Review and Maintenance Programme (RAMP) Technology

Themes in the research literature

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1. Introduction

The RAMP review

In the second half of 2014 the Ministry of Education initiated a process to review all materials funded and managed by them to support learning in the senior secondary school years. These are the years of schooling when achievement is predominantly assessed by achievement standards that build towards NCEA qualifications (the National Certificate of Educational Achievement). The process was given the acronym RAMP (Review And Maintenance Programme), and the stated focus was to ensure "that materials that support NCEA continue to be aligned with *NZC*[1] and support the development and use of quality teaching and learning programmes in the secondary school".[2] For the purposes of the review, these support materials were to include all those associated with NCEA: the achievement standards themselves; the matrix of key outcomes that accompanies the suite of achievement standards at each of NCEA Levels 1–3; student exemplars and other assessment resources; and any specified conditions of assessment. The online senior subject guides were also within the review's scope.

The Ministry of Education has sought several types of external input into the review process. An advisory group with demonstrated curriculum leadership and pedagogical expertise in the relevant learning area has the role of providing 'on the ground' expertise related to the challenges of teaching and learning. The Ministry has also requested a literature search for recent research related to the implementation of NCEA in the relevant learning area and/or the uptake and enactment of *NZC* in the final 3 years of schooling, informed by wider research on achievement in New Zealand across the years of schooling and by any associated policy debates. External input from teacher and student focus groups was planned for a later stage of the review process. Achievement data for at least the 3 previous years, along with feedback from relevant groups in the New Zealand Qualifications Authority (NZQA) and the Ministry itself, provided internal sources of feedback. These processes were initially implemented for the Mathematics & Statistics[3] and Science[4] learning areas of *NZC*. In early 2015 a similar set of processes got underway for the Technology and Health/PE[5] learning areas.

This report provides input to the RAMP process from the literature review of technology education in the New Zealand senior secondary school context. The review, which includes an

[1] *The New Zealand Curriculum (NZC*), which provides an overarching national curriculum structure for all the years of schooling (Years 1–13).
[2] Ministry of Education briefing materials.
[3] Neill & Hipkins, 2015
[4] Hipkins & Joyce, 2015
[5] Boyd & Hipkins, in press

Endnote file of the cited literature, took place in early 2015.[6] Three specific areas of importance to the Ministry of Education were outlined for the advisory group and the literature review team:

- the critical connection between *NZC*, teaching and learning, and NCEA
- the needs of priority learners
- the effect of support materials on school programmes.

With these priorities in mind, we, the NZCER reviewers, searched for all the relevant local literature we could find. A small number of large-scale international reviews were used to help organise the mainly smaller local studies and to check for emergent issues that might be of interest to the Ministry because they determine their next steps in the provision of curriculum support for senior technology. Search and selection processes are described in the Appendix.

Compared to reviews undertaken for the Science and the Mathematics & Statistics learning areas, it was more challenging to locate a wide range of research papers specifically related to the teaching and learning of technology in the senior secondary years. (Several strong pockets of research activity that we did locate had a focus on technology in primary schools.) Sixty-one references were added to the Endnote file.

The following sections summarise the key findings, organised to reflect the areas of concern for the RAMP process. Where findings from the Science and the Mathematics & Statistics reviews are also applicable to Technology, we have mostly chosen to paraphrase and cross-reference from the earlier reviews, thus keeping the focus of this report on substantive new issues. Note that this report does not seek to reach specific conclusions, which we see as the prerogative of the Ministry's internal RAMP team. However, the manner in which we have structured the results of the literature review process inevitably represents our thinking about the significance of the papers we found.

Neither of us is a member of the technology education community in New Zealand. However, we do have the advantage of being able to bring insights from the two previous RAMP reviews to the process, as well as broad expertise in curriculum and assessment in the primary sector (Chris) and the secondary sector (Rose). Rose attended 3 days of the meetings of the RAMP Technology Advisory Group. This served as a useful check on the key themes that emerged from the literature search. Members of this group helped us to locate additional material to complement the articles that were more readily discoverable.

Thinking critically about the paradigm shift used to frame issues and challenges

The first of the RAMP review series identified a paradigm shift in science education and noted that this shift affects the way in which the implications of research findings might be used to inform future actions. We described the nature of the shift in terms of two quite different frameworks for thinking and drawing conclusions. One framework might be characterised as

[6] An annotated Endnote file constituted the second source of input from the literature search.

‘business as usual’; that is, traditional curriculum thinking, assessment and pedagogical practice familiar to adults who were school learners in the 20th century. Alternative frameworks rethink these familiar assumptions and practices to arrive at different conclusions about appropriate curriculum, assessment and pedagogical practices for the 21st century (Hipkins & Joyce, 2015, p. 1). We subsequently found evidence of similar 20th/21st century tensions within the Mathematics & Statistics learning area, with a predominance of 20th century framing in the research and commentary about mathematics, in contrast to a distinct trend to 21st century framing in statistics (Neill & Hipkins, 2015).

Tensions generated by the 20th/21st century paradigm shift will again be evident in this review, although they play out somewhat differently. The Technology learning area was developed comparatively recently, appearing in the national curriculum for the first time in the 1990s (Ministry of Education, 1995). Section 2 provides evidence that some commentators have been aware of—and strongly endorse—the 21st century sensibility that has been a feature of the learning area right from this comparatively recent inception. However, the antecedents of the Technology learning area include a range of pre-vocational subjects with a strong practical focus. These subjects came with a long-established tradition of providing for ‘vocational’ students who were not destined for 20th century post-school academic pathways. As such, these subjects were firmly grounded in 20th century assumptions about the nature of learning and which types of students would be singled out as successful ongoing learners. Students taking pre-vocational subjects were expected to leave school to enter trades or clerical roles (in the case of typing). It was not anticipated that they might become designers or engineers, or take up other technological career pathways. With this history it is not really surprising that an academic/vocational tension plays out strongly in the literature we found. Those on either side of the paradigm shift understand the issues differently and have different views about what should be done to address them.

2. Technology in *NZC*

This report begins with themes in the literature related to the structure of the Technology learning area of *NZC* and the contribution of this learning area to the overall curriculum. As already noted, Technology was developed as a new learning area in the 1990s. It has some features that do not have the same history of curriculum traditions as the science and mathematics learning areas.[7] Building on the curriculum development in the 1990s that resulted in Technology in *NZC* (Ministry of Education, 1995), the Technology development team for *NZC* took the opportunity to revisit the overall structure and focus of the learning area. At this time some nascent aspects from the 1990s such as the Nature of Technology (NoT) were revisited and reworked. No doubt these developments have contributed to the debates that are still very much a feature of the literature in this area. In this section we present evidence that Technology remains a contested learning area, with some research indicating that its intent is still poorly understood.

The structure and scope of the learning area

The Technology learning area is structured into three strands, as follows.

- **Technological practice** subsumes but extends beyond the practical 'making' activities of traditional 20th century vocational/craft subjects such as woodwork, metalwork, cooking, sewing, typing, and information & communication technology (ICT). Students develop briefs for their own projects, taking into account stakeholder needs, impacts on the environment, and aspects such as legal and ethical considerations.
- **Technological knowledge** explores "how and why things work" (The New Zealand Curriculum, 2007, p. 32), including a focus on the properties and uses of materials. Activities such as prototyping, modelling and exploring systems challenge and extend students' thinking and practical experiences.
- The **Nature of technology** (NoT) strand explores the disciplinary basis of technology and the implications of its socially embedded nature. (This strand will be discussed in more detail shortly.)

[7] Possible exceptions to this comment are the more recent addition of the Statistics strand in Mathematics & Statistics (Neill & Hipkins, 2015) and the reworking of the Nature of Science strand of the Science learning area (Hipkins & Joyce, 2015). Both of these non-traditional components potentially reflect 21st century approaches to curriculum development, as does the entire Technology learning area.

NZC describes the place of technology in the overall curriculum as follows:

> In technology, students learn to be innovative developers of products and systems and discerning consumers who will make a difference in the world. (Ministry of Education, 2007, p. 17)

In the lead-up to the *NZC* development work, Compton and Jones (2004) noted that technology can be seen as a combination of four main areas of understanding: technology as artefacts, technology as knowledge, technology as activities, and technology as an aspect of humanity (p. 193). They argue that these four aspects of technology should not be taught independently, but "will all run together" in learning activities that meet the learning specifications sketched in the above purpose statement in *NZC*.

After *NZC* was published, six specialist areas for students at Levels 6−9 have been introduced under the umbrella of the Technology learning area: design in technology, manufacturing, construction and mechanical technologies, design and visual communication, digital technologies, and processing technologies.

How technology reflects the high-level intent of *NZC*

NZC aims to shift educational practice into the 21st century. One curriculum commentator (Abbiss, 2011, p. 121) has summarised the paradigm shift signalled by the front section of *NZC* as involving:

- a redefinition of what it means to achieve
- teaching for dispositions, understanding and critical thinking
- equipping learners to participate in a knowledge society as producers, not just consumers, of knowledge
- supporting students to think differently about "the self as learner".

Abbiss goes on to discuss how these intentions might play out in the Social Sciences learning area. However, it will be apparent throughout this review that these four transformative shifts have also proven to be very challenging for technology teaching and learning. The challenge resides, at least in part, in how the learning objectives from the back part of *NZC* are developed in ways that reflect the high-level intent of the front part of *NZC* so that the two halves work well together. In the literature for technology there was some discussion of the match between the front part of *NZC* and the Technology learning area.

Evidence from the literature

- Compton (2009) explores the relationships between the Technology learning area and the principles outlined in the front part of *NZC*, which are described as "foundations of curriculum decision making" (Ministry of Education, 2007, p. 9). She also explores the relationship between technology and the *NZC* vision statement. She says that the Technological Practice strand ensures that authentic opportunities are provided for students to engage with the community in various ways, and that they confront key *future focused themes* such as sustainability as a core part of their participation. Working with authentic needs and/or opportunities creates a high level of *expectation* and commitment for students, and success in meeting these results in a growing level of empowerment and sense of place. In this way technology also contributes significantly to the *NZC* vision of developing "confident, connected, actively involved, lifelong learners" (Ministry of Education, 2007, p. 7).

- In the same paper Compton also comments on potential links between technology and the values and key competencies outlined in the front half of *NZC*. She notes that technology "can provide strong leadership in supporting the development of a democratic literacy for all students—in its own right and through its mutually enhancing relationship with values education and the key competencies" (p. 34). However, she also cautions against an expectation that technology should focus on meeting *NZC* needs "if it endangers the distinctive quality and integrity of technology as a learning area, and/or overloads our teachers and students" (Compton, 2009, p. 35).
- Noting that *NZC* intends to be a curriculum for the 21st century, Snape and Fox-Turnbull (2011a, 2011b) align its features and intent to *The Framework for 21st Century Learning* developed in the United States by the Partnership for 21st Century Skills. Like Compton, they identify the vision, values and key competencies as points of connection. They also assert that changes in approaches to teaching will be needed because *NZC* acknowledges that discipline content alone is insufficient (Snape & Fox-Turnbull, 2011a, p. 150). They advocate a curriculum that is "interdisciplinary, integrated, inquiry, problem or project-based, values and competency driven, and one that engages and excites children" (ibid., p. 150).
- Snape (2012) puts his own recommendations to work, describing the development of an innovative programme for a combined class of Year 11–13 students, mostly with a computer science or digital technologies background, using an inquiry- or project-based approach. Students were to be given opportunities to experience collaborative technological practice to develop a range of skills and understanding to transfer to their individual projects. Key competencies and values were to be integrated into the programme, and learning dispositions for 21st century living were to be taught explicitly. (Note that this was a conference presentation, with an intention to carry out follow-up research indicated. We did not find any more recent reference to follow up on this.)

Relationship of technology to other learning areas

Advocates for technology note that it is inherently interdisciplinary and draws on elements of the sciences, arts and social sciences (see, for example, TENZ & NZAATE [Technology Education New Zealand & NZ Association of Academics in Technology Education], n.d.). In a recent briefing paper to inform the initiative that resulted in the policy document *A Nation of Curious Minds* (Ministry of Business Innovation and Employment, Ministry of Education, & Office of the Prime Minister's Science Advisory Committee, 2014), TENZ and NZAATE noted that the *diversity of contexts* through which students can develop general technological literacy is a strength of the learning area. These contexts include: digital technologies, biotechnology, and food, textile, structural and control technologies. One or more of these might be combined with design technology.

However, this wide-ranging scope can also be seen as problematic, particularly as the cross-over with other learning areas can make the boundaries of what counts as technology—or, indeed, of the other subject(s) with which it is combined—somewhat "fuzzy" (Jones, Buntting, & Vries, 2013, p. 192). As the following papers show, different curriculum commentators focus on a diverse range of issues and/or favour different approaches when addressing this set of challenges.

Evidence from the literature

- France & Bolstad (2004) note that the Science and Technology learning areas both provide opportunities for biotechnology education. While this potentially provides more opportunities for students to explore the scientific, technological and social perspectives of biotechnology, teachers need to be aware of how biotechnology is perceived within the learning area in which they are working. These researchers identified issues for both science teachers and technology teachers who teach biotechnology. Science teachers may not be confident about teaching the social and ethical dimensions, while technology teachers might not have a sound understanding of the scientific aspects.
- Jones et al. (2013) express similar concerns about appropriate explorations of the social aspects of technology when it is taught in science contexts. They argue that the teaching of technology as a subset of science can be detrimental to students' development of "a clear understanding of the interactions between science, technology, society and the environment"; i.e. a consideration of values and ideas incorporated into the economic, political, social and environmental aspects (p. 198).
- Although design is often integrated with a specific technology context (e.g. textiles and design), McGlashan (2011) argues for design to be kept as a separate subject to "ensure undiluted, faithful coverage of the ways of design, where students may develop tacit knowledge through practice" (p. 282). McGlashan argues that integration will dilute the focus on design, resulting in "invisibility through integration" (p. 282).
- In a subsequent paper, McGlashan (2014) takes this further by making the case for design and visual communication to be a separate subject in the senior secondary curriculum. The benefits would be that: coverage of design is assured; dilution of design within another subject is eliminated; and the creative design approach would act as a thread across subjects.
- A recent *Education Gazette* article (Jackman, 2015) describes a workshop for Year 10 students at one school during which the students made music and moving objects out of rubbish and computers. The workshop combined music, art, science, and programming and engineering, with a specific intention to "cut through single disciplines and get students engaging with more than one subject at a time". Note that this workshop was designed by academics from Victoria University and staff from Google, bringing together their different fields of expertise.
- Advocating for a different approach to developing cross-curriculum links compared with the fully integrated workshop just described, Compton (2009) makes the case for curriculum

collaboration rather than curriculum integration. Her reasoning is that it is important for the different learning areas to maintain their own integrity.

- Education for Enterprise (E4E) aims to develop an enterprise culture that is embedded across schools' curriculum programmes and reflects their local community. A key feature is schools developing partnerships with local businesses and community groups. E4E therefore potentially provides a rich context for technology learning opportunities. In an evaluation of E4E regional clusters, Bolstad, Hodgen and Roberts (2009) report survey responses from 409 students in 18 schools: 30 percent of the respondents were at senior secondary level (Years 11–13). For just under a third of these students, E4E occurred in either "enterprise" classes or business/commerce-related classes. However, design and technology and trades-linked subjects also provided enterprising learning opportunities for some students.

The status of digital technologies

Since *NZC* was developed there has been a separate process to develop what is, in effect, a distinct senior secondary curriculum for digital technologies, published online as the *Digital Technologies Guidelines* (the *Guidelines*).[8] An *Education Gazette* article that discussed this development noted that the Ministry of Education had responded to a call from industry and tertiary experts who sought "a coherent body of knowledge for Digital Technologies that could serve as a basis for the development of teaching and learning guides" ("Digital Technologies and the Senior Secondary Curriculum", 2009). This article also noted the formation of a new teacher association (the New Zealand Association of Computing and Digital Information Technology Teachers) as one response to this initiative.

Similar ground was covered when Kathryn Ryan interviewed[9] Evan Blackman (Microsoft New Zealand's Education Sector Director), Professor Tim Bell (Canterbury University Director of Software Engineering Studies) and 17-year-old student Sebastian Hallum Clarke, who is set to study computer science and economics at Princeton and currently runs his own software company, Zibity. Concerns were expressed that the education system has failed to recognise the importance and value of digital technologies to the economy and that not enough people are entering the IT industry with the skills needed. Females and Māori and Pasifika young people are absent in tertiary IT courses. The group noted that some overseas countries are beginning to make coding a core part of the curriculum, and Sebastian said that the "fundamental logic of programming" (how things work) was one of the strong influences on his pathway choices. Tim Bell advocated for support to be provided for teachers so that they develop effective pedagogy for teaching programming and coding.

During the Radio New Zealand interview this group debated whether digital technologies should be a stand-alone subject. The *Guidelines* state unequivocally that "Digital Technologies

[8] http://dtg.tki.org.nz/

[9] "Review of Teaching of Digital Tech in Schools", *Radio New Zealand National*, 4.32 pm, 17 April 2015.

sits within the Technology learning area of the New Zealand Curriculum".[10] Nevertheless the very existence of separate guidelines for digital technologies points to perceptions that it is substantively different from the other contexts in which technology is studied. Indeed, one lobby group has continued to lobby for digital technologies to become a separate learning area of *NZC* (Institute of IT Professionals, 2014).

The *Guidelines* develop Year 11–13 objectives for five sets of technological context knowledge and skills: electronics and control; programming and software; business technology; digital media; and digital environments and systems. In addition, objectives for 'Digital society' and 'Digital concepts and tools' link this new development back to the knowledge and NoT strands of the Technology learning area of *NZC*. Suites of achievement standards have been developed to support this new curriculum.

We found a small number of papers that addressed teachers' understanding of this new curriculum development, but it is probably too soon to draw any firm conclusions from them. They are presented in reverse order because the earlier papers provide commentary during, or just after, the process of development of the new curriculum, before teachers had had much chance to understand it.

Evidence from the literature

- Hallam Clarke (2015) reports that currently around a third of New Zealand secondary schools offer students the new computer science NCEA standards. He notes that there is no requirement for digital technologies to be offered and that teachers are more familiar with non-digital technologies. In any case, there is no defined curriculum for digital technologies below the senior secondary school level.
- Thompson and Bell (2013) discuss the results of a survey carried out in 2013 to investigate teachers' responses to the implementation of what they describe as the computer science curriculum.[11] They compare the responses with a survey a year earlier, before the full suite of NCEA standards was available. Thompson and Bell note that teachers typically came to the subject from a background of ICT, so there were issues of teacher confidence in the move to computer science. A lot of upskilling had to be done on the job. They report that teachers were showing an increase in confidence after just over a year of experience, and they note an increase in participation in the new standards. However, a lack of time and resources to prepare to teach the unfamiliar topics was an issue, and therefore resources specifically designed for the standards were highly valued. Overall, the transitional period was clearly demanding for teachers, but many were already seeing the benefits of adopting the *Guidelines* and their associated NCEA standards.
- Bowker (2011) outlines the 3-year project (2007–2010) to develop the *Guidelines*, noting that interactions between schools, tertiary institutions and industry were part of the project, and have continued. Bowker also sees professional learning as an essential component, and notes

[10] http://dtg.tki.org.nz/Strands

[11] In fact there is no curriculum for computer science; rather, it is a body of knowledge that falls under the digital technologies body of knowledge.

the availability of the senior secondary teaching guide for digital technologies.

- While the *Guidelines* and NCEA resources were still being developed, one group of researchers (Muragesh, Bell, & McGrath, 2010) noted that relatively few teachers had a background in computer science. They had already located “a wealth of suitable resources” (p. 175) to support some parts of the in-development digital technologies, but noted that knowledge of software development processes and methodologies was going to be more difficult to resource. They also noted that teachers with an ICT background were accustomed to using unit standards for assessment (e.g. in aspects of word processing), and would need time and support to get to grips with the new achievement standards.

Debates about the focus of learning in Technology

The RAMP review for the Science learning area documented considerable policy activity and debate about why students should have rich and engaging opportunities to learn science at school (Hipkins & Joyce, 2015). We did not find an equivalent collection of policy papers for the Mathematics & Statistics learning area (Neill & Hipkins, 2015). However, as we now outline, this debate is alive and well in the technology education community, although its form and substance are quite different from the debate in science.

What students might expect to learn in technology is contested. As we have seen in the previous RAMP reviews, a difference of paradigms sits at the heart of debates that are essentially about the purposes for learning a subject. The craft/vocational subjects[12] that have found a new home under the technology umbrella tend to reflect 20th century thinking about differences between academic and practical learning. From this perspective, 21st century ideas about technology are not appropriate to the learning needs of the students these subjects have traditionally served. This debate is sometimes generic and sometimes specific to NoT as a centrally important aspect of the learning area. Discussion of curriculum understandings reflects this tension, as outlined next. Section 3 elaborates further on aspects related to meeting students’ learning needs, and section 5 discusses how this tension plays out in debates about assessment.

Debates about the Technology learning area in general

A number of papers assert that teachers from traditional crafts/vocational backgrounds do not understand the intent of the Technology learning area and do not support it. Some of these papers describe similar attitudes and expectations from students whose preference is for a pre-vocational, practical emphasis in their chosen technology class or classes. A high-level discussion of these issues is provided by Ferguson (n.d.). Note that most of the papers that follow are small-scale qualitative studies involving only a few teachers or schools.

[12] These include the traditional subjects such as woodwork, metalwork, cooking, sewing and tech drawing.

Evidence from the literature

- One small-scale research project (four teachers in three schools), undertaken during the implementation phase for *NZC*, explored teacher and student perceptions of technology in *NZC* (Almutairi, 2009). Despite taking part in Ministry of Education-funded professional learning and development, two of the four teachers did not appear to understand the new concept of technology as presented in the 2007 curriculum. They provided their personal practical aims for learning, with no reference to *NZC*'s theoretical underpinnings.
- In the same study Almutairi also reported that students in these teachers' classes were not aware of the changes to the curriculum and came into their courses with preconceptions about the subject. Their idea of technology was based on a traditional understanding (i.e. a less theoretical, more practical curriculum). Almutairi notes that this was particularly true of ICT classes.
- Another small-scale study (Hawkins, 2010) explored the views of five secondary teachers who taught materials technology. When asked about implementing the 2007 technology curriculum, these teachers talked in terms of their previous experience of technical subjects. They came from trades backgrounds and, according to Hawkins, were not very receptive to implementing the new curriculum.
- Another small-scale study reported similar findings (Williams & Gumbo, 2011). The four lower secondary teachers in this study interpreted the curriculum in different ways, held differing conceptions of learners, and saw the purpose and aims of technology education differently. Two of the four teachers believed that skill development and vocational goals were the main purpose for learning technology, although problem solving and creativity skills were important. For them, Technology was not adequately developing or promoting a practical approach to learning.
- In the early 2000s the Ministry of Education funded a small number of Curriculum Innovation Projects, one of which was set in the Technology learning area (Boyd et al., 2005). The school involved investigated a new approach to Year 11 technology, which was intended to "increase student knowledge and understanding of the technological process, to enhance their ability to use this process independently, and to increase student engagement in learning" (p. 163). Students self-selected an individual project and worked right through the technological process. Boyd et al. reported that some students found the course too academic, preferring skills-based approaches.

In traditional craft/pre-vocational subjects, teaching and learning was typically geared towards the making of a specific product. Producing the best product possible was a cogent achievement aim for every student, and the students in one class would often make the same thing in essentially the same way. Given this heritage, one especially challenging area of debate concerns the role that knowledge (about technology and technological processes in general) should play in learning. Jones, Buntting and Vries (2013) see this as an important issue to debate because the philosophical position a teacher holds regarding the purposes for learning technology will underpin the conceptual framework on which their teaching is based. Williams and Gumbo

(2011) make the same point. In support of their argument, Jones et al. cite an earlier paper by Moreland (2009), which makes the case that the interactive processes of thinking and decision making in technology are more important than the products the students create. We will come back to this debate in the next section of the report.

Challenges with understanding the intent of the NoT strand

When the NoT strand was being developed, Compton and Jones (2004) outlined the purposes it would be expected to serve. These can be broadly paraphrased as:

- understanding the purpose and concept of technology
- building awareness of the impacts and influences on technology
- understanding the distinctiveness of the knowledge base for technology and how it draws knowledge from other domains, operationalising this for a specific purpose
- seeing technological knowledge as a social construct, validated by function and referenced to the "made world".

They then explained the need for an NoT strand as follows:

> As traditional boundaries are crossed in the establishment of new technological outcomes, focusing on the more generic underpinnings of technology is becoming more and more important in ensuring such things as fitness for purpose and assessment of risk. (Compton & Jones, 2004, p. 2)

As part of their wider discussion about what it means to be learning in a technology classroom, Jones et al. (2013) also discuss why it is important to be aware of how teachers and students understand the concepts of NoT. However, despite the importance the curriculum developers attached to this strand, the pertinent few papers we found argue that NoT is currently not well understood and that the overall structure of the Technology learning area does not necessarily inform teachers' curriculum thinking. Note that two of the following references are international commentaries rather than being specific to *NZC*.

Evidence from the literature

- Compton and France (2007) reviewed the history of technology education in New Zealand. They note that the 1995 technology curriculum supported a shift from functional technological literacy to a more socio-critical focus. However, students' technological literacy appeared to be limited in breadth and depth and their critical analysis was also limited. They argue that opportunities should be provided to increase students' understanding at a philosophical level and they see that the new structure of the Technology learning area in *NZC* provides the opportunity to do so. They argue that "teachers must be supported to make changes to their philosophical and theoretical understanding, which may translate into pedagogical changes" (p. 171).
- Compton and Compton (2013) conducted a number of case studies that illustrated how students could struggle to understand ideas related to NoT and to technological practice. This

work is discussed more fully in section 5 of the review.

- In their recent position statement, TENZ and NZAATE (n.d.) identify problematic inconsistencies in the use of the term 'technology'. They also note a lack of clarity about the natures of science and technology and how these relate to each other. For them, the difference is that the epistemology of science relates to understanding natural phenomena and the epistemology of technology relates to intervention in the made world. The processes of science involve scientific inquiry, while those of technology involve design and invention. They further note that both areas are influenced by, and influence, each other and that understanding the differences between the two disciplines can enable co-operation for social and economic benefit.
- Martin and Ritz (2014) undertook two Delphi studies,[13] one an international panel and the other a US panel, to identify research needs for technology education. Both study groups identified a need for research related to technological and engineering literacy knowledge as being the most important.[14]
- In a review of technology curricula in a number of diverse countries, Banks and Williams (2013) found that there is still no consensus about what school technology should be, how pupils should learn it, or what constitute effective teaching strategies. They note that technological literacy is a common goal of curricula, but that the actual content is broad and variable in different curriculum documents. Jones et al (2013) make a similar comment.

Getting past an academic/vocational binary

We found one book chapter by a New Zealand author (O'Sullivan, 2013) that developed a high-level critical discussion about the vocational/academic debate. Like other authors, O'Sullivan associated the vocational perspective with craft and employment preparation, and the more academic perspective with a greater emphasis on the nature of technology and technology in a critical social context. He saw these differences arising from different perspectives about the *purpose* of education in general. For him, the intention to support the development of students' "broad technological literacy" (p. 82) was likely to provide more equitable outcomes in terms of developing informed and empowered citizens. But he did not see these different aims as being logically incompatible, arguing instead that technology should be *both* vocational and academic. This would entail a "combination of liberal education values with the practicalities of new vocationism" (p. 84). Section 3 picks up on this possibility and asks if it is supported by research evidence.

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[13] A qualitative methodology where participants rank predetermined statements to arrive at a consensus view of what is the most important.

[14] 'Literacy', when used in relation to a specific subject, denotes a focus on the disciplinary nature of that subject.

3. Enacting a rich technology curriculum

Section 2 has shown that bringing the three technological strands together to build and enact a coherent technology curriculum can be demanding. There is some evidence that the NoT strand is not well understood. Together with the Technological Knowledge strand, the specifics of the learning area have prompted debates about whether traditional vocational/craft-based subjects can still be taught under the umbrella of Technology in ways that benefit the types of students who would have taken practically based pre-vocational subjects in the past.

This section introduces a different evidence base, shifting the emphasis to the 21st century side of the binary. The voices and experiences of those who have worked to enact the technology curriculum along the lines intended are represented here. A range of issues are raised, but the debate for these researchers and commentators is not presented in a binary framing of the relative merits of academic versus vocational learning.

A different take on supporting achievement in technology

The academic/vocational tension discussed in section 2 subsumes an interesting debate about the role of conceptual knowledge in the Technology curriculum. The literature presents some evidence that conceptual knowledge positively enhances students' achievement of a wide range of outcomes, including the more practical outcomes intended to be developed in the Technology learning area. One paper reverses this argument to signal that certain iterative design processes successfully build knowledge. The shift signalled by all these papers is from either/or thinking to seeing both intellectual and practical outcomes as being co-developed and interacting positively with each other during learning, as advocated by O'Sullivan (2013).

Evidence from the literature

- One doctoral research project makes the case for placing an explicit emphasis on enhancing students' conceptual understanding of technological modelling[15] (Harwood, 2014). This researcher found a positive connection between student understanding of concepts underpinning technological modelling and curriculum achievement in the components of technological practice. Stronger understanding of technological modelling enhanced students' competency to undertake development of briefs and planning for practice. Their outcome

[15] Technological modelling is the trialling of design ideas to test if the design is fit for purpose. There are two types: functional modelling, which is the testing of design concepts, and prototyping, which is producing a functioning model. These involve two different types of reasoning: functional and practical.

development and evaluation competencies also increased. Students who held a more sophisticated understanding of technological modelling (Level 6 or above) could discuss how practical and functional reasoning work together to identify risk, and to enable informed and justifiable design decisions to be made. They could also justify the technological outcomes they developed as fit for purpose.

- Williams (2013) synthesises a range of research literature to discuss teaching and learning challenges in technology. He addresses the debate about whether students need to develop a practical skill set and an understanding of materials *before* they develop designs that work. Alternatively, should they be engaged in design activities at the same time as developing practical skills and understanding? His research suggests the latter approach is more effective (p. 7). He argues that progress develops through the interaction of thinking and doing, and as students get better at designing, the more fluid this interaction becomes (p. 6).
- McGlashan (2014) argues that creative design has the potential to shift the emphasis in technology learning from information gathering to a new pedagogy that develops creative and curious minds. She cites earlier research (Scrivener, 2000) that contrasted two different approaches to design processing: a linear approach (problem solving) and a more iterative approach (creative production). The former resembles formulaic traditional technology programmes, whereas the latter "better reflects the integrity of inquiry, manipulation of thought and decision making inherent in creative design practice" (p. 41). McGlashan notes that modelling this iterative design process supports students to develop *tacit knowledge* through their own creative practice. However, teachers who are new to design processing will not be well equipped to do this sort of modelling.
- The Curriculum Innovation Project research introduced in section 2 (Boyd et al., 2005) reported that many students were interested in following a more academic course. At the time, newly available Level 3 achievement standards allowed them to do so. Students who thrived in the course benefited from increased ownership over their learning (being motivated by the autonomy of individual projects); being able to work across technology areas; the opportunity to follow their interests; developing a different relationship with teachers, as compared to their other classes; working with peers; and enjoying the more informal classroom environment.

'Authentic' learning programmes

The potential for technology learning to make use of 'authentic' contexts is seen as one of its strengths. Some commentators discuss what is meant by authenticity. For example, according to one review of relevant research, authentic technological practice is described as involving the use of rich contexts; a social construction of meaning; building meaningful connections between learning and life contexts; and strong student engagement (Snape & Fox-Turnbull, 2013). These authors say that an increasing number of primary school students are actively engaged in authentic learning opportunities, but "many secondary schools continue to use individualistic, text-oriented and assessment-driven courses" (p. 67).

We did find some rich examples of authentic practice. Some were special events, designed and supported from outside the school sector. (This could be an artefact of what is seen as newsworthy, because these articles tend to be from the grey literature, including various news sources.) Other examples are from more routine school learning programmes, though their innovative nature makes them far from routine (in its traditional meaning).

Evidence from the literature

- The EVolocity Electric Vehicle high schools programme in Canterbury is designed to support the technology learning area ("EVolocity—bigger and better!", 2015).[16] Students working in teams design and build an electric bicycle using supplied components, and then compete against each other using their completed bicycle. This initiative is described as "driving practical interest in mechanical, electrical, automotive engineering and programming. It is offering more assessment opportunities for students and interest in recruitment in courses in the tertiary sector". Some schools have embedded the programme into the Technology curriculum, while others have run it as a club activity that supports technology, science and physics courses. One student took the project to Scholarship level. This year the competition categories are: performance, innovation, show, video, and community awareness. It is being extended to other South Island schools. EVolocity is an initiative of Drive Electric, and the partners are CPIT, Enviroschools and Electroflash.
- Year 10 students (all girls) working in groups of three took part in a workshop run by Victoria University tutors and Google experts to make music and moving objects out of rubbish and computers. A combination of music, art, science, programming and engineering was used to complete the work, and the workshop was "designed to cut through single disciplines and get students engaging with more than one subject at a time" (Jackman, 2015). One student commented that she thought computer programming would be very difficult, but now says that everything you can imagine is possible. One of the tutors noted that there is a shortage of engineers, perhaps because it is hard for students to understand why engineering might be interesting to them. The intention was to show the students that it could be, by introducing engineering through art, music and science.
- Newsletters included as a centre-fold in the *Education Gazette* discuss a road safety resource available on the New Zealand Transport Agency's Education Portal. The February 2015 edition (NZTA, 2015) highlighted the work of a Year 13 digital technologies class who selected and imported data from the New Zealand Transport Agency's crash database to produce a GPS-enabled interactive map that demonstrated accident patterns in relation to a specific question. "One student looked at the relationship between weather conditions and crashes, another looked at the influence of drugs and alcohol, while a third investigated the extent of crashes involving animals and made recommendations about the setting of rural

[16] In 2015, 38 high school teams took part.

speed limits". This work was assessed with the Level 3 Achievement Standard 91633.

- One MEd study (More, 2011) explored student learning during an interactive learning experience in a live historical village. The researcher wanted to know whether the experience helped students learn about technologies used to produce food and to better understand the complex relationship between food technologies and society. Prior to this study, students demonstrated little knowledge of food composition, the sources of food and the technologies used to produce food. Developing an appreciation of the technologies used in the 19th century helped address these gaps, providing a platform for making connections between food and technology today, and their community and societal impacts.

Education for enterprise and pedagogy that draws on authentic contexts

Although the E4E evaluation introduced in section 2 (Bolstad, Hodgen, et al., 2009) is not specifically set in the Technology learning area, the potential for synergies to be developed between E4E and technology is clear. The E4E research adds student voices to this section of the review. It is clear that students are broadly supportive of the types of learning experiences that would ideally be enacted when the three strands of the technology curriculum are woven together. Another part of the evaluation provides evidence that technology projects completed as part of E4E are highly likely to access rich authentic contexts (Bolstad, Roberts, & McDowall, 2009).

Evidence from the literature

- Bolstad, Hodgen, et al., (2009) reported that students typically described their learning as involving designing a product, planning an event, or delivering a service for a specified or unspecified client or purpose. Twelve percent of survey respondents described authentic learning linked to "real world" contexts. Most students reported working on their E4E activities in groups, using knowledge and skills from more than one curriculum area, having extended time periods to work on their projects in-depth, and having different roles and responsibilities for different people within their groups. Sixty-four percent of students' enterprising learning involved working with people from business or the community, but it was generally less common for students to work outside the school. Most students agreed that their learning should occur through real-life projects and that they should be able to plan their own learning. Many agreed they should have learning experiences that contribute to the wellbeing of the community and to the environment and sustainability. More than half agreed that schools should have partnerships, and that teachers should do some of their planning with people from businesses or the community.
- A different part of the evaluation of E4E reported on principal and teacher survey data from Term 4, 2008. Twenty-one principals, 18 lead teachers and 45 other teachers from 15 schools responded (Bolstad, Roberts, et al., 2009). Twenty-three of the 61 projects described involved students in Years 11–13. Technology subjects were the most common context for these E4E projects, followed by commerce and enterprise subjects. Eighty-five percent of the projects

involved students working with people from businesses or the community. The most common types of partners were community groups, small to medium businesses, and schools or educational institutions. Central or local government agencies, large companies, charitable organisations, community and regional health boards, local theatre companies and friends of the school also featured. Most students produced or did something that benefited people from business or community organisations, the community or the school.

Challenges for developing authentic learning experiences

A number of the papers that describe authentic learning experiences also discuss the ways in which it can be challenging to set up these types of opportunities. Between them they identify a considerable range of potential barriers. Mostly the papers are in agreement, but two different views are expressed about whether assessment requirements are a barrier to authentic learning experiences. One paper identifies them as a barrier in traditional learning contexts. On the other hand, in rich, authentic E4E contexts they can be seen as less challenging than making community contacts, etc.

Evidence from the literature

- Boyd et al. (2005) say that teachers reported limited success in developing relationships with employers. They found it challenging to make the considerable time needed to do this.
- More (2011) identifies a range of potential barriers to taking students on field trips. These include: costs to the students for transport and site entry fees; costs to the school for relief teachers; time required for administration of the trip (e.g. planning, pre-site visits, and arranging permission letters); negative feedback from teachers of other subjects who do not want students absent from their classes; finding a food-related site that can make relevant links to the teaching programme and that welcomes visitors; and matching an available site with the technological practice needs/programme of the students.
- Snape and Fox-Turnbull (2013) note the use of authentic learning in rich contexts in primary school technology programmes as a contrast to the text-oriented and assessment-driven courses in many secondary schools. They identify timetabling and assessment requirements as examples of potential inhibitors of authentic learning experiences in secondary schools.
- Bolstad, Roberts, et al. (2009) also identify working within the constraints of the school timetable as a challenge. When working with community partners it could be challenging to ensure that students completed work to the expected timeframes of the partner. It was also challenging for the teacher to manage and support students while they carried out activities in the community, and to cater for students who struggled with working independently. For their participants (all active in E4E), meeting curriculum and assessment needs and working within the constraints of subject and discipline boundaries were among the least challenging aspects of the teacher’s role.

Culturally responsive pedagogy

A PowerPoint developed for use by all four technology advisers in the Te Tapuae o Rehua consortium emphasises the importance of rich, authentic, project-based learning. Teachers are encouraged to select contexts relevant to priority learners, when appropriate, including Māori and Pasifika students (Pym, Howard, Myers, & Price, 2015). However, this focus on practice-based advice does not appear to have been a target for published research. Compared to the earlier reviews, we found very little discussion about challenges such as supporting Māori students to achieve success as Māori when learning technology. We did, however, find some papers that discussed matters raised by the imperative to use more authentic contexts for technology learning.

Evidence from the literature

- Williams and Gumbo (2011) note that there was no evidence in any of their sources of data that the four secondary teachers with whom they worked had structures in place to enhance all students' understanding of indigenous technology. Any instances of integration of indigenous technology they found seemed superficial, despite one school including cultural heritage as a faculty goal each year.
- Bondy (2011) draws attention to the fact that the Technology learning area does not mention intellectual property rights. She reports that many respondents to a nationwide survey of secondary schools (both teachers and students) lacked an understanding of intellectual property in technology education in general, and of indigenous knowledge as a specific component of intellectual property. She clearly sees this as a gap that should be addressed: "intellectual property is relevant to technology education because ideas embodied in the material and designs being studied and developed must be recognised and protected" (p. 391). She also advocates exploring intellectual property rights in ways that incorporate and acknowledge bicultural perspectives. As one output of this project, resources for teaching and learning about intellectual property were developed.[17]
- Writing about future food technologies and Māori wellbeing, Hutchings, Taupo and Barnes (2012) report "general distrust of scientists from Māori who participated in the study: they were concerned about the future direction of new technologies especially when it came to food." Generally, though, "if the technology supported the natural process of Te Ao Tūroa (the natural world through a Māori worldview) and connected with mātauranga (Māori knowledges) and kaumātua (elder) knowledges, then the technology was more likely to be acceptable to Māori" (p. 2). Participants were interested in a holistic way of developing food technologies that would yield food that was closer to its natural state. They also were more interested in addressing issues that are relevant to Māori at the local level, as opposed to addressing international questions. While this report summary is not directly about technology education, these insights could be useful when thinking about contexts and pedagogy when working with Māori students.

[17] http://www.techlink.org.nz/ip

Professional learning that supports new pedagogies

The literature outlined in this section points to substantive learning benefits for students when teachers do weave a rich curriculum from the various strands of technology. However, it is also evident that learning to work in this way is demanding for teachers. If they have a strongly established traditional pedagogy, rethinking who can learn—and the role of knowledge in that learning—can be confronting. What might help teachers to shift their curriculum thinking?

Evidence from the literature

- Hawkins (2010) makes the case that the management skills of the head of department (HoD) are important, and that there is a need to foster leadership responsibilities at all levels of management in order to facilitate a culture change across a whole department. Hawkins notes that there has been limited professional development in middle management roles for HoDs of technology because the focus has tended to be on curriculum, assessment and strategies for student learning.
- Granshaw (2010) interviewed 10 technology teachers or HoDs from secondary schools within one region. Critical aspects of professional learning and development identified in this research included: the examination and critique of student work; the development of pedagogical content knowledge; and "building on teachers' existing knowledge and experiences within a constructivist theoretical framework" (p. 72). Granshaw also notes that relationships built by the facilitator are crucial.
- Hume, Eames, Williams and Lockley (2013) carried out a TLRI[18] study that researched ways to support early-career teachers to build their pedagogical content knowledge (PCK) for teaching technology. The researchers note that while the inter-related nature of procedural and technical knowledge in technology education has been identified, "the lack of consensus on what constitutes content (what can and ought to be learned) in the technology domain makes progress in understanding PCK in technology education more challenging" (p. 37). Their specific focus was on the use of CoRes (content representations) to support the development of professional knowledge bases of early-career secondary teachers in science and technology. Experts (such as experienced teachers and technologists) worked with early career teachers to develop and implement the CoRes. The team reported that taking part in CoRe design with content experts and experienced teachers shows potential for enhancing the PCK of early career technology teachers. However, engagement in CoRe design exposed differences between participants in terms of how the content for technology education is conceptualised. Early-career teachers reported improved levels of confidence about teaching their subjects using expert-informed CoRes as planning tools—the CoRe encouraged teachers "to identify and weave more conceptual thinking into their lessons and to think of ways to help their students understand more of the fundamental ideas behind materials technology" (p. 38). Using a CoRe, teachers said they could see the big picture, identify underlying concepts and principles, and make decisions about appropriate content to teach rather than

[18] Teaching and Learning Research Initiative.

just teaching what was needed to complete a specific project (p. 41). “They realised the need for a conceptual framework before determining the key ideas for the topic, and so believed that students also needed a broader framework of understanding beyond their specific needs related to their project” (p. 42). However, this team also note that some students preferred to just get on with the project, indicative of a difference between teachers’ and students’ expectations about the learning area.

4. Pathways that meet students' learning needs

The first two RAMP reviews provided evidence of a very wide spread of achievement for students with differing learning needs in science and mathematics. The need to change this situation for priority learners was seen to be of real concern (Hipkins & Joyce, 2015; Neill & Hipkins, 2015). It is not possible to present similar types of evidence in this review because technology has not been systematically assessed at national or international levels (e.g. via TIMSS or PISA).[19] Nor has this learning area been the subject of a systematic Education Review Office review since the inception of *NZC*.

This section begins with a discussion of the features of pedagogy in technology that provide space for students to take a more active role in making decisions about their learning, as compared to the likelihood that such opportunities would be offered in other subjects. The challenge of explicitly addressing the literacy demands of learning and assessment in technology is also addressed.

In contrast to these proactive themes, the most widely debated challenge for addressing students' learning needs relates to the advisability of differentiating between academic and vocationally oriented groups. The transformative 21st century shifts summarised in section 2—such as redefining what it might mean to achieve, and supporting all students to see themselves as successful learners—do not appear to have been brought to bear by some commentators and practitioners. This seems like a missed opportunity, given the evidence presented in section 3 that the so-called "intellectual" components can strengthen success in achieving the practical aspects of technology learning.

Involving students in making learning decisions

The three papers cited here all present positive commentary on opportunities for student involvement in making learning decisions in technology or E4E, which more often than not involves technology subjects. There is a clear implication that such opportunities contribute to student engagement and support the development of lifelong learning attributes.

[19] TIMSS: Trends in International Mathematics and Science Study; PISA: Programme for International Student Assessment. Nor has it yet been a focus for national monitoring in the post-NEMP (National Education Monitoring Project) era, although that is about to change. In the previous NEMP era, technology assessment was contentious, generating considerable curriculum debate.

Evidence from the literature

- Snape (2011) identifies authentic learning opportunities and formative assessment as two of the key elements of an educational design for successful teaching and learning in technology. He says that good formative assessment practice involves the student in deciding on what and how to gather evidence to judge their own achievement, supported by formative dialogue with the teacher. He mentions *Strategies for Engaging Students*, a Ministry of Education resource that provides teachers with diverse strategies to support higher-order and meta-cognitive thinking and collaborative activities. In these ways the technology learning area provides "more meaningful learning (p. 95).
- Snape and Fox-Turnbull (2011a) comment that "the socially embedded nature of Technology integrates a variety of skills, ethics and cross-cultural themes, offering opportunities for students to participate in, and understand many local, national or global community issues" (p. 156). For them the potential for students to build rich cross-curriculum links from their technology learning experiences was one way in which students could take greater ownership of their learning. They assert that the "professionally aware" teachers (p. 157) facilitate a wider range of skills and process learning than most classroom teachers. In this way, technology teachers proactively address the challenge of supporting life-long learning for the 21st century.
- Bolstad, Roberts, et al. (2009) identify opportunities for students to take responsibility for deciding how they use their time each day as one characteristic that makes E4E different from "normal" teaching. Students have an extended period of time to work on one project in depth, often doing something that is useful and important" to someone other than themselves. In their research cases teachers were likely to be involved in deciding the parameters of the work and how it would be assessed, although in some cases students and community/business partners were also involved. But it was common for students to be involved in deciding how that work would then be carried out.

Different purposes, different pathways

The Learning Curves research project (Hipkins, Vaughan, Beals, & Ferral, 2004) provided an early discussion of the question of which students are encouraged to take technology as a subject. Although this research was conducted during the initial phase of NCEA implementation, and hence predates *NZC*, it does reflect the tensions outlined in section 2. The six medium-sized secondary schools in the study were grappling with providing pathways for different sorts of students, but doing so was compromised by "old understandings of technology" (p. 127).

Evidence from the literature

- Technology leaders in all six Learning Curves schools were grappling with the 'intellectualisation' of their subject area. Some felt that practical skills were undervalued, even though students wanted to develop these and felt successful when they did so. As one technology teacher put it, "the kinaesthetic approach to problem-solving has been diminished in favour of a more intellectual approach" (Hipkins et al., 2004, p. 123).

- Some of the Learning Curves schools offered unit-standards-focused courses, and some worked with polytechnics and industry training organisations (ITOs) to develop pre-trade training courses at school. One school preferred non-academic students to pursue trades-focused learning through the Gateway programme.
- One HoD noted that technology was attracting a greater number of high-achieving students, while another said that attracting academic students to technology courses was a challenge. Reasons given for this second perspective were that parents, students and some teachers didn't recognise that the focus on problem solving with technical knowledge is designed to meet real-life needs, and the career pathways it can lead to are not well understood.

Pathways beyond school

While the comments of the Technology HoDs in the Learning Curves project were made a decade ago, it would appear that lack of knowledge about pathways beyond school is still an issue, and that too few students are taking up technology-related careers or further study when they leave school. We found a number of papers that addressed this challenge. A lack of understanding of the many possible pathways that technology subjects open up is a clear theme across the diverse technology contexts addressed in these papers. Students, parents, teachers, school leaders and even careers advisers in some cases are named as groups who could benefit from a better understanding of the scope and potential of careers in technology-related areas.

Evidence from the literature

- TENZ and NZAATE (n.d.) consider that technology is an undervalued school subject. They see a need to raise students' awareness of possible STEM[20] pathways, including food technology, engineering, architecture, ICT development, and textile and fashion design.
- A recent news item ("Engineering Student Numbers Set to Rise", 2015) noted that the Government aims to increase the number of students enrolling in institutes of technology and polytechnics to become qualified to diploma or degree level. This is a response to the shortage of engineers graduating with a New Zealand Diploma in Engineering (Level 6) or Bachelor of Engineering Technology (Level 7). The goal of increasing the number of Level 5+ engineering students opens up opportunities for a wide range of technology students, not just those who aspire to be professional engineers.
- Thompson and Bell (2013) claim that computer science is often not well understood by students, career counsellors or school management. Ensuring management and students are better informed so that the right students take the subject can be a problem, but as courses

[20] Science, technology, engineering and mathematics.

develop a reputation, they attract good students, which is in turn more rewarding for teachers. Overall, the transitional period as the new digital technologies curriculum bedded in was found to be proving demanding for teachers, but many were already seeing the benefits of the new *Digital Technologies Guidelines*.

- Hallum Clarke (2015) also notes the importance of ensuring that parents, students, teachers and other people who advise students are made more aware of the many possibilities for careers in digital technologies.
- Bowskill (2012) describes the experiences of five students of technology who had all recently graduated from secondary school. Factors that influenced their choice to remain on technology pathways were: family background; the environmental context of their secondary school; financial considerations of both their families and their schools; students' abilities and aspirations; and the educational philosophy and priorities held by the school's management. However, the predominant factor that influenced the *outcomes* of their secondary education in technology was their family background.
- Bowskill also argues that traditional vocational technology education has been useful in engaging some students, building their confidence, fine motor skills and manual ability. He notes that some teachers were concerned with the move away from the practical trades training to a more academic focus, seeing this as disconnected from the needs of industry. However, he also says that "vocational education pathways and secondary school level ITO qualifications have gone some way to allay those fears" (p. 2). He notes that vocational technology education continues to have a trades training focus and is still popular with students who want to go into the trades. It is also popular with many technology teachers who are ex-trades people themselves. Bowskill discusses the role of ITOs as intermediaries between schools and industry. ITOs can influence learning through the teaching and assessment material they provide to schools, and these tend to focus on the development of students' knowledge and skills to achieve specific tasks.
- One recent study of tertiary study choices (Research First, 2014) reported that barriers to studying engineering occur early and are compounded as students move through their schooling. The researchers say that engineering is perceived "to consist only of the tradesperson or the professional, each of which is subject to off-putting stereotypes" (p. 10). Among those students who retained an interest in studying engineering at the tertiary level there was a clear preference for studying engineering at a university (p. 4). The researchers noted that STEM teachers—and career advisers in some cases—had little idea of the wide range of engineering careers. The broadness of the term 'engineering' was no help to dispelling these assumptions. Many of the students who had stayed with STEM subjects until the end of secondary school talked about how other career pathways were better defined.
- The Research First study identified some initiatives that encourage secondary students' interest in engineering. These included: 'Get a Life' careers month (run by Wintec, Connexis and WECA); Wintec's Trades Academy; Massey University's Engineering Your Future Camp; and the Futureintech Ambassador programme run by IPENZ and Callaghan Innovation (p. 24).

- A recent report summarised activities and observations since the release of *Vocational Pathways* in April 2013 (Ministry of Education, with Industry Training Federation, 2014). At the time the report was written there were five vocational pathways, covering: primary industries; construction and infrastructure; manufacturing and technology; social and community services; and services industries. A sixth pathway, for creative industries, was due to be launched in June 2014 (p. 1). Provisional NCEA Level 2 data for 2013 showed that around twice as many students would have achieved the qualification with at least one vocational pathway award than in 2012, with the number approximately doubling for each pathway. The estimated percentage of students rose from 20 percent in 2012 to 42 percent in 2013 (p. 2). While the results are early, they are regarded as being evidence that the vocational pathways are "driving more coherent approaches to assembling NCEA Level 2 qualifications that include the skills and competencies recommended for industries" (p. 3). Implications for supporting students on technology-related pathways include the need to develop a shared language and understanding between the Ministry and ITOs, and to clarify relationships between NCEA, the vocational pathways, and industry-owned credits and qualifications. Recommended future work included developing an online tool that allows teachers to link the standards from the *Vocational Pathways* booklets to career examples and skill application in lessons, curriculum mapping exemplars, and a "model school/provider/employer" exemplar (p. 5).

5. Assessment issues and challenges

This section collects together the papers we found that explicitly discussed matters related to assessment of learning. The tension between vocational and academic learning pathways is again evident. Here it is manifested as debate about the relative merits of using unit or achievement standards to assess learning in the senior secondary school. Before turning to that debate, the section begins with papers that discuss aspects of assessment related to teachers' pedagogy and students' learning experiences. The final part of the section outlines the advice the national technology advisers have recently provided to teachers across New Zealand.

What does progress look like?

As outlined in section 2, big changes were made to the structure of the Technology learning area in 2007, and in any case it was a totally new curriculum learning area in the previous decade. When teachers begin working with a restructured learning area they face an initial challenge of building their own pedagogical content knowledge about the nature of progress and what they can expect of students at different ages and with differing degrees of ability. Some papers noted this challenge of recognising what progress might look like. While this thread of discussion is about teaching and learning in technology in general, it has implications for NCEA, and two papers made specific reference to that.

Evidence from the literature

- Jones et al. (2013) define progression as something that requires students to deal with a greater number and more complex array of variables. It follows that teachers need to "collect and interpret multi-dimensional data" (p. 200) in order to document evidence of progression. They note that making sound judgements is currently difficult because of the newness of the subject. However, over time, as more evidence is collected about learning trajectories, teachers will be better equipped to understand likely progressions and hence develop appropriate tasks and learning intentions.
- Bowker (2011) noted that the uptake of new Level 1 achievement standards in digital technologies had been good.[21] However, implementation had been challenging. Teachers not only needed to "understand the nature, purpose and expected outcomes of the standards, but in many instances they have had to change their practice to ensure the standard of work now

[21] They were offered for the first time in 2011.

reflects level 6 of *The New Zealand Curriculum*".

- Bowskill (2012) notes that *NZC* does not describe grade-level indicators for manual skills and competencies in general technology education. He suggests that this might have "encouraged the over-emphasis of written, design work" (p. 112) in NCEA, which caused a reaction against general technology education by both students and teachers.
- In commentary based on research from 2002 and 2003, when NCEA Level 1 was being implemented across the whole curriculum for the first time, Blewett and Cowie (2007) note that implementation was particularly challenging for technology teachers, who came from a range of subject areas. They say that technology teachers expressed concern about the nature of evidence required for students to demonstrate a broader base of knowledge than previously, including knowledge of societal factors such as values, ethics and legislation.

We also found evidence that the challenge of supporting teachers to build their pedagogical content knowledge of progression has been proactively addressed via Ministry of Education-funded research and development work to produce support resources for teachers.

Evidence from the literature

- Compton and Compton (2010) conducted research with a specific focus on developing classroom-based understanding of progression in the Technological Knowledge and Nature of Technology strands of the Technology learning area. Diagrams of draft learning progressions were developed and trialled during this project. The draft progressions were published on Te Kete Ipurangi.
- The developers noted that the draft indicators had been based on the Technology achievement objectives rather than classroom practice. So, in a subsequent phase of the work, Compton and Compton (2013) explored the usefulness of the draft indicators as a guide for teacher decision making. They worked with 32 teachers in 22 schools (16 teachers from the secondary sector) to identify and describe teaching practices that successfully provided opportunity for students to progress. A revised draft of the indictors was published. The researchers note that student misconceptions about characteristics of technology were common across all age groups and tended to reflect typical public understanding about technology. Interestingly, students who held these misconceptions could still work successfully at Level 2 of the curriculum but could not work successfully at Level 3. Compton and Compton therefore suggest that these types of misconceptions only become a barrier when more complex ideas are being taught.
- Much of the commentary in the Compton and Compton (2013) work concerns students' understanding at lower curriculum levels. One finding with implications for lower secondary, if not the NCEA, years was that students have difficulty with the concept of 'human possibilities' in one of the Level 4 indicators. They also have difficulty 'illustrating' the role of creativity and critical thinking in supporting technological innovation because they could not identify what creativity and critical thinking in

technology might look like.

Involvement of students in assessment decision making

A widely cited policy paper, *Directions for Assessment in New Zealand (DANZ)* (Absalom, Flockton, Hattie, Hipkins, & Reid, 2009), made the case for involving students in making meaningful judgements about their progress and achievements. The term ‘assessment capability’ was introduced to signal that such involvement would build knowledge, skills and dispositions for ongoing (lifelong) learning. *DANZ* noted that teachers would also need to build their own assessment capabilities in order to support students to develop theirs. Having a clear understanding of what progression in learning looks like is one obvious facet of this challenge, and, as the above example shows, awareness of semantics in achievement terminology can be one facet of this.

The earlier RAMP reviews did not find any explicit discussion of this challenge in Science or in Mathematics & Statistics. We did find one paper that addressed the challenge for technology. We also found one paper that discussed the consequences of students’ decision making in relation to the course/assessment pathways they chose.

Evidence from the literature

- Snape (2011) addresses the involvement of students in making learning decisions, thus increasing their motivation and engagement. Formative assessment is identified as an important aspect to consider in best practice teaching and learning. Snape argues that evidence of learning will be more efficiently collected if the learning activities generate the evidence, and this includes evidence of engagement. He outlines aspects of good formative assessment, including the involvement of the student in judging achievement, deciding on what and how to gather evidence and formative dialogue.
- The Research First study introduced in section 4 (Research First, 2014) includes a discussion of student decision making that identifies a number of “leak points”. These are the points at which students take pathways that limit their ability to continue following an engineering pathway. They include not selecting maths or physics for NCEA subjects (p. 11) and misunderstanding the scope of technology as a subject for those interested in degree-level engineering courses.

NCEA and assessment options

The academic/vocational tension discussed in earlier sections was also a clear theme in papers that discussed which types of assessment standards (i.e. unit standards or achievement standards) provide the most appropriate means to assess students’ learning. While most papers support the availability of ITO unit standards, one paper sounds a cautionary note if these are the only option provided to assess technology learning.

Evidence from the literature

- Blewett and Cowie (2007) note that teachers in their 2002/03 study were concerned about a perceived loss of practical skill development for students. These teachers believed that the achievement standards would be "challenging for students because more academic knowledge and skills are required for success" (p. 178). However, some of the teachers also struggled with the concept of *generic* technology unit standards rather than specific assessments in different subjects, as in the past. Collaboration among technology teachers was considered to be one of the most effective strategies for increasing their confidence and developing new knowledge and skills, and all the studied teachers valued ongoing professional discussion and moderation when marking NCEA assessments.
- Bowskill (2012) discusses the results of the review of assessment standards during the alignment project that began in 2010, noting that the generic unit standards had been, or were about to be, phased out. Those unit standards owned by ITOs, and delivered in schools in partnership with the ITOs, were to be retained. The generic unit standards were replaced with a broader suite of achievement standards, updated and brought into alignment with the achievement objectives described in the Technology learning area. Bowskill expresses concern about the "risk in the Ministry's vision and drive towards academic general technology that teachers and students who want a solely vocational pathway into trade's apprenticeships will feel marginalised and undervalued" (p. 2).
- The four teachers in one small study (Williams & Gumbo, 2011) also expressed concern that technology achievement standards were too theoretical for the type of students attracted to the subject. Some teachers offered a mix of both types of standards. One teacher said there was an expectation from industry that standards above Level 2 must be offered in an industrial context. For this teacher this constituted a reason for offering unit standards, since so few suitable achievement standards would be available for Year 13 students. Williams and Gumbo also note that these teachers tended to assess products (projects, portfolios) rather than use written tests.
- From a different perspective, the Research First study (2014) notes that using unit standards for assessment makes a class unattractive for students who aspire to attend university. Unit standards lower a student's Grade Point Average (GPA) by precluding the possibility of merit and excellence achievement. However, they also note that technology teachers believe their less-academic students are not capable of some of the advanced concepts covered in the class, simply because they may not have the maths or English skills to complete the work.

Enacting assessment using achievement standards

Some of the challenges entailed in NCEA assessment of technology learning can be inferred from advice to technology teachers provided by advisers from the University of Auckland and Te Tapuae o Rehua consortium (2014). In a newsletter for technology teachers, they brought the following points to teachers' attention.

- NZQA exemplars for internally assessed standards are extracts from student evidence and do not represent all the evidence that any one student submitted for a particular standard.
- Some teachers are still using the assessment resources from Te Kete Ipurangi without any modification. Assessment tasks and schedules should be modified to make the context relevant and authentic.
- For some of the specialist skills and knowledge standards it is acceptable to use a hypothetical scenario. However, if using the technological practice standards, students should create solutions for real needs and opportunities rather than for made-up scenarios.
- Teachers should get into the habit of checking NZQA's clarification documents at the start of each year, as they are likely to be updated at that time. They should be checked more often if necessary.
- The external moderation process is about the moderator understanding how a teacher made a judgement; it is not about the moderator marking the student work. Teachers should annotate their assessment schedule and/or provide accompanying notes that help explain to a moderator how they made a particular judgement.

The PowerPoint developed for use by the technology advisers (Pym et al., 2015) adds an additional clear message about the desirability of using naturally occurring evidence, where possible, particularly if this evidence can be captured in modes that do not rely on extended written text.

6. Supporting technology teachers

A clear theme in the research literature is the *complexity* of the curriculum and the assessment thinking now being asked of teachers. The challenges they experience imply a need for ongoing professional learning and support. While the predominant focus of the science review (Hipkins & Joyce, 2015) was on pedagogical support as teachers try out new ideas and make changes to their practice, the mathematics commentary that we found is directed more at teachers' own knowledge and strength of background in the discipline area. As we will outline shortly, both these themes are also evident in the Technology learning area. Interestingly, the political nature of curriculum making was more in evidence than in either of the previous reviews. We begin by outlining the tenor of this commentary in two papers that explicitly locate the need for curriculum support in a broader socio-political context.

Evidence from the literature

- Jones et al. (2013) note emerging evidence that the gains made in technology education in the 1990s may have been lost. They note that being able to build on experiences from other learning areas is a strength of technology, but that this potential for integration also creates fragility in terms of technology's status as a subject. As one response to these challenges, Jones et al. argue for greater support for teacher preparation and professional learning, along with the establishment of professional bodies to support teachers. Echoing the paradigm tensions in evidence throughout this review, they also call for critical attention to be directed to the "socio-political environment of schooling" (p. 192).
- In their international review, Banks and Williams (2013) note that there is often an increased focus on technology education when there is an economic downturn. However, different stakeholders tend to have different rationales for technology education. They identify a number of factors that can work against technology education in some countries, including a shortage of teachers, the lack of a cohesive approach to the subject, and changes to science education in response to STEM challenges.

A number of papers provided a discussion of the need for greater support that was grounded in the day-to-day realities of technology teaching and learning.

Evidence from the literature

- One researcher catalogued a long list of challenges that imply support needs for teachers of senior technology (Almutairi, 2009). These include a need for more resources, including funds; mentoring for both beginning and more experienced teachers; regular meetings for technology teachers; and more professional development, especially in relation to the nature of technology as a new curriculum concept.

- In the area of biotechnology, France and Bolstad (2004) note a need for resources that are relevant to New Zealand, address both technology and science, and model teaching programmes in a variety of curriculum areas. These resources need to enable teachers and students to develop an understanding of the nature of science and technology; enable students to understand the reasons for technological development; and tell stories about people involved in biotechnology. France and Bolstad argue for a virtual resource that can provide examples of biotechnological practice, and access to and communication with biotechnologists.[22]
- France and Bolstad (2004) also note a need for professional development with a focus on the nature of science and technology, pedagogical practices for managing socio-political discussions, and planning for integration across subjects relevant to technology.
- In two papers McGlashan (2010, 2014) argues the case that when technology teachers first encounter design processing they are not well equipped to model ways in which designers actually work, or to support students to develop tacit knowledge through their own creative practice. (In the 2010 paper she described the non-linear, task-specific ways in which three designers actually worked). Her preferred solution is to keep design and visual communication as a separate subject (see section 2). However, the challenge she identifies could also be seen as one target for professional learning that immerses technology teachers in authentic practice.
- Ferguson (n.d.) notes the limited professional development opportunities for both pre- and in-service teachers, with implications for specialised teacher supply in intermediate and secondary schools (p. 50). He suggests developing partnerships with business, industry and tertiary sectors as one way to provide support for schools and teachers.

Pre-service teacher education

The Research Division, Ministry of Education (2014) recently noted that teaching positions across the range of technology subjects made up the greatest proportion of vacancies in secondary schools. Technology made up 19.6 percent of all vacancies at the beginning of the 2014 school year, an increase from 13.3 percent in 2013. Half of these vacancies were in hard materials (e.g. woodwork and metalwork), and relatively few were in computer technology. One implication that could be drawn from data such as these is that more effort needs to be made to educate beginning teachers for technology positions. Ferguson (n.d.) makes this point explicitly.

[22] This paper arguably anticipated the Biotechnology Learning Hub: http:// www.biotechlearn.org.nz

In their MBIE briefing paper introduced in section 2, TENZ and NZAATE (n.d.) also note the need for pre-service training to be investigated. We found just one paper that explicitly addressed this challenge.

Evidence from the literature

- McGlashan and Wells (2011) outline the findings of a longitudinal study of the effectiveness of the one-year Graduate Diploma of Teaching (secondary) pre-service training of teachers of technology. They note that the programme values the pre-service students' prior learning, career experience, skills and understanding and uses these to benchmark further learning. There is a focus on building a learning community that is supportive, open to discussion and flexible. The programme models best classroom practice in workshop and design environments to encourage a creative approach to problem solving. Opportunities are provided for peer and individual assessment of assignment work to model and give feedback on assessment practice and encourage reflection-in-action. Past students come to meetings arranged to maintain their support network and unofficial dialogue once they are classroom teachers. Feedback from graduated students indicates that many are disappointed by the realities of working in schools. Some experienced outdated programmes, with a lack of interest in learning from the students. Very few of them felt able to contribute to planning a holistic, student-centred approach such as they had experienced in their pre-service course. The researchers note that "school programmes tend to reflect school-wide, departmental or individual teacher interests, levels of understanding and expertise, but with little evidence of coherence across school communities nationwide" (p. 2).

7. Some concluding observations

When carrying out this literature review we found a comparatively large number of papers that explore the subject of technology education within a strong philosophical, holistic framing. This is in contrast to science and mathematics, where there were fewer philosophical papers. In those learning areas many papers had a narrower framing, with a focus on examining a particular issue or challenge relevant to the learning area. We wonder if this is because of the relative newness of the Technology learning area, and because technology is still in the space of establishing its identity and purpose. We found a lot of commentary about initial debates and concerns raised prior to, and immediately after, the introduction of *NZC*. There has been less of this sort of commentary more recently, although the issues raised still appear to be unresolved.

One clear message is that teachers' beliefs about the purpose for learning technology are fundamental to their pedagogy. However, while there is commentary about pockets of innovative practice, we did not find many papers that address the extent to which the intentions of the Technology learning area in *NZC* have become more widely embedded in practice over time, and to what extent the shift in teachers' attitudes and pedagogy implied in the earlier literature has actually been achieved. The academic/vocational divide, for example, continues to dominate pedagogical debates in one form or another (e.g. there is a predominance of commentary about 'pathways' for different students). However, we have a less clear picture of the extent to which the paradigm tension has been resolved by practitioners, although some resolutions that attend to both vocational and academic needs are suggested by researchers.

It is possible that the overall mix of papers we found is partly skewed by publication opportunities. For example, the very existence of the journal *The New Zealand Science Teacher* gave us access to a range of articles grounded in classroom practice and written for a teacher audience. These articles enriched the RAMP Science review and provided a counter-balance to the more academic journals. By contrast, most of the articles in this current review come from more academic journals or from broadsheet sources such as *T-News*. The middle ground between these poles could be a space of opportunity.

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Appendix

Methodology for searching and constructing the Endnote file

To support the Review and Maintenance Programme (RAMP) for the Technology learning area, we undertook to gather evidence about current curriculum content, pedagogical and assessment practices and student achievement in the context of the learning area in *The New Zealand Curriculum* (*NZC*) and NCEA at Levels 6–8. We used the literature we found to build an Endnote file that provides summaries of the research papers, plus commentaries, and other relevant documents we found.

Search parameters

We gave priority to papers published since around 2010 (when the *NZC*/NCEA alignment was being undertaken) unless we judged a piece of work completed before then to be substantive and relevant to matters raised in the more recent papers. We mainly focused on New Zealand-based publications with an explicit focus on NCEA and/or *NZC* and learning technology in the senior secondary school years. However, seminal international research and summaries were included where they addressed significant gaps, had something of real interest to say in terms of the review questions, or represented significant meta-analyses of a large body of relevant international research.

We began our search with a range of sources that included Google Scholar, the New Zealand Educational Theses Database, the New Zealand Council for Educational Research's research papers, Ministry of Education research reports, various journals for technology researchers and teachers, and Technology Online. Where we were aware of interesting in-progress or unpublished research, particularly in schools, we contacted researchers, educators and/or teachers directly to check for papers written or presentations given.

Search terms and keywords for the Endnote file

As well as using key search terms to locate papers, we needed to build a typology of key words to enter into the Endnote file so that it can function as a searchable data base. First-tier search terms were derived from the description of the overall RAMP review. Some second-tier search terms were added to cover issues we predicted might arise, based on our understanding of the future-focused literature, and from our knowledge of NZCER's ongoing programme of research on *NZC* and NCEA. (Note that the keywords are not case-sensitive.)

1. *NZC* alignment:

- PLD
- Curriculum integration
- Dispositions (motivation, engagement, agency)
- Digital Technologies Guidelines
- Body of knowledge
- Computer sciences
- Electronics
- Food technology
- Biotechnology
- Graphics and design

2. Innovative programmes:

- Non-traditional outcomes (Nature of Science, action competence, inquiry competencies, literacies, creative design, etc.)
- Future focused
- Technology (online teaching)

3. NCEA:

- Assessment
- Online assessment

4. Priority learners:

- Māori, Pasifika, special learning needs
- Equity
- Diversity

5. Pathways:

- Vocational
- STEM

Three other keywords further categorise collected sources as:

- Research;
- Evaluation; or
- Commentary.

For each entry a short summary of the research, evaluation or commentary was entered in the Notes section. The summaries focus on areas of interest for the RAMP review, so they do not necessarily include all of the findings or recommendations from a particular piece of work.