *Business of* Science presentations—for example, health science, biomedicine, or environmental sciences.

On balance, the existing research literature suggests two things: first, that careers advice and information *does* make a difference to students, and second, that many students feel they do not get enough advice and information. Leach and Zepke's (2005) review of previous research suggested that the most effective kind of information is interpersonal information, as opposed to mass information; and that:

> …interpersonal information is best utilized when constantly exchanged by active partners in the choice process...[including] tertiary providers, schools, prospective students and their networks of close advisers such as parents, family, and friends (p. 25).

Vaughan's study (2005) suggests it is important to consider what might be going on "beneath the surface" for young people as they navigate their pathways from school, and to question whether young people really *need* to have a clear idea of what kind of work or career they are heading towards. The young people in Vaughan's study felt it was important to have goals, but some saw definite plans for adulthood as dull and closing down their options. This, says Vaughan:

> …does not necessarily point to a lack of commitment to education, training and/or work. In fact the young people seemed to be very motivated and determined and were committed—just not necessarily, or with any long-term vision, to a career or job at the end of the pathway they were currently on (p. 181).

Vaughan argues that it does not necessarily make sense to put greater pressure on young people to choose or commit to pathways:

> Instead adults—including parents, policy-makers, careers educators and other practitioners—may do better to understand the character of young people's navigations of transition today and support young people beyond the merely informational…a number of our participants spoke out strongly against being left alone to fathom the meaning of tertiary education promotional material given out by careers teachers at school (p. 183).

Concluding comment

Earlier in this review of literature, we suggested that a key question for MoRST is: Are there ways to support or influence young people's choices and pathways so that they continue to participate in science at least to tertiary level education, and perhaps into their careers?

This review and discussion of existing research has shown that there is still a great deal we don't yet know about students' decision making in relation to science study. That contextual factors such as family background have an impact seems clear, but these are not New Zealand studies and we have yet to find out whether the SES effects, and the role of parental support, are as evident in this country. A systematic survey of New Zealand students across a range of schools should contribute insights into these questions.

It is also clear that there is no single way to explain choice patterns. Students have different reasons, in different circumstances, and according to their personal dispositions, interests, future plans, and choice-making experiences. Understanding the complexity of choice making should help inform any future careers and transition guidance strategies that MoRST may wish to undertake. We aim to contribute valuable New Zealand data from both the focus groups and the survey stages of this research.

The impact of schools seems similarly complex. The first section of this background paper showed that there are trends to declining school participation. But these trends need to be set against a context of expanding school rolls at the senior level, with an attendant proliferation of different types of courses. Science faces more competition than in the past! Again both the survey and the focus groups should provide insights into the shape and extent of this competition in New Zealand classroom settings.

What does seem clear is that to compete effectively with other options, science courses need to be interesting, and relevant to real life, and the actual working worlds of scientists with their diverse careers. There is nothing particularly new in these claims—the science education literature has been rife with them for some years. How to achieve them is another matter. It may be that there is policy space here where MoRST initiatives could bring the world of the school classroom and the worlds of working science closer together. This is a matter for future debate.

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