Seeing yourself in science

The importance of the middle school years

Report prepared for the Royal Society of New Zealand

Rachel Bolstad and Rosemary Hipkins
New Zealand Council for Educational Research

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New Zealand Council for Educational Research
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Wellington
New Zealand

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1. Introduction

This report has been commissioned by the Royal Society of New Zealand, in conjunction with MoRST. NZCER has been asked to review available evidence related to the hypothesis that *Years 7 and 8 are a time when attitudes to ongoing science learning are likely to consolidate, impacting on choices made in later years.* Our synthesis of evidence strongly supports this hypothesis. It is presented in three sections and draws on the following sources:

An **international perspective** is provided by a comprehensive literature review carried out jointly by leading Australian and UK science educators (Tytler, Osborne, Williams, Tytler, & Cripps Clark, 2008). We became aware of this review shortly before its publication, through our network of contacts. We have sought and been granted permission to use the insights generated by the review, which is referred to throughout our report as the "Tytler review".

New Zealand national data, drawn from large-scale surveys, come from Programme for International Student Assessment (PISA) and National Education Monitoring Programme (NEMP) findings. International comparisons are provided by the recently released results from the Organisation for Economic Co-operation and Development (OECD)'s survey of science literacy, *PISA 2006* (OECD, 2007). A longitudinal snapshot of the attitudes to science learning held by New Zealand's Year 4 and Year 8 students is provided by four rounds of NEMP data (Crooks & Flockton, 1996, 2000, 2004; Crooks, Smith, & Flockton, 2008).

More detailed insights from New Zealand-specific research come from NZCER's own work. The longitudinal study Competent Children/Competent Learners, has followed around 500 students from early childhood right through their school years. Some data from analysis at age 16 are included (Hodgen, 2007). Edith Hodgen has modelled likely influences on science choices, using the existing data sets, and these findings are published here for the first time.

Patterns from the trial data for a new tool, "Me and My School", that measures students' overall engagement with school, are also reported. We have also drawn on insights from the Evaluation of the Business of Science initiative (Bolstad, 2003), and the Staying in Science research we conducted for MoRST in 2006 (Hipkins, Roberts, Bolstad, & Ferral, 2006). Indeed, this report could be seen as something of a prequel to that one.

Overview of the sections

Section 2 scopes the nature of the challenges of maintaining students' interest in, and active engagement with, science learning across their years of schooling, with particular reference to the first two middle school years—Years 7 and 8. At this time students could be studying in full primary schools (Years 1–8), intermediate schools (Years 7 and 8 only), middle schools (Years 7–10), area schools (Years 1–13), or Years 7–13 secondary schools. The section presents a picture of an emergent trend to disengagement with science learning in those years, and discusses the potential significance of this for students' interest and engagement in science during their subsequent years of schooling. However, it also warns that care is needed when considering the import of such data, because disengagement from science sits within a general trend to disengagement from school in general.

Section 3 digs under the surface of these trends to discuss what seems to us to be an important new emphasis[1] when considering how best to understand and respond to disengagement. Here we look at the issue of identity construction—how students see themselves in relation to science (or not). Two broad themes in literature about the identity of so-called "late-modern" youth are described. One theme relates to the more participatory ethos within which youth in late-modern society negotiate life pathways and choices—on the one hand they have more freedom to develop their interests in different directions, but on the other this freedom comes with greater responsibility and the burden of high-stakes consequences for key decisions. The second theme relates to an active quest for personal meaning that informs the ongoing study and career choices of late-modern youth, and it is here that implications for science education would seem to be most pertinent.

Section 4 draws the threads together to discuss possible ways forward, with their associated policy and action challenges. A brief analysis of the framework for learning presented in *The New Zealand Curriculum* (Ministry of Education, 2007) suggests possibilities for creating positive new learning opportunities, and we consider these in relation to policy and practice implications for organisations such as the Royal Society of New Zealand.

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[1] The importance of identity construction is not a new idea in the science education literature (Gilbert, 2001) but the emphasis given to this in the Tytler review, and indeed in the new version of *The New Zealand Curriculum*, seems to us to represent an important elevation of awareness that this is a key issue to address.

2. Scoping "the problem"

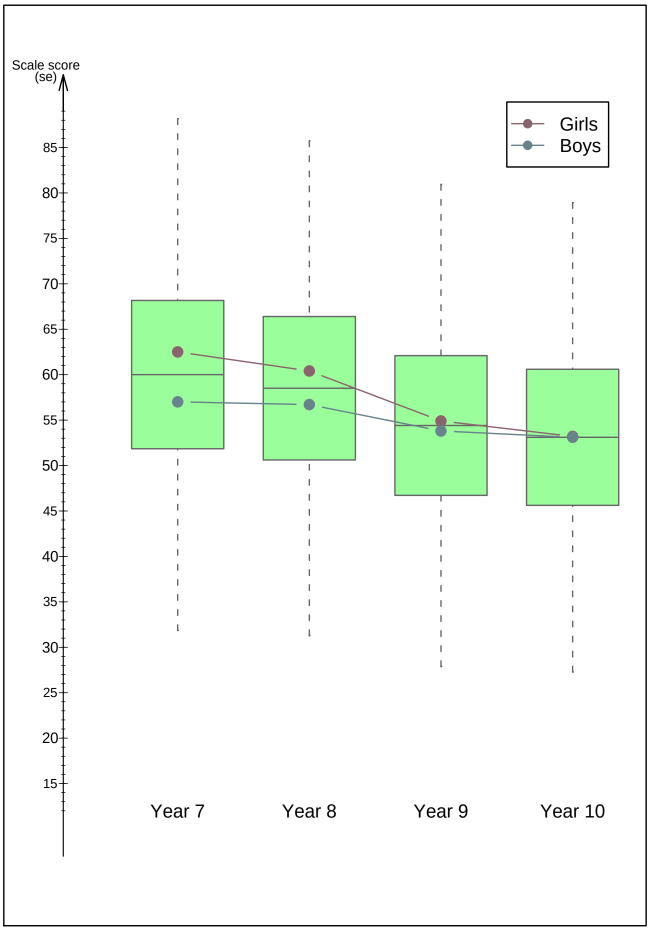
A report prepared by Russell Tytler and colleagues for the Australian Federal Government documents many issues that potentially impact on the continuing choice of STEM (Science, Technology, Engineering, Mathematics) careers by today's students. This report paints a clear picture of disengagement with science learning that, for some students, begins before they even reach secondary school. While Tytler et al. acknowledge "some disagreement" (2008, p. 59) about the extent of disinterest in science in the middle years of schooling, the overall pattern they report is one of a decline in Australian students' interest in science learning across these years, especially just after the primary/secondary transition. Reasons given for this decline include:

- a more impersonal relationship between students and teachers, given the fragmented timetable structures of secondary schools
- a shift in the balance between activity-based and more transmissive teaching methods, and a decline in opportunities for students to express their views in lessons
- student perceptions of a lack of relevance of the taught curriculum
- the learning becomes more demanding.

The Tytler review points out that engagement with school in general declines at this time. Nevertheless, the authors conclude that interest in science does seem to decline at a greater rate than the overall drop in engagement would predict.

A general drop in engagement has also been NZCER's experience when recently developing a tool, "Me and My School," to measure general levels of engagement with school in New Zealand. Item responses were analysed using Rasch modelling and a scale developed against which students in different groups can be compared. The data reported here have not yet been published elsewhere. The survey has been completed by around 8500 students from more than 50 schools to date and all results so far have been used in Figure 1. The pattern documents a drop in engagement that begins at Year 8, accelerates at Year 9, and continues into Year 10. Note that disengagement for girls tends to begin later, but by Year 10 their responses match those of the boys. Note, too, the variability of the construct—across all year levels there are wide variations in levels of engagement.

Figure 1 **Patterns of overall engagement with school in New Zealand**



(Source: NZCER Engagement Survey, n=8500 rounded)

Does the Australian pattern of a greater decline in science than in other subjects also hold in New Zealand? Attitudinal data collected during the NEMP project show the decline in engagement, and suggest that this starts earlier than might be anticipated from the Australian report. However, NEMP data do suggest the engagement challenge is not unique to science. Of more concern is that, by Year 8, very few students appear to actively envisage a possible adult role in a STEM career. These trends are documented next.

NEMP data: a trend to disengagement

This subsection reports patterns and trends in student attitude data from four rounds of NEMP science testing—in 1995, 1999, 2003, and 2007. General trends are reported here and the detailed tables that support the analysis can be found in Appendix A.

For NEMP, Year 4 and Year 8 students from a nationally representative sample of schools (1440 students at each year level each time) are tested at three-yearly intervals, using a combination of pencil and paper and practical tasks, some completed alone and some in groups. Attitudinal surveys are also administered.

Experiences of learning science

The Year 4 data reveal a pattern of liking science, despite having seemingly not many opportunities to do interesting learning related to science at school or away from school. However, caution is needed when reading meaning into these responses. It may be that at this young age students are not sure what counts as a science learning experience, if the things they do are not explicitly identified to them as such. Evidence to support this claim can be found in the 1998 NEMP *Social Studies* report. Asked an open question about the *social studies* topics they liked, 41 percent of students gave responses that the researchers coded as science (planets, animals, environmental issues). Flockton and Crooks commented that the two subjects are often combined in a slot called "topic" and that such thematic work may not allow students to differentiate between disciplines (Flockton & Crooks, 1998, p. 47).

At Year 8 there is a noticeable cooling of overall enthusiasm. Whereas around two-thirds of the Year 4 students said they like science a lot, just one-third of the Year 8 students were as positive in earlier rounds and there was a big drop to just a quarter of the students sampled in 2007. It is not that the others were necessarily negative—the cumulative sum of the most positive and next most positive categories did not decline markedly between Year 4 and Year 8 (again, except in 2007). Rather, many more Year 8 students were merely lukewarm about their liking of science.

Across the four sample rounds (1995, 1999, 2003, 2007), at both Year 4 and Year 8, there is a trend to a decline in the numbers of students perceiving that they learn "heaps" or "quite a lot" about science at school. In each sample year, about 10 percent fewer Year 8 students reported these opportunities than Year 4 students but a majority of students did nevertheless perceive that they were offered these opportunities. (Again, the Year 8 data for 2007 show indications of a sharpening of the decline and the number saying they learnt heaps or quite a lot dropped below 50 percent for the first time since sampling started.) It is of concern that less than half of the students at Year 4, and only between a third and a quarter at Year 8, thought they did "really good things" in science a lot, or even quite a lot.

Compared to Year 4, Year 8 students were also less inclined to do science things in their own time, and there was a drop across the first three sample rounds in those at Year 8 who said they did this. (While there was no further decline in 2007, at 3 percent for the most positive category and 15 percent for the top two categories combined, there was not much room for responses to fall even further.)

Perceptions of personal ability in science

Between a quarter and a third of the Year 4 students were positive about their personal ability in science. Again, it is not that the others were necessarily negative—the cumulative sum of the most positive and next most positive categories adds to at least 80 percent in every round. By contrast, the most positive response rate halves for the Year 8 students. Again, the others are more lukewarm than outright negative—cumulative responses in the top two categories added to just under 80 percent in the first three rounds, with a drop to 61 percent in 2007.

The NEMP science surveys also asked whether students could see themselves being engaged with science in the future. These questions provide useful pointers to identify aspects of their thinking, and so are also shown here.

Table 1 **Year 4 students' responses**

Students who said yes to each question (figures in brackets show "yes" plus "maybe" responses)	1995	1999	2003	2007
Do you want to keep learning about science when you grow up?	53 (96)	43 (90)	46 (93)	57 (98)
Do you think you would make a good scientist when you grow up?	22 (81)	28 (80)	24 (82)	27 (76)

Table 2 **Year 8 students' responses**

Students who said yes to each question (figures in brackets show "yes" plus "maybe" responses)	1995	1999	2003	2007
Do you want to keep learning about science when you grow up?	-	33 (92)	31 (89)	34 (91)
Do you think you would make a good scientist when you grow up?	-	9 (55)	9 (55)	5 (46)

Note that a 4-point scale and somewhat different wording was used at Year 8 in 1995 so results cannot be directly compared.

Allowing for the decline in enthusiasm (signalled by a shift from "yes" to "maybe" responses for around two-thirds of Year 8 students) most of these school children can see themselves continuing to engage with science at some level in their adult lives. This is a positive response that could be built on.

However, the percentage of students who believe they would make good scientists, already low in Year 4, is down to single figures for Year 8 students and again shows the drop in 2007 that has characterised many of the other responses. Even when "maybe" responses are added, there is a marked decline at Year 8. Theorists who research the development of children's career thinking emphasise the importance of being able to build narratives that "enable individuals to organise their memories of past experiences and events and establish a sense of self-continuity and self-understanding" (Watson & McCahon, 2007, p. 41). If relevant types of learning *experiences* are lacking, such stories will not be shaped, with the consequence that, even at this early age, relatively few students appear to clearly see a STEM identity for themselves as adults.

NEMP trends in other subjects

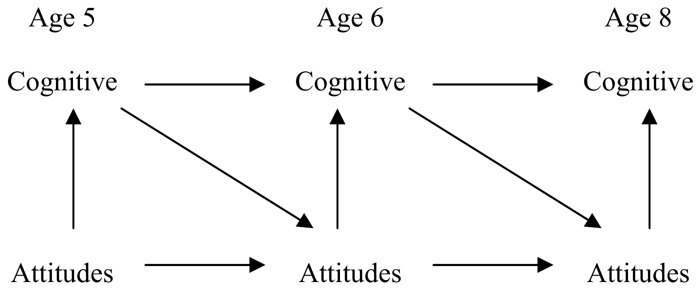
How do the patterns reported for science compare with attitudes in other subject areas? There is no straightforward answer because the picture is quite complicated. For example, in the most recent round of NEMP surveys there are substantive falls in the numbers of Year 8 students choosing the "most positive" categories for liking and thinking they're good at art and writing in comparison to Year 4 responses. Mathematics shows less difference between the two levels, while technology seems to be similar at Years 4 and 8 and for some items Year 8 responses are actually more positive. At both Year 4 and Year 8, students tend to like social studies somewhat less than science, yet say they do more of it (but recall the caveat that they may conflate learning experiences in these two areas). What we can say is that science is not unique in showing a trend to a level of disengagement at Year 8. Nevertheless, there may be opportunities here to provide interventions that boost interest via more engaging learning experiences.

Insights from the Competent Children/Competent Learners longitudinal study

Does it matter if students become less enthusiastic about their learning between Years 4 and 8? The Competent Children/Competent Learners study provides compelling evidence that children's attitudes towards learning and beliefs about their own capability will have a powerful effect on their *future* learning and engagement. This study has tracked a group of around 500 children, all originally from Wellington-area early childhood centres, right through their school years. A comprehensive data set collected from the children, their parents, and teachers has traced the development of their cognitive, attitudinal, and social competencies and has used statistical modelling to explore interactions between these.

The diagram below draws on data from the early rounds to illustrate relationships between attitude and cognitive scores observed over time in these students. The data show that the children's attitudes at each age level were linked both to their prior attitudes, and the degree to which they had experienced success as a learner. Experiencing oneself as unsuccessful in learning often led to a decline in the children's attitude to learning in subsequent years, which was in turn linked to lower achievement scores in the cognitive areas sampled (literacy, mathematics, and logical problem solving).

Figure 2 **Today's success, tomorrow's motivation: relationships between attitude and cognitive abilities from the Competent Children/Competent Learners research**



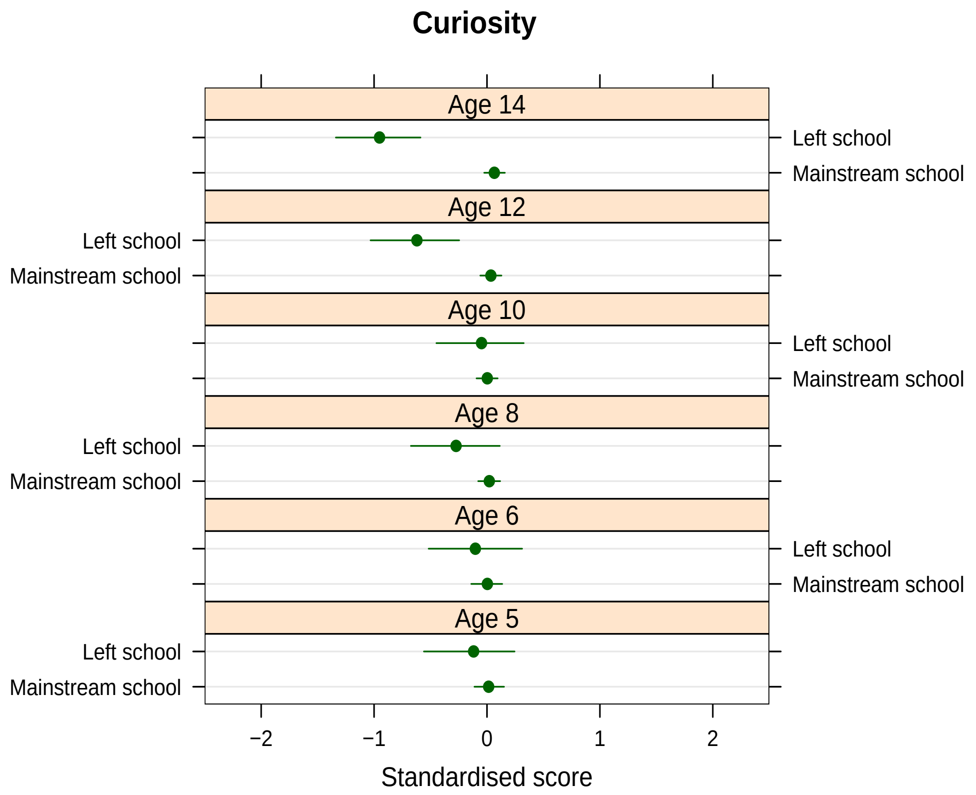
(Wylie, 2006)

The age-16 round of the Competent Children/Competent Learners project provides evidence that declines in primary-aged learners' attitudes and experiences of learning success have longer-term consequences. For example, students who had left school by age 16 were more likely than their in-school counterparts to have started school with lower-than-average early number knowledge and literacy scores, and slightly lower logical reasoning scores (Hodgen, 2007). By the time they were eight, and when they were 10, they were more likely to give up easily, not to take responsibility for themselves and their actions, and were behind in all their cognitive competencies.

Of significance for this report to the Royal Society, differences evident in the children who would go on to become early school leavers were present from their early primary years, but these differences "crystallised" between the ages of 10 and 12 (that is, by Year 8). The differences recorded in the statistics at age 12 tell of increased disparity in the cognitive competencies, and a much more marked disparity in the attitudinal competencies. At 12, the young people who left school by 16 were giving up, playing up, and increasingly alienated (lower social skills with both adults' and peers' scores), and this trend was even more marked at age 14.

Figure 3 illustrates this pattern. A composite measure of "curiosity" shows that students who went on to leave school early had similar scores to nonschool-leavers up to the age of 10. However, between the ages of 10 and 12, differences increased markedly. From a range of possible figures (all showing similar patterns), we chose to highlight curiosity because science is widely seen as a curriculum area that *ought* to foster curiosity about the natural world. There are implications here for the way it is taught.

Figure 3 **Increasing differences in curiosity score between those in school at 16 and those who have left school, Competent Children/Competent Learners research**



(Hodgen, 2007)

Appendix B shows similar patterns in Competent Children/Competent Learners' scores in mathematics, and self-efficacy at ages five, six, eight, 10, 12, and 14. It seems that the middle school years are a critical time for keeping students engaged and achieving.

While leaving school early is perhaps one of the more extreme consequences of disengagement, the link to achievement (measured in Competent Children/Competent Learners as literacy, mathematical, and problem-solving competencies) should not be overlooked. As Tytler et al. comment, the transition to secondary school is a time when the difficulty of mathematics and science increases rapidly and both subjects become more formally structured (Tytler et al., 2008). Opportunities to continue on STEM pathways are likely to become closed off when students do not have the necessary self-efficacy to keep up at this stage.

Patterns of engagement in the secondary school years

The New Zealand Staying in Science research found that, of a sample of 496 students taking at least one science subject at Year 13, those who said science was the main thing they planned to study at tertiary level were more likely than other students to agree with both the statement "I was interested in science even before I started high school", and the statement that "high school has increased my interest in science" (Hipkins et al., 2006).

NZCER's Competent Children/Competent Learners longitudinal study provides limited confirmation that patterns of interest or disinterest in science, once set, are likely to continue. We reviewed data from several rounds of fieldwork to look for patterns likely to be relevant to this report. We found that students who nominated science or mathematics as a favourite subject at 14 were also likely to do so at 16. (They were not asked their opinions about different subjects in their primary school years, unfortunately.) Furthermore, these students were likely to have higher overall scores for cognitive competencies (that is, they were "bright" students), they were more engaged in school, and they expressed a preference for problem solving and generally more challenging learning opportunities. Logistic regression models showed that students in this study were three times more likely to nominate mathematics or science as favourite subject if they said their lessons gave them time to think about ideas and problems in new ways. Note that 62 percent of the Competent Children/Competent Learner sample nominated either mathematics or science as their least favourite subject at age 16, and 40 percent did so at age 14.

The 2006 PISA round, which had "science literacy" as its main focus, surveyed 15-year-olds in 57 nations. Five attitudinal responses were averaged to give a measure of the *general* value students ascribed to science. Compared to other nations, New Zealand's students collectively ascribed a below-average value to science. Just 66 percent agreed or strongly agreed that science can bring social benefits, compared to an OECD average of 75 percent. New Zealand was one of 10 nations where there was a particularly strong association such that individuals who were more positive about the value of science were also likely to have gained a higher overall score for science ability. The UK and Australia were also in this group, along with the Scandinavian nations, Ireland, and the Netherlands (OECD, 2007, pp. 128–129).

For other attitudinal scales, our students were sometimes just above and sometimes just below, or right on, the OECD average. That is, they are not showing substantively different patterns of engagement from their international counterparts. For example, New Zealand students were just above the OECD average with their views about the personal value of science for them in their own lives, and just below it with their views about their ability to learn science, their personal interest in science, and the amount of time they spend on science-related activities. In New Zealand, average enjoyment of learning science sits right on the OECD average. Immigrant students were more positive about the personal value of science and about their interest in it than were New Zealand-born students, a pattern that is common in several nations. Our students were slightly above the OECD average for motivation to learn science now, and right on the average for a future-oriented motivation to learn science. (But note that the OECD average across the four items in this scale was just 29 percent, and for expressing an intention to spend a lifetime in "advanced science" was just 21 percent. New Zealand students averaged 17 percent for this item.)

However, our students were again below the OECD average for self-efficacy in science. This scale comprised seven items that probed students' perceptions of their ability to use science as a tool to "think with". As might be expected, students with higher achievement also showed higher self-efficacy, but on balance, compared to other nations, New Zealand students were located in the higher performance, lower self-efficacy quadrant when these two scales were placed at right angles to each other (OECD, 2007, p. 136). There was a similar pattern for awareness of, concern about, and level of optimism regarding environmental issues, as well as students' sense of responsibility in relation to sustainable development. Our students are below the OECD average for all these scales, notwithstanding the above-average overall pattern of achievement. Thus the early NEMP patterns of a general interest in science that does not necessarily translate into seeing oneself as good at *using* science continues into the secondary school years.

Does early engagement or disengagement with science matter?

Research into young people's interest, attitudes, and tertiary education and career aspirations with respect to STEM often focuses on identifying whether there are particular and identifiable "points of choice" in which students opt to remain in, or move out of, a STEM-related pathway. Such research is often underpinned by concerns about a "leaky pipeline" (Tytler et al., 2008) in the production of future science graduates and working scientists. An example is the Staying in Science research undertaken by NZCER for MoRST in 2006, which sought to address the drop-off in science participation between senior secondary school and the first year of tertiary education (Hipkins et al., 2006). Research into student interest and retention in STEM often focuses on secondary students, particularly around the ages of 14 to 16 when they begin to move into a post-compulsory curriculum, and participation in science education becomes optional. However, the NEMP data, Competent Children/Competent Learners, and Staying in Science research already discussed above each provide small pieces of evidence which are consistent with Tytler et al.'s (2008) suggestion that "recent research evidence … strongly supports the idea that the majority of children are making their mind up about whether to follow a STEM related career before the age of 14" (p. 86). The international evidence to support this proposition includes longitudinal studies of young people's career expectations and subject decisions over time. For example:

- A longitudinal study of 3359 students in the USA asked 14-year-old students about their career aspirations for age 30, and then compared this with the subjects of the degrees that students actually went on to earn (Tai et al., 2006, cited in Tytler et al., 2008). The study found that students *with* expectations of a science-related career at age 14 were 3.4 times more likely to earn a physical science and engineering degree than students *without* similar expectations.
- A small longitudinal study following 70 Swedish students from age 12 to age 16 found that their career aspirations and interest in science was largely formed by age 13 (Lindahl, 2007, cited in Tytler et al., 2008).

- A study for the Engineering Council in the UK found that more than three-quarters (79 percent) of students surveyed at age 14 claimed that they already had an interest in working in a specific job or career area, and more than two-thirds of those (72 percent) reported that their subject choices were suitable for their area of work.

Other studies have asked students and adults *already* in STEM-related pathways to identify retrospectively when their interests and career aspirations began, and these provide further evidence to support the proposition that some young people's choices and interests in relation to STEM are influenced by experiences prior to the age of 14. For example:

- A Royal Society (UK) survey of 1141 scientists, engineers, and technologists found that just over a quarter (28 percent) first started thinking about a career in STEM before the age of 11, and a further third (35 percent) between the ages of 12 and 14 (Royal Society, 2006, cited in Tytler et al., 2008).
- A US study which interviewed 116 scientists and graduate students in science found that 65 percent of the respondents reported early interest in science (prior to middle school), 30 percent reported their interest began in middle or high school, and only 5 percent claimed they did not find science interesting until their college years.

Tytler et al. suggest a clear policy implication of studies such as those cited above. Namely:

> …that the priority for expenditure on initiatives to interest young people in school science should be given to those working with young people of age 14 or under. After that, gaining young people's interest in the study of science and mathematic becomes progressively harder as initiatives are addressing a diminished audience. (2008, p. 87)

What it could take to gain that interest is the challenge we address in the next two sections.

3. What's going on? Identity issues

The previous section has outlined a pattern of declining interest and attitudes between Years 4 and 8. New Zealand and international research provides evidence that students who *do* remain interested in science and pursue STEM pathways later in life have often developed science interests, and can imagine themselves in particular kinds of STEM careers, prior to the age of 14. Taken together, these findings suggest there is value in developing initiatives and approaches to support and enhance engagement amongst students under the age of 14.

Identifying particular ages/stages of schooling at which young people's interests and aspirations regarding STEM may begin to develop or decline is one thing. Developing meaningful initiatives and practices to better engage these students is another. We need to better understand *how* and *why* these interests and aspirations develop or decline—and what might be done differently to support wider engagement in STEM. As we discuss in this section, many researchers argue that we need to think about these issues in relation to the notion of *identity.*

Identity in late-modern society

UK academic Gunther Kress recently discussed the likelihood of an international convergence of curriculum directions in an era of globalisation (Kress, 2008). In that paper, he identified two key impacts on youth identity of the changes in social conditions signalled by the phrase "late modernity". These are:

- a *participatory* impetus that requires young people to actively choose amongst a plethora of options, some with high-stakes consequences, and to actively *construct* an ongoing career/life that works for them[2]
- an associated search for *personal meaning* as a key influence on identity construction.

Both stand in contrast to the impetus to fit in and conform to predetermined subject pathways, which constitute the organisational underpinning of traditional school structures. The tensions created by this mismatch between current youth identities and school tradition are likely to be a key influence on declining engagement. There are implications here for how we organise and support school science education.

[2] Karen Vaughan, an NZCER researcher of youth identity and transitions, has called this the "responsibilisation" of young people (Vaughan, 2003).

The Tytler review says that we must think about young people's interest and engagement in STEM within such a framework of identity in late-modern society. Illustrating what this could mean, these authors comment that, in the past, society has tended to value attributes such as *obedience*, *conscientiousness,* and *humility*, while in late-modern society youth are more likely to be motivated by an appeal to *the contribution of the individual*, and to value such things as care for the environment, democracy, care for others, creativity, and self-realisation. In short, "what engages modern youth is not the stepping stones by which we arrived at this point in history but rather *their* potential individual contribution to the future", and "in this context, education is continuously evaluated against how it contributes to students' self-development asking 'what does it mean for me'?" (Tytler et al., 2008, p. 84). While at a superficial reading this may seem to imply that young people have become more narcissistic and self-interested, in fact it is simply a reflection of the deep shifts and changes that have occurred in the social, economic, and cultural frameworks of late-modern or "knowledge age" society.[3] As Kress (2008, p. 259) puts it, the world has changed from one in which "acquisition of skills and knowledge in school provided entry onto a clear path to work and the professions, and to social structures more widely, to a world in which that path has collapsed and disappeared, and the responsibility for these things has fallen to the young themselves". The range of choices available to young people is now much greater than it has ever been. As Tytler et al. comment:

> The decision-making landscape that young people negotiate as they select their school subjects, decide who they want to be, and aspire for fulfilling futures is complex terrain, and analysis is complicated by the fact that the barriers that hinder young people's decision-making are not always immediately apparent and will change over time, and change in degree, as students grow and develop. (2008, p. 91)

A significant body of research has considered the impact of identity on young people's education-related choices:

> Identity is a construct that goes beyond concerns such as curricula, intrinsic interest or career intentions, to instead frame aspirations and perceptions in terms of social relationships and self processes (Lee, 2002). Identity theory understands that the self (or selves) is bounded by social structures, and that interactions shape the organization and content of self. Analysing decisions to participate in and choose STEM courses and careers through an identity framework, involves emphasising relationships with family, teachers, peers, and others, and identifying the degree of synergy, or disjuncture, experienced by young people between their everyday lives and their educational pursuit of STEM. (See Louise Archer et al., 2007, cited in Tytler et al., 2008, p. 91.)

[3] For a deeper exploration of these ideas, see Gilbert (2005) or Kress (2008).

Identity and choosing science

What does this mean for science? Tytler et al. (2008) suggest the problem may be that young people do not associate school science with the kinds of activities which offer the potential for self-realisation, creativity and innovation, working with people and helping others, making money, or whatever other values they believe will give meaning to their working lives. For New Zealand's students there are some hints of this challenge in the "value of science" pattern of PISA responses and in their responses to the various environmental scales (see Section 2). However, a limitation of PISA is that trends are reported mainly in relation to OECD nations and they are "countries like us" in many respects. The international ROSE (Relevance of Science Education) project, initiated and led by Norwegian researchers, illustrates the challenge of perceptions of personal relevance and interest across a wider range of nations. Although New Zealand was not part of the ROSE study, it is telling that the data revealed a clear trend to decline in support for the value of science, both personally and for society, as the wealth of the nation increased. Students from African nations, for example, were much more likely to agree that science is important for society, and to aspire to be scientists, than were students of relatively more wealthy Western nations. The most sceptical of all were the Scandinavian students.[4]

Tytler et al. suggest that a transformation of the vision of school science is needed; one which portrays the value of science, and why science is needed, in terms that align with the kinds of values outlined above. For example, "students need to see that the work of the scientist and the engineer is at the centre of solving humanities problems and involves working *with* people" and "school science needs to offer a vision which shows that it is the physicist or the engineer who is going to make the major contribution to providing alternative energy sources, animal- and environmentally-friendly food production, new methods of eliminating disease, and solving the challenges of global warming" (Tytler et al., 2008, pp. 84–85). In other words, young people need to see science as relevant to the identities that they are building, or wish to build for their future selves, and they need to develop this insight against an international backdrop of global issues and concerns.

Various studies, including some from New Zealand, support the contention that identity plays a central role in young people's attitudes and decisions with respect to STEM (the related issue of gender in these matters will be discussed in the following subsection). While much of this research applies to young people in their early and late teenage years (when they are in a position to "choose" science, as opposed to it being a part of their compulsory curriculum), the core issue of identity as a framework for thinking about the development of interest in science seems equally relevant for younger students, particularly in view of the findings reported in the previous section.

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[4] These patterns were reported by Svein Schoberg, the ROSE project leader, at a 2007 international conference, sponsored by the Nuffield Foundation and the British Council, and held at the National Science Centre, York University, UK, to discuss challenges for future supply of STEM graduates.

Tytler et al. (2008) highlight two international studies which point towards the significance of thinking about identity in seeking to understand young people's differing levels of interest and attitudes towards STEM. (One of them is the Norwegian national data from the ROSE project.) Both studies used a cluster analysis process to sketch likely identity "types" in relation to thinking about STEM careers. A summary of the detail of these studies is included as Appendix C. Key features of identity thinking common to these analyses are:

- working with people (a stronger preference for girls)
- relating school science learning to own life and interests (again, a stronger preference for girls)
- interest in addressing environmental concerns and ethical issues
- technology and practical applications (a stronger preference for boys)
- some students are science enthusiasts and will choose it regardless.

A New Zealand study adds additional insights to these patterns. The Staying in Science research (Hipkins et al., 2006) surveyed 496 students from 20 randomly selected New Zealand secondary schools. All these students were taking at least one science subject in Year 13 and were nearing the end of their secondary schooling when surveyed. This project also used a cluster analysis. Again, details are included as Appendix C. Because this analysis took into account characteristic ways the students combined sciences with other selected Year 13 subjects, as well as differing attitudes towards science as a subject and a career pathway, and students' future plans and aspirations, it is able to add several additional insights to the above broad patterns. This research showed that continuing to take science at school is not necessarily an indication of an interest in a STEM career pathway, because:

- some of the most able, and potentially entrepreneurial, science students (mainly males) do not believe STEM careers will be sufficiently rewarding financially
- some students try to keep their options open for as long as possible, and continue to take science at school for that reason.

Additionally, those students who were intending to carry on with science at tertiary level tended to be on the pathway towards traditional careers such as medicine, dentistry, and veterinary science, and tended to have reasonably limited awareness of the range of other possible careers involving STEM.

The role of gender

There appear to be recurring gender patterns in students' orientations and aspirations with respect to STEM. The cluster analyses undertaken by Haste (2004, cited in Tytler et al., 2008), Shreiner (2006, cited in Tytler et al., 2008), and Hipkins et al. (2006) all identified particular groupings that had strong relationships to students' genders. Many authors have discussed issues of gender, identity, and STEM. More often than not, these discussions centre on concerns about girls' and women's participation in STEM.

Particular social factors may operate to support or discourage the participation of women in STEM. Tytler et al. (2008) cite an abundant literature which argues that STEM subjects and careers have a masculine image that leads girls to reject identities connected with STEM. Cultural stereotypes about gender have an impact on students' career aspirations and subject choices. Tytler et al. cite Alloway et al. (2004) who found evidence of a "strong social militancy that restricted the range of student choices by means of gender stereotyping" (2008 p. 93). Such militancy is most visible as peer pressure, but other more subtle means of reiterating gender stereotype are expressed in students' daily rituals, cognitive style, as well as teachers' and parents' gender-coloured expectation of student achievement. Drawing on the ROSE data, Schreiner and Sjoberg (2007, cited in Tytler et al., 2008) speculate that the main reason young people, especially girls, are reluctant to participate in the physical sciences is because they often perceive the identities of engineers and physicists as incongruent with their own. Other researchers have found that female students are more likely to aspire to non-STEM careers. This aspiration may not represent a disinterest in STEM, but rather a competing interest that pulls females away from STEM (Cleaves, 2005).

Various authors have suggested that particular kinds of classroom teaching practices could enhance girls' engagement, and encourage a feeling of belonging in the environment of STEM. Suggested approaches cited in the Tytler review include:

- low levels of competitiveness and of drill and practice
- high levels of teacher attention to all students including the development of a positive self-image in relation to the discipline, hands-on activities
- the use of real-life materials that cater for the specific interests and experience of girls
- teaching concepts in specific contexts that represent life in the real world.

While many have focused on the problem of girls' under-representation in certain areas of STEM, there is also reason to consider emerging trends in boys' engagement with STEM. For example, Gilbert (2005) suggests that the recent success of female students in forging increased access to "high-status" career fields such as veterinary and medical science may be illusory. More adventurous male students, she suggests, have vacated these fields to chase the greater rewards to be found in entrepreneurial and cutting-edge areas of knowledge development, including in the ICT field. The traditional high-status fields, with their emphasis on learning large volumes of information in a demanding and developmentally structured "knowledge apprenticeship", carry little appeal for them now because they are no longer the most high-status or financially rewarding occupations. Gilbert's prediction may have been reflected in the attitudes of the "science/business" student cluster (mainly male, as Gilbert would predict) identified in the Staying in Science research. These students were clearly science-able but, compared with the "serious science" students (where 57 percent were females), tended not to see STEM as a worthwhile career area to pursue (Hipkins et al., 2006).

In discussions of the role of gender in young people's interest and engagement in STEM, it is important not to stereotype and assume that certain approaches and practices will appeal to all girls or all boys. The key message here is to recognise that gender and identity issues are interwoven in complex ways in the development of young people's engagement (or disengagement) with school science, and their ability to "see themselves in science" in the short and long term.

The challenge of relevance

A common recommendation is that curriculum content should be reshaped to be relevant and meaningful to students at each stage of schooling. This poses significant challenges of interpretation. Who is to determine what is "relevant" and "meaningful"? The research outlined in this section suggests that resource developers need an awareness of the different identity positions that can be occupied by late-modern youth. Bolstad's (2003) evaluation of the Business of Science initiative suggests that a one-size-fits-all approach will not work, and that there is a need to take into account a variety of different interests, aspirations, and identities.

The Business of Science initiative was targeted at Year 13 students who had studied science subjects at school, and were intending to enter courses such as business, law, or commerce at tertiary level. The project aimed to encourage these students to retain some science (or science/technology) papers in their tertiary degrees. The central component of the Business of Science initiative was a roadshow that went into secondary schools to showcase the value and benefits of combining science/technology with business or law. Students had the opportunity to meet and listen to the personal stories of people with interesting jobs that combined these two disciplines, and were shown examples of New Zealand companies that have succeeded at a national and international level in science and technology innovation. This approach is clearly congruent with the advice outlined above so it is instructive to consider in some detail how this initiative was received.

Follow-up telephone interviews and surveys with students who attended these presentations found that many students found them to be interesting and informative, liked seeing examples of successful New Zealand companies in the presentation, and hearing the personal stories of real people and their career paths. 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. However, other students, particularly in the telephone interviews, said the seminar had "not really" had an impact on their plans and ideas. In some cases this was because students already believed in the message that the Business of Science initiative was promoting. For example, Student 20, a male student who was taking Year 13 chemistry, physics, calculus, and statistics. His intention was to go to university to be an inventor and "make some money". His goal for the future was to be his own boss, and to have a big company, and "to feel like I'm doing something big":

> There's a lot of scientists out there who can't make a lot of money. I will market what I think is good. (Student 20)

By contrast, student 142 was a female Year 13 student who was taking biology, chemistry, and statistics. She was interested in biogenetics, and felt the Business of Science seminar had had an impact on her ideas for the future, encouraging her to combine science, language, and management. However, before doing this, student 142 was planning to do a year at a performing arts school, with a major in vocals and a minor in dance "so I get a break doing something I love". In spite of her interest in science, student 142 suggested she felt there was a clash between her own values and sense of identity, and those that she perceived to be involved in working in commercial science and technology careers:

> It really sux that people [working in science and technology] have to hide their knowledge, they can't share their ideas. I really hate that about sciencey stuff. It's all so top-secret… I would want to have an environment where I could bounce ideas off other people. It's hard when the whole science [field] is set up that way … it's scary, it sort of keeps me away from science—you'd get so cynical and cold…

The evaluation suggested that future initiatives of this type would be strengthened by:

- recognising the range of interests and motivations of students in the target audience, and thinking about what different kinds of information different students may need to connect the science-promoting messages to their own personal situation
- using a wider range of examples of careers/businesses that involve science; for example, in areas like health sciences, environmental sciences, and other areas that are of interest to different students
- continuing to use examples of real people and their education and career pathways, and helping students to see how they might make decisions at different points in their own education and career pathway that would lead them towards various kinds of careers.

Given the evidence presented in this report that students' career ideas and interests are already forming before the age of 14, these recommendations seem as relevant for initiatives designed for younger students.

4. Possible ways forward

So far this report has identified a pattern of disengagement from science learning that begins in primary school. While this trend is likely to relate to a level of general disengagement from school it cannot be ignored or excused on those grounds. Recent research clearly shows an association between ongoing identity development and career thinking, and suggests that these developments begin at a much younger age than might have been assumed (Watson & McCahon, 2007). The Tytler review concludes that:

> by the age of 14, many young people have made identity related decisions concerning their futures, as school students (am I and will I be a committed and successful student?) and as future workers (might I work in a science related occupation?). (Tytler et al., 2008, p. 131)

While subsequent experiences and interventions can certainly influence identity at later stages, it has been argued that focusing energy and resources at the later years of schooling and university "attacks the problem too late in the decision cycle":

> The primary focus for action should be on attracting more students to commit to such programs, and this requires intervention in early secondary school and primary school. At the same time, ways to provide opportunities for late STEM 'maturers' need also to be considered. (Tytler et al., 2008, p. 131)

Work on identity formation provides descriptive parameters within which interventions might be planned. But what can teachers and schools actually do, and how can they best be supported in their work? This is the focus of Section 4.

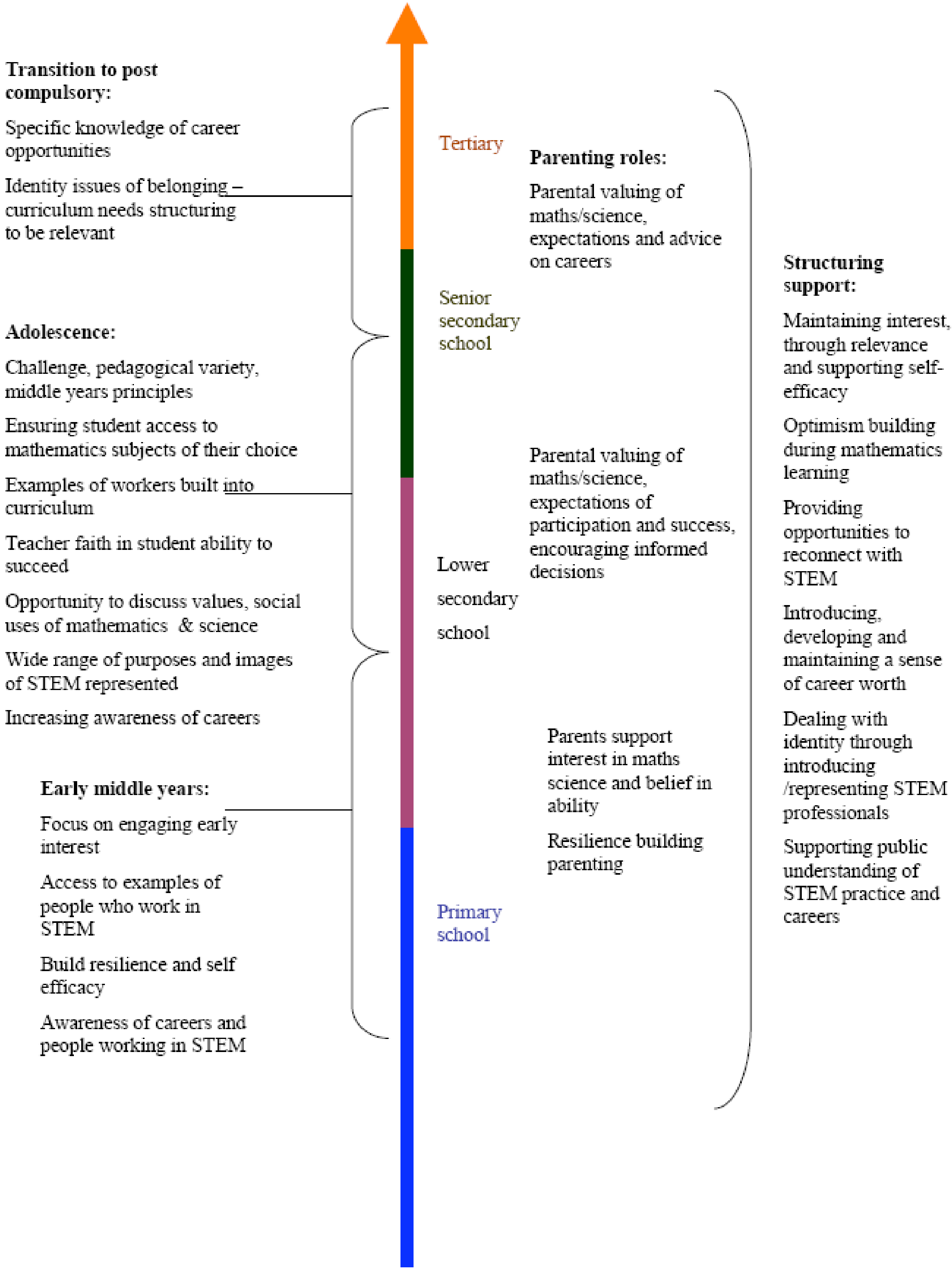
Encouraging students to stay in science

Influences and supporting structures that Tytler et al. (2008) say are needed across the years of schooling are summarised in Figures 4 and 5. These show that science education before the age of 14 should focus on:

- engaging early interest
- building resilience and self-efficacy
- providing young people with access to examples of people who work in STEM.

Later stages of learning build on this early foundation.

Figure 4 **Factors influencing engagement with STEM at different stages of schooling**



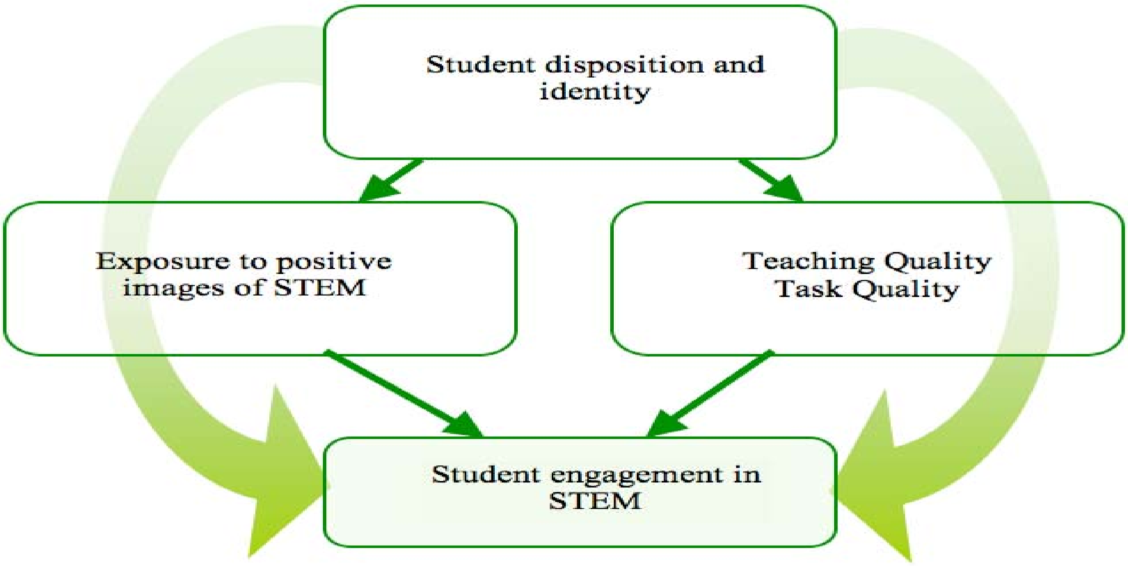
(Reproduced from Tytler et al., 2008, p. 133)

Summing up their overall findings, Tytler et al. (2008) suggest that representing to students the value of STEM pathways and career opportunities will change in nature across the stages of schooling, and could involve:

- the development of curriculum resources that represent contemporary STEM practice
- the professional development of teachers regarding STEM careers
- a public campaign aimed at parents, concerning the variety and worth of careers in STEM
- the promotion and co-ordination of enrichment initiatives that link students with STEM practice and practitioners.

The relationship of these components to each other is summarised in Figure 5. The middle two boxes present strong areas of possibility for developing initiatives that strengthen students' engagement in science. Several timely possibilities in the New Zealand context are outlined next.

Figure 5 **Engagement of student interest in STEM**



(Reproduced from Tytler et al., 2008, p. 126)

Opportunity One: Supporting the implementation of *The New Zealand Curriculum*

The above advice about what should happen in the middle years is clearly congruent with the intent of the Nature of Science (NOS) strand of the most recent science curriculum. This represents a timely opportunity to support a change of direction in science teaching in these years. However, our research suggests that the implementation of *New Zealand Curriculum* (Ministry of Education, 2007) represents both an opportunity and a risk for primary (and secondary) science teaching. We address the risk first, using this to then frame the opportunity.

Recent research on the implementation of NZC in so-called "early adopter" schools suggests that the decline in science teaching in Years 4 to 8 will, if anything, accelerate. With the explicit mandate to design a school-based curriculum, many primary schools appear to be designing programmes of learning that emphasise literacy, numeracy, and inquiry learning around high-level themes that integrate knowledge from other curriculum areas.[5] Section 2 cited NEMP evidence that primary students may not see the science component of a "topic" and the trend to integration is clear. Of course, science can be implicated in inquiry themes, and inquiry methods can be developed in ways that model scientists' own approaches to knowledge building, but where teachers were already reluctant to engage with this curriculum area, it seems unlikely science will feature even to the limited extent that it did when full curriculum "coverage" was perceived to be required.

NZC specifically addresses the need for adoption of pedagogical models that pay close attention to meanings that students actually build during their learning (Ministry of Education, 2007, pp. 34–35). Congruent with this, the Tytler review highlights the need for teachers to use pedagogies that are more varied and more supportive of young people's need to actively engage with ideas: "This implies a greater focus on student engagement with thinking and working scientifically … rather than on the exclusive focus on establishing canonical content, or on low level processes. Problem solving in authentic contexts, higher order thinking, and investigation should be major aspects of the curriculum" (Tytler et al., 2008, p. 137). This suggests the "inquiry learning" risk just outlined needs to be recast as an opportunity to change some aspects of teaching practice. The redevelopment of the NOS strand of the science learning area in NZC presents such an opportunity, and could underpin new approaches to addressing the identity challenges outlined in Section 3.

There are four achievement objectives in the NOS strand and they are intended to be the main focus of learning, with traditional content providing the contexts in which they are developed, as appropriate to the different curriculum levels:

- understanding about science, with a focus on learning about the work of scientists
- investigating in science, with an explicitly wider focus than the "fair testing" that came to prevail as the main method of student practical inquiry in the 1990s
- communicating in science, with a focus on how science knowledge is shaped and shared in a wide range of settings
- participating and contributing, which explicitly links science learning to the contexts of students' lives, interests, and concerns, and to the high-level aim of helping prepare them for drawing on science as relevant to their future participation in a democratic society.

The structure of the 1993 science curriculum had the same broad intent but research suggests this was widely ignored (Loveless & Barker, 2000). Unpublished implementation studies suggest that the structure of the latest science curriculum may be better understood and accepted, and hence is

[5] Again, these data are not yet published, but a report to the Ministry of Education is pending.

more likely to be adopted. A caveat to this is that good exemplars will be needed if teachers are to fully understand these new directions.

The NOS strand was developed with the intent of showing how the five "key competencies" to be developed across the years of school can be addressed within a science learning programme (Barker, Hipkins, & Bartholomew, 2004). However, recent NZCER research into the complexity of these competencies suggests that their impact will differ depending on whether they are understood and implemented within a 20th-century framing of knowledge and learning, or a 21st-century one (Bull, Hipkins, Joyce, & McIntyre, 2007). If the more traditional framing is used, teachers may miss opportunities to address the identity issues that Section 3 suggested are so compelling for keeping students engaged with science in this century's prevailing social conditions. To illustrate: a 20th-century framing of Communicating in Science may see teachers focus on existing literacy-across-the-curriculum initiatives; for example, teaching specialist vocabulary. This could allow them to say "we already do that"[6] (Hipkins, 2006) when thinking about this new NOS objective. By contrast, a 21st-century framing could adopt a semiotic framing, helping students to explicitly explore how different knowledge systems, with their particular ways of communicating ideas, in turn shape ways of seeing the world. Such a focus would clearly have the potential to engage the late-modern sensibilities of today's young people, but would also, by its very nature, be new to most science teachers. There are obvious resource implications here.

Recommendation One:

The Royal Society and MoRST could consider leading the development of resources and professional learning opportunities that help middle school teachers unpack the scope and possibilities of the NOS strand of NZC. Doing so could prove effective in helping reverse the recent trends to early disengagement with science. Since schools have until 2010 to give effect to the curriculum, any useful and timely advice and examples in this area are likely to be well received.

Opportunity Two: Building on existing initiatives to provide a wider range of narrative materials for students

The suggestions in the Tytler review summarised above in Figures 4 and 5 align in an interesting way with research literature on the development of children's career thinking more generally. Watson and McCahon (2007) recommend shaping narratives about potential careers to use as resources that link to and build on children's *informal* career experiences.

One challenge to this advice is that children, and indeed adolescents, are less likely to have informal experiences in relation to scientists' work than to other careers that are more visible in the community. The more general example used by Watson and McCahon (2007) is building on

[6] NZCER's National Survey of Secondary Schools shows that almost all had such a programme in place by 2006 (Schagen & Hipkins, 2008).

the informal experience of taking a sick pet to the vet to shape narratives that extend such experiences to explore this as a career option. However, the Staying in Science project (outlined in Section 3) highlighted the dominance of traditional applied science careers in the plans of science-able New Zealand school leavers. The Tytler review also suggested that students often have limited or stereotyped ideas about what STEM careers involve, and the extent to which these match the kinds of values/aspirations students desire for themselves/their identities. The challenge here is to *widen* young people's views of what it is possible to do with an education in science.

New Zealand studies (Bolstad, 2003; Hipkins et al., 2006) and research reviewed by Tytler et al. (2008) support the contention that young people (particularly in their teenage years) enjoy seeing and hearing first-hand accounts of people's STEM careers and the kinds of everyday activities that these careers involve. Young people are particularly engaged in hearing stories not just about what these people *do,* but also how they *got there.* Hearing about another person's "journey" seems to be important in helping young people to imagine themselves in different possible futures, particularly if they feel some personal connection to the storyteller. They could think, "That person is a bit like me, and these are the kinds of experiences and choices they have encountered."

Existing initiatives funded by MoRST show considerable promise here. Both the Biotechnology Hub (www.biotechlearn.org.nz) and the Science Learning Hub (www.sciencelearn.org.nz) carry a range of rich stories of actual New Zealand scientists and their work, as do some of the Crown Research Institutes' websites. These already available resources could be used to promote wider teacher awareness of the impact of narrative on middle school students' early career thinking.

Recommendation Two:

Review availability and suitability (reading level, format, etc.) of existing New Zealand-based STEM narratives. Consider ways to incorporate innovative use of these materials into any curriculum implementation resources developed, as outlined in Recommendation One.

Opportunity Three: Supporting teachers to reframe their expectations of student success in science

Science learning can be demanding and this highlights the importance of building learning *resilience* as a curriculum goal. Again, there are strong connections to NZC, which has *learning to learn* as one of eight underpinning curriculum principles (Ministry of Education, 2007, p. 9). However, what this could mean in practice is likely to be unfamiliar to many teachers, and could well be another productive focus for the development of both narrative resources and exemplars of new teaching approaches.

Professional development may also need to challenge existing assumptions about the sorts of students who should expect to continue to engage with science. Illustrating this challenge, Tytler et al. highlight:

> the need to build students' resilience and self efficacy through pedagogies that provide encouragement and stimulate intellectual engagement that can lead to successes for all students and do not support premature judgments, or send the message to students that they are not capable of success in STEM. Thus, early interest in science and mathematics needs to be supported in later years by a belief that students can successfully and meaningfully engage with ideas and the enactment of pedagogy consistent with this belief. (2008, p. 137)

They argue that care needs to be taken not to prematurely exclude students from science and mathematics pathways on the basis of tests involving recall of answers, which can contribute to a decrease in students' resilience if they do not perform well. This advice is again fully congruent with the directions signalled by NZC, and in particular by the inclusion of key competencies to be developed by all (Hipkins, 2006).

Opportunities One and Two have highlighted possibilities within new curriculum directions. This next part of the discussion serves as a useful reminder that the challenge of teaching traditional "content" in interesting and engaging ways still retains its salience, albeit with an even more demanding twist. Early explorations of the interweaving of curriculum key competencies and content have demonstrated that opportunities for students to develop content knowledge are strengthened rather than diminished,[7] but teachers need a much wider awareness of likely learning challenges. They need to recognise and pick up on cues to students' thinking—what has sometimes been called pedagogical content knowledge (PCK)—and they need to know how to link traditional content to new NOS learning goals and to contexts of relevance to students' lives. If they are to offer intellectually demanding learning experiences, teachers do need strong PCK.

The Tytler review suggested that a lack of specific science teaching at primary school may be the result of teacher avoidance if they lack the confidence to teach it in any shape or form. This reason is likely to hold in New Zealand as well as in Australia, but we also see an opportunity here. In the second half of the 1990s the Ministry of Education invested in the Building Science Concepts series in the belief that poor science knowledge had contributed to a poor showing in international testing at Year 5 (Hipkins & English, 2000). However, no professional development accompanied this initiative and the series now needs updating to match the recently released national curriculum. Such an update could be a cost-effective intervention to support primary teachers, but there is a caveat. Tytler et al. (2008) also note that interventions to support primary teachers have tended to be short term, with interest declining as soon as the intervention is completed. Anecdotally, our experience suggests this would also be true in New Zealand. This suggests some form of ongoing, active professional support should ideally accompany any investment in resources, even those already developed.

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[7] A range of recently developed resources on the Science Assessment Resources Banks (www.nzcer.org.nz) illustrate and discuss these new possibilities and challenges.

Recommendation Three:

The Royal Society and MoRST could consider ways to support effective and ongoing use of resources such as the Ministry of Education-funded Building Science Concepts series designed to strengthen teachers' pedagogical content knowledge in science. This series could be aligned to NZC, and opportunities to develop key competencies via some of the many activities outlined could be identified and explained. It is possible that links to a "learning to learn" focus could also be developed, with the explicit aim of building students' resilience when encountering intellectually demanding learning in science.

Opportunity Four: Leveraging on partnership initiatives

The importance of parents' knowledge of and valuing of science careers was a factor that emerged as important in the Staying in Science project (Hipkins et al., 2006). This, too, is identified in Figure 4 as a possible point of intervention for engaging more young people in science.

Working in greater partnership with parents has been a significant stream of work for the Ministry of Education for some time now. One initiative is the development of the Team Up website (www.teamup.co.nz) that is designed to speak directly to parents' interests and concerns about their child's education. It could be that any narrative materials developed for students (as in Recommendation Two) are simultaneously redeveloped as part of a growing information base for parents.

The NEMP patterns reported in Section 2 suggest another avenue of possibility. Perhaps more children would have opportunities to engage with interesting science learning experiences if simple ideas for providing these were outlined for interested parents.

Recommendation Four:

Consider possibilities for working with the Ministry of Education to provide opportunities for parents to support and enhance their child's early interest in science.

In conclusion

It is a clear finding of both this and the Tytler review that the middle school years are an effective time to put STEM innovations in place.

The timing is fortuitous in that the implementation of NZC, currently underway, supports the directions suggested. Additionally, the downward trend in just-released 2007 Year 8 NEMP attitudinal data is likely to put science education in the policy spotlight again, as it was after New Zealand's perceived poor showing in the first Third International Maths and Science Survey international survey.

Collectively, the possibilities outlined in this section would constitute a strong response, one that is likely to be engaging to a wide range of potentially interested parties. The recommendations build on the collective work of the science education sector over the past decade, while also suggesting new possibilities for moving that work into a new framing for a new century. Now is the time to act, in the interests of all our students as future citizens, and to ensure ongoing, or even increased, support for STEM careers.

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Appendix A: Details of NEMP data

Note that the format of the various questions was somewhat different in each round. Each table shows the percentage of responses in the most positive category for that year. The next level of response is then added to provide the cumulative frequency shown in brackets.

Table 3 **Year 4 students' responses to a selection of NEMP attitude items**

Questions put to Year 4 students (n=1440 in each cycle)	**Number of students who gave the most positive response % (brackets show % total when next most positive response is added)**			
	1995	**1999**	**2003**	**2007**
How much do you like doing science at school? (response = four versions of a face, from smile to frown)	60 (92)	67 (91)	62 (91)	64 (88)
How much do you think you can learn about science at school? (response = heaps/quite a lot/sometimes/never)	34 (77)	28 (69)	25 (62)	24 (53)
How often does your class do really good things in science? (response = heaps/quite a lot/sometimes/never)	16 (94)*	16 (43)	12 (39)	12 (30)
How good do you think you are at science? (response = four versions of a face, from smile to frown)	25 (89)	37 (85)	32 (82)	35 (81)
Do you do some really good things in science in your own time, when you're not at school? (response = heaps/quite a lot/sometimes/never)	NA[8]	15 (36)	17 (39)	22 (42)

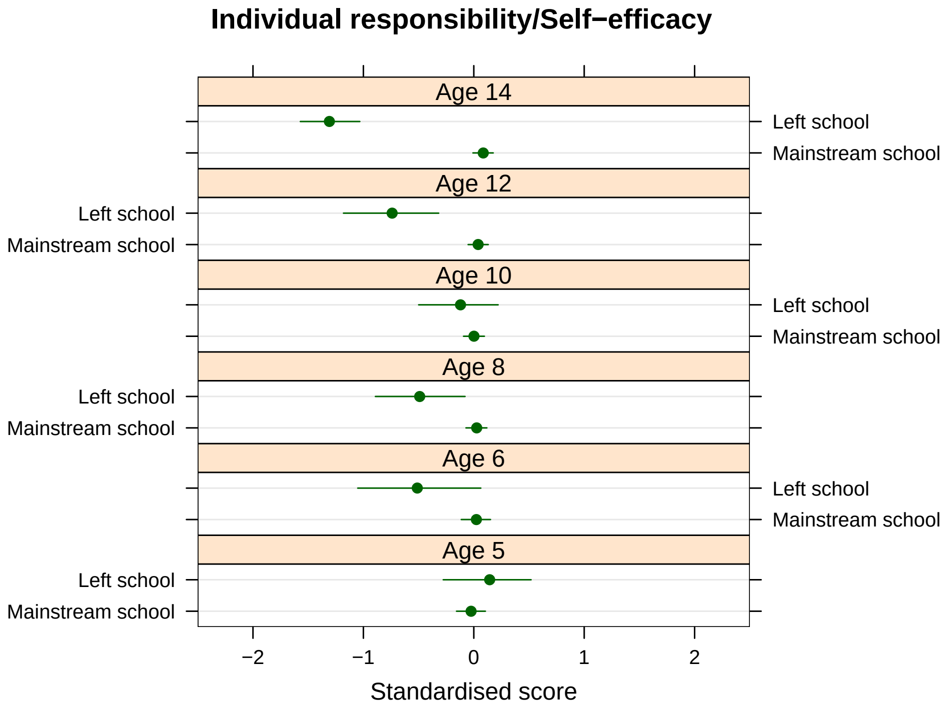
* Three categories were provided in 1995, compared to the four shown for the subsequent rounds.

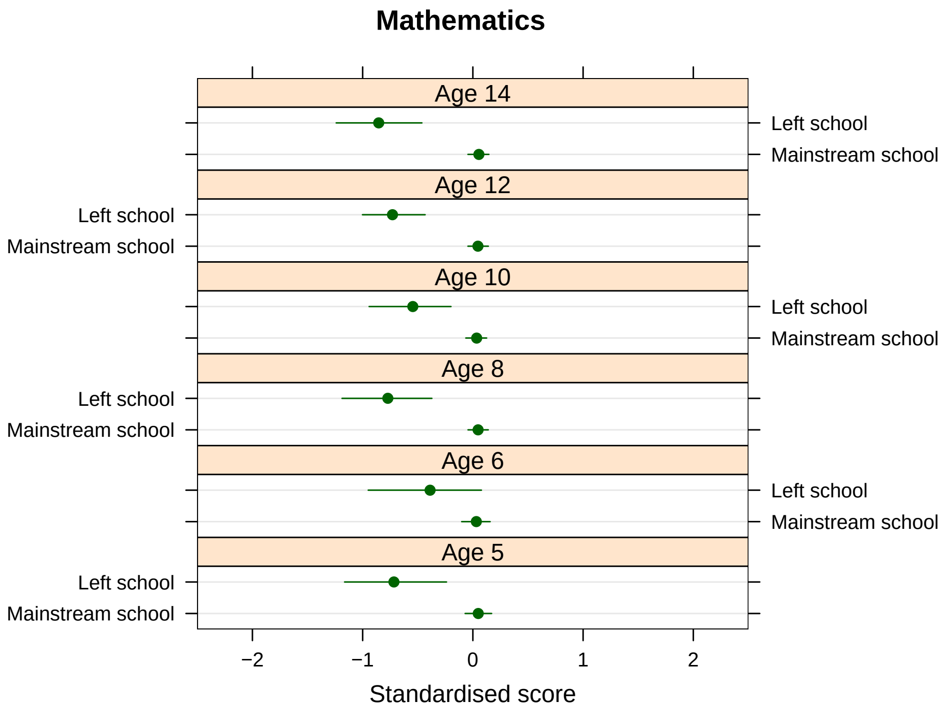
[8] This question was asked with slightly different wording, and with a 3-point scale that cannot be directly compared.

Table 4 **Year 8 students' responses to a selection of NEMP attitude items**

Questions put to Year 8 students (n=1440 in each cycle)	Number of students who gave the most positive response %			
	1995	1999	2003	2007
How much do you like doing science at school? (response = four versions of a face, from smile to frown)	33 (92)	37 (85)	32 (83)	24 (63)
How much do you think you learn about science at school? (response = heaps/quite a lot/some/very little)	11 (64)	13 (59)	15 (57)	10 (49)
How often does your class do really good things in science? (response = heaps/quite a lot/sometimes/never)	5 (32)	7 (29)	3 (26)	2 (20)
How good do you think you are at science? (response = four versions of a face, from smile to frown)	10 (81)	16 (78)	17 (77)	12 (61)
Do you do some really good things in science in your own time, when you're not at school? (response = heaps/quite a lot/sometimes/never)	9 (33)	5 (20)	3 (14)	3 (15)

Appendix B: Additional data from NZCER's Competent Children/Competent Learners longitudinal study





(Source: Hodgen, 2007, pp. 95, 99)

Appendix C: Details of “identity” cluster analyses

UK study

Haste (2004, cited in Tytler et al., 2008) conducted a survey of values and beliefs of 704 11- to 21-year-olds in the UK regarding science and technology. Her findings suggested the young people could be classified into four broad groupings:

- The “Green”—predominantly girls under 16 who would be interested in a career in science. The Green students held ethical concerns about the environment and were sceptical about interfering with nature.
- The “Techno-investor”—mainly boys under 16 and young men over 16 in the workforce, who were enthusiastic about investing in technology and the beneficial effect of science. Such individuals trusted both scientists and government.
- The “Science Orientated”—predominantly boys over 16 both in full-time education and in the workforce, who were interested in science and who held a belief that a “scientific way of thinking” can be applied widely.
- The “Alienated from Science”—predominantly younger girls and young women over 16 in the workforce who were not interested in a job related to science, found science boring, and were sceptical of its potential.

Norwegian study (ROSE project)

Schreiner (2006, cited in Tytler et al., 2008) surveyed 1204 Norwegian students and performed a cluster analysis which yielded five student groupings:

- The “Selective Boy” who, as the name implies, was predominantly but not totally male. He has clear ideas about who he is and shows his identity by expressing very high interest in stereotypical masculine topics. School science is interesting and not difficult but not as interesting as other subjects. Working with people is not important for him.
- The “Selective Girl” who was predominantly but not totally female. This student is modern, reasonable, outspoken, and self-expressive. She knows who she wants to be and who she does not want to be. School science is somewhat difficult, and not very interesting and she prefers other subjects much more. The topics she is interested in learning about are predominantly concerned with the human body and health.
- The “Reluctant” group, consisting of 37 percent girls. These students are aloof and unwilling and make clear to their peers that science is not their kind of stuff. They are not interested in

learning about anything much in science, do not see the benefit of science to society and, in general, do not plan for a job that requires an advanced education.

- The "Undecided" group, consisting of 40 percent girls. These students are not disinterested but there is not much interest either. Schreiner argues that this type of student is more or less invisible. These students do, however, prioritise environmental protection for society.
- The "Enthusiast" group, consisting of 53 percent girls who find school science interesting, useful, and not too difficult but science classes are not more interesting than other subjects. These are the school-committed student types; they like science and school and appreciate the value of education and school.

Schreiner's survey included 17 items which identified what students considered important in any future job. These were reduced to six composite variables, including the following:

- "Realise and develop yourself" which all groups considered very important though the "Reluctant" less so.
- "Using hands and tools" which all bar the "Selective Boy" group responded negatively to and the "Selective Girl" group very negatively.
- "Work with and help people" which was important to the "Selective Girl" group and "Enthusiast" group but unimportant for the "Reluctant" and the "Selective Boy" groups.
- "Reach power and glory" which was unimportant to all groups though marginally more important for the "Selective Boys".

New Zealand study (Staying in Science)

The Staying in Science research (Hipkins et al., 2006) surveyed 496 students from 20 randomly selected New Zealand secondary schools, all taking at least one science subject in Year 13. This project also used a cluster analysis that revealed four groups as follows:

- "Serious science" students (one-third of those surveyed). These students tended to be taking more than one traditional science subject, and at least one mathematics subject in their final year of school. Many had a committed intention to study science at university, and to see this as leading to somewhat traditional careers; for example, in medicine, dentistry, or veterinary sciences. Unsurprisingly, the "Serious science" students said that their learning at school had increased that interest, and that they had done well in (general) science, and in biology. They were pleased they had taken science subjects, and indeed were more likely to say they had been encouraged by their parents and their teachers to do so. They were more likely to see science as a worthwhile career to pursue. Fifty-seven percent of these students were female.
- "Science/business" students (a quarter of those surveyed). These students tended to have chosen physics and calculus in combination with some form of computer science/ICT as well as the business-oriented subjects. Eighty-six percent of the students in this cluster were male and they were less likely than the "Serious science" students to see science as a worthwhile career to pursue.

- Just under half the students (44 percent) belonged to one of the other two clusters, both of which showed different variations on the theme of “Keeping options open”. These students had chosen a more mixed bag of subjects and said that sciences were not among their “top choices”. The “Keeping options open (1)” cluster (predominantly female), tended to combine one or more, often alternative, types of science course with other Year 13 subjects that were likely to include English but not mathematics. In the “Keeping options open (2)” cluster (predominantly male), ESOL replaced English and there was a stronger combination of IT/business subjects with alternative versions of science. Students in these two clusters were likely to be less confident than the other students of their academic ability in sciences, or to be enjoying their science learning. They were also less likely to be encouraged to persevere with science studies by their families and many of them seemed poised to drop sciences on transition to tertiary, despite the fact that a number of them agreed that science may be needed for their future career plans.