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STEM Education in New Zealand at the Senior Secondary Level: Cross-Curricula Course Design and Assessment for NCEA

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Abstract

This paper considers the design and assessment of Integrative-STEM courses at senior secondary level in New Zealand. Integrative-STEM education places emphasis on students drawing together knowledge from science, technology, engineering and mathematics, in order to solve design problems. The paper identifies important elements of an integrative-STEM course and whether the current range of NCEA achievement standards provides a suitable fit for assessing students' STEM learning. The conclusion reached is that a partial fit exists at Levels 2 and 3 of NCEA but a stronger fit exists at Level 1. For comparative purposes, the paper also considers how well the design of NCEA social science achievement standards harmonise with cross-curricula course design. The interpretation is suggested that the subject-by-subject development of NCEA standards provides significant limitations on the validity of assessment of cross-curricula learning. Some of the important learning engendered by cross-curricula design lies outside the assessment covered by NCEA standards.

Keywords: STEM education, course design, senior assessment, cross-curricula learning, integration, interaction.

Introduction

This paper builds on previous work (Granshaw, 2016) that discussed the nature of STEM education (see below) and how it might fit within the structure of the New Zealand Curriculum (Ministry of Education, 2007). It extends this earlier work with the main objective of evaluating the current range of Technology assessment standards within the National Certificate of Educational Achievement (NCEA) to judge their potential fit for NCEA-related STEM courses that are integrative in design. In addition, the paper identifies some STEM education considerations relating to course design and assessment involving the notion of cross-curricula integration.

The term STEM (science, technology, engineering, and mathematics) education describes a group of key subjects that are considered to be important if a nation is to compete in a global economic and scientific world (Granshaw, 2016). The notion of *integrative-STEM* education is based on an integration or interaction (Williams, 2011) of subject content knowledge where emphasis is placed on students drawing together knowledge from science, engineering, technology and mathematics, in order to solve design problems. Solutions to these problems may take many forms including conceptual (modelled) or practical scientific/technological outcomes. This paper particularly focuses on STEM courses that have technology as the principal subject with science, engineering and mathematics acting as contributing subjects.

The idea of integrated (cross-curricula) education is common in primary and intermediate schools in New Zealand where learning experiences are frequently drawn from multiple curriculum areas. According to Furner and Kumar (2007), "Research indicates that using an interdisciplinary or integrated curriculum provides opportunities for more relevant, less fragmented, and more stimulating experiences for learners" (p. 186). Other research suggests that it improves higher level thinking skills and problem solving, fosters retention of learning, and tends to be student-centred (Fillis & Fouts, 2001; King & Wiseman, 2001; Smith & Karr-Kidwell, 2000). However, an integrated curriculum is less common in New Zealand secondary schools where generally a silo (subject-specific) approach to curriculum delivery is the norm.

Although this paper acknowledges the existence of integrative practices (some of which involve STEM subjects) in intermediate or middle schools, its main focus is on the relationship of assessment to STEM course design in the senior secondary context. The paper includes an analysis of the Technology achievement standards currently available to students for NCEA. The aim is to see how well these standards fit with an integrated-STEM course design; a corollary of this aim is to suggest changes that might be made to increase the content validity of the current standards to improve their fit with an integrative-STEM education design.

While the principal focus of this paper is on Technology achievement standards, the study includes an inspection of NCEA standards in Mathematics and Science to ascertain potential assessment opportunities for an integrated-STEM course. As will be seen later, this particular analysis suggests that little exists in the way of opportunities in Mathematics and Science that provide an integrative approach to assessment across the different STEM subjects. Hence primary attention is given here to the current range of Technology standards.

A brief description of the generic Technology standards for Levels 1 and 2 of NCEA is given later in Tables 1 and 2. For the moment, the main contextual point to note is that these standards are aligned with the three strands of the Technology learning area of the New Zealand Curriculum (2007). These strands comprise:

- Technological Practice
- Technological Knowledge
- The Nature of Technology

The first of these strands incorporates, but extends learning beyond, the content of traditional craft and practical subjects (e.g., woodwork, metalwork, cooking, etc.). Students develop briefs for projects that address a need, opportunity or problem; they gain knowledge and skills in the use of planning tools to guide the design and development of a problem solution; and they produce one or more of a conceptual design (e.g., a model), a prototype (artefact), or a system that represents a problem solution. The second strand (technological knowledge) focuses learning on how and why particular technological developments work and includes the goal of building students' understanding of materials and their uses. The third strand focuses on providing students with a contextual understanding of the place of technology in society, including how technology developments impact on the social and physical environments of people (e.g., change people's lives).

Design of Integrative-STEM courses: Preliminary considerations

As noted above, this paper highlights some important considerations related to course design and assessment in relation to STEM education. Some points are mentioned now because they will assist readers' later understanding of the complexities inherent in designing an integrated-STEM course and undertaking assessment within the current range of achievement standards in Technology, Science and Mathematics. Four points are made here:

- Integrative-STEM education should not be seen as a new stand-alone curriculum;
- Integrative-STEM education generally involves co-operative course design, teaching and assessment from teachers in the different contributing subject areas;

- The notion of integrative-STEM education embodies ideas that also apply more generally to cross-curricula course design; and
- Integrative-STEM education has the capacity to expand and deepen students' understanding of concepts and processes in the individual contributing STEM subjects.

These points are now briefly explained.

Integrative-STEM education is not an argument for a new stand-alone curriculum

It is not the intention of this paper to suggest that STEM education should be seen as a new stand-alone curriculum area. Various writers draw attention to the concern that Technology as a learning area should not be subsumed by other curricula areas. For example, Williams (2011) argued that Technology should not be seen simply as a means to enhance science and mathematics – it has a purpose, distinctive content, and pedagogical features that give it the status of a discipline in its own right. Compton (2009) challenged the notion of curriculum integration, preferring instead the concept of "curriculum collaboration" as this better captures the importance of different curriculum areas maintaining their own identity. Other perspectives have been identified in a thematic literature review conducted by Joyce and Hipkins (2015); the conclusion reached by these writers is that the wide-ranging curriculum cross-overs possible with Technology (from other STEM subjects, arts and social sciences) "can make the boundaries of what counts as technology—or, indeed, of the other subject(s) with which it is combined—somewhat 'fuzzy'" (p. 7). However, despite this fuzziness between curriculum boundaries, it is unrealistic to expect individual teachers to have comprehensive expertise in the range of subject content knowledge covered by science, mathematics or other curriculum fields that might be combined with technology.

Notwithstanding the argument by Compton that the concept of curriculum collaboration might be more appropriate than curriculum integration, the writers here will continue to use the concept of integrative-STEM education. This is because the focus is not on merging whole curriculum areas but on designing individual courses that are intended to build cross-curricula learning connections. Students are expected to demonstrate from such courses that they have drawn together knowledge and skills from all contributing subjects. Such integration aligns with the higher level skills advanced in the front end of the *New Zealand Curriculum* (Ministry of Education, 2007); these skills are often espoused as being central to the educational goal of life-long learning. Hall (2016) included the skills of critical analysis, synthesis, transfer, problem solving, creativity, co-operative learning, and metacognition as examples of what should be the focus of education for life-long learning.

Integrative-STEM education departs from a more traditional view of STEM education, which has simply meant learning in the four separate and distinct fields of science, technology, engineering and mathematics. Integrative-STEM education explores course design, teaching, learning and assessment across any two or more of the STEM subject areas (Sanders, 2006; Sanders & Wells, 2005). For example, it is not uncommon for technology students to use mathematics or consider certain scientific principles when undertaking technological practice, but it is not usually the case that the technological learning context or task is intended to teach in isolation a specific science or mathematics concept or process. With this in mind, support exists here for the notion of "purposeful design and enquiry" (Sanders, 2009, p. 21) as an effective approach to the design of integrative-STEM education, including the research and teaching practice that underpins such design.

Integrative-STEM education involves co-operation between teachers

Integrative-STEM education requires resources including materials, tools, machinery, digital technology, and scientific facilities, as well as teacher expertise, in order for students to engage with authentic real world design problems and processes. Whilst the former are commonly found in schools, especially secondary schools, the latter (teacher expertise) can be problematic. As mentioned, it is unrealistic to expect individual teachers to engage with this breadth of subject content knowledge at a secondary level. As noted by Granshaw (2016), an integrative-STEM course is likely to involve co-operative design and teaching from two or more teachers in order to span the range of content and skills being addressed; contributing teachers need to buy-in to the purpose and rationale of the course. Co-operative teaching practices are also important for helping teachers new to cross-curricular design to develop a sense of self-efficacy for undertaking the design and teaching involved. In short, because integrative-STEM education draws upon the connections between subjects, it will usually involve multiple classes, facilities and teachers.

Integrative-STEM education embodies ideas that apply more generally to cross-curricula learning

There are many examples of "integrated units of work" available to teachers and students (see TKI's *Technology Online* website), and a wealth of literature exists around the effectiveness of curriculum integration. *The New Zealand Curriculum* (Ministry of Education, 2007) includes the statement that future focussed issues provide "a rich source of learning opportunities that encourage the making of connections across the learning areas" (p. 39). Whilst this paper focuses mainly on the integration or interaction of content and skills from two or more STEM subjects, opportunities exist for students to make connections in their learning from other combinations of subjects. As noted by Hall (2016), "It is of interest that the International Baccalaureate Diploma (IBD) includes as a philosophical position on education and learning that students should understand connections between the knowledge and skills that exist within and between disciplinary fields" (p. 2).

Integrative-STEM education has the capacity to deepen students' understanding of learning in the individual STEM subjects

An integrative STEM programme has the potential to provide opportunity for students to engage in more complex design solutions and scientific/technological processes than might be the case if their study was confined to Technology, Science or Mathematics alone. Students are typically encouraged to explore and integrate knowledge from STEM subjects in a practical sense, drawing upon knowledge from a range of curriculum specialists (teachers and other stakeholders) in order to resolve their design challenges. Consequently, the scope of a student's scientific, technological or mathematical knowledge may be expanded and/or deepened as they undertake design projects that give meaning to concepts and processes in a way that is not exemplified in subject specific learning.

Course design: Important elements of an integrated-STEM course

This section briefly describes some course design features that an integrated-STEM course should address: the purpose is to make clear to readers some of the course design thinking and decisions that are part of the STEM education context.

As noted by Hall (2013), while course design can follow different routes and employ different models, certain elements are normally addressed. These elements were summarised by Granshaw (2016) as including:

> A clear statement of the purpose/rationale of the course; a specification of the learning objectives that students should demonstrate or achieve; a statement (or mapping) of the course content and sequence; an articulation of the teaching-learning processes (pedagogy) that will be used; a content valid and manageable assessment framework (including formative feedback); and strategies for ongoing and end-point course evaluation. (p.6)

An indicative course title might be: *Technology with Mathematics and Science—Developing Design Solutions.* The intention here is that a STEM course should involve students developing design solutions by drawing upon and integrating Technology, Mathematics and Science subject knowledge and skills. The indicative course title identifies Technology as the principal subject with contributing content and skills coming from Mathematics and Science. The course could be adapted to either students who intend to proceed to university or students who are following a vocational pathway.

Although the course has an applied focus, it still requires students to consider theory and display understanding of the properties of materials being used. Students will need to develop the skills associated with the tools/equipment/digital applications that are relevant for creating a solution. Students will also be expected to demonstrate understanding of research and enquiry processes generally associated with problem-solving and systematic investigation.

The intention is that design problems will require solutions involving:

- A technological/engineering outcome that represents a “transformation of materials, energy and information” (see Compton, 2010), such as an artefact, a digital application, a system process, or an architectural environment; and
- A conceptual design such as a model that is, for example, digital, oral, graphical or material based.

Examples of contexts where such design problems may be located could be architectural, biological, chemical, digital, electrical, environmental, marine, mechanical, or structural in nature.

The following learning objectives are indicative of the direction that student learning might take.

> Students will demonstrate the ability to:
>
> - Plan and develop solutions to design problems in an integrated-STEM context;
> - Integrate learning from a combination of knowledge bases (i.e. technology, mathematics, engineering and science); and
> - Reflect critically upon how the integration of knowledge from the STEM subjects has guided the design and development process.

The examples of learning objectives above are broadly stated but, as the course unfolds, can be translated into more specific learning objectives to further clarify for students what is expected of them.

In relation to assessment, for each project task undertaken, the teacher or teaching team will need to provide students with a clear context and provide guidance and support to students who develop their own brief. In addition, teachers will need to set any additional assessment tasks that relate to important course content that is not covered by the project task.

For the design and development project, one approach is to require students to submit a portfolio setting out descriptions, analyses and formulations relating to the selection, research, design, and development of the project outcome. If the development is a group project, consideration will need to be given to the method by which each student’s contribution to the work is assessed. In addition, the work should be conducted in stages with reporting from students at specified milestone dates. It is essential that students’ progress is periodically supervised and monitored for both formative and summative assessment purposes.

In relation to the integrative-STEM component of the project, the assessment focus should include evidence that students have integrated (drawn together in an appropriate way), the knowledge and skills from all contributing subjects. A direct assessment by teachers of the important integrative links made by a student is an obvious inclusion. Students could also be required to include in their portfolio a reflective statement of how the different knowledge areas have been drawn together.

For NCEA assessment purposes, students' work will need to be assessed against an appropriate selection of assessment standards (Achievement and/or Unit Standards, the latter being relevant for vocationally oriented projects). This step may be problematic if current standards in Technology (or in Mathematics and Science) are not well suited for students undertaking a cross-curricula project of the kind described here (see next section). However, in as far as suitable assessment standards exist in the contributing subjects for an integrated-STEM course, these should be used to determine students' achievement and formally to record their grades.

Availability of achievement standards suitable for assessing students undertaking an integrated-STEM course

Current NCEA Achievement Standards in Technology

Currently there are 121 Technology achievement standards listed under the NCEA Technology Matrix. There are 42 standards each at Levels 1 and 2, and 37 standards at Level 3. The Matrix separates standards into Technology Generic and Specialist Categories of Technological Knowledge and Skills. The latter comprises standards related to Construction and Mechanical Technologies; Design and Visual Communication; Digital Technologies; and Processing Technologies.

Procedure

The analysis was conducted on three areas discussed below.

1. An examination of the wording of each Technology standard at all three levels to identify specific references that indicate whether a standard has been designed (whether intended or not) with a cross-curricula application possible. In addition, analysis has included inspection of on-line resources that are mentioned in the explanatory notes to specific standards to see whether these provide illustrations or specific evidence that support assessment for an integrated-STEM course.
2. An examination of the wording of each Mathematics (Levels 1-3), Biology (Levels 2-3), Chemistry (Levels 2-3) and Physics (Levels 2-3) standards to identify specific references that support a possible cross-curricula application.
3. For comparative purposes, an inspection was also undertaken of the titles of achievement standards in four non-STEM Social Science subjects for indications of possible cross-curricula assessment. The subjects chosen were Geography, Media Studies, Psychology, and Economics. There was no particular reason for choosing these subjects other than the writers were aware that potential exists in all of them to cross subject boundaries with other subjects. Because of the scope of the work involved, only standards suggestive of a cross-curricula link were read in full. The inspection of standard titles was made to obtain a general feeling for the extent of recognition of cross-curricula learning more generally within NCEA.

It should be noted that all NCEA standards and supporting documents are available to be accessed publicly on-line through the NZQA website. This enables readers, if they wish, to verify the data that the researchers have drawn upon.

Findings

The overwhelming conclusion reached by the writers in relation to the Social Science subjects chosen for inspection, is that NCEA provides little or no explicit opportunities for assessing cross-curricula learning. Standards are largely written to match important content and skills (processes) that are subject specific. If a cross-curricula course is established, the assessment for NCEA generally requires the selection of standards from the contributing subjects which, in only a limited way, address integrative learning from the chosen subjects. Having said that, it is clear that some subjects (e.g., Geography, Psychology and Economics) all provide research-type achievement standards that incorporate material that is also taught in statistics; they also involve elements of systematic research design, such as surveying people and use of questionnaires that are commonplace in social science research. However, specific references to cross-curricula design in the wording of standards and associated explanatory notes are absent.

However, scope is available for covering some (Levels 2 and 3) or much (Level 1) of the assessment that is needed for a STEM course of the kind described in the previous section. This arises mainly from the Technological Practice strand and one Level 1 standard related to the Technological Knowledge strand; the latter specifically addresses the need for students to demonstrate understanding of how different disciplines influence a technological development (see Table 1, Standard 1.8). There are no equivalent standards of the latter kind at Levels 2 and 3. Scattered across the full Technology Matrix are standards that, depending on the specifics of a course, might contribute to the assessment for an integrated-STEM course, but these focus on specific elements of the technological development (e.g., understanding of the materials being used) not on the particular role of the contributing STEM subjects in enabling the development to take place.

Tables 1 and 2 help illustrate the potential suitability of the Generic Technology standards for enabling cross-curricula STEM education. These Tables set out the titles for NCEA Levels 1 and 2 standards. Titles are organised in line with the three strands of the Technology curriculum: Technological Practice; Technological Knowledge; and Nature of Technology. The shadings within the tables represent standards that have potential application for an integrated-STEM course. A table for level 3 NCEA is not presented because, apart from the Technological Practice strand, there are no standards that have an obvious relevance.

Table 1. Level 1 NCEA Generic Achievement Standards

Curriculum Strand		
Technological Practice	Technological Knowledge	Nature of Technology
1.1 AS 91044 Internal 4 credits Undertake brief development to address a need or opportunity	1.5 AS 91048 External 4 credits Demonstrate understanding of how technological modelling supports decision-making	1.9 AS 91052 Internal 4 credits Demonstrate understanding of the ways a technological outcome, people, and social and physical environments interact
1.2 AS 91045 Internal 4 credits Use planning tools to guide the technological development of an outcome to address a brief	1.6 AS 91049 External 4 credits Demonstrate understanding of how materials enable technological products to function	1.10 AS 91053 External 3 credits Demonstrate understanding of design elements.
1.3 AS 91046 Internal 6 credits Use design ideas to produce a conceptual design for an outcome to address a brief	1.7 AS 91050 External 4 credits Demonstrate understanding of the role of subsystems in technological systems	1.11 AS 91054 Internal 4 credits Demonstrate understanding of basic human factors in design
1.4 AS 91047 Internal 6 credits Undertake development to make a prototype to address a brief	1.8 AS 91051 Internal 4 credits Demonstrate understanding of how different disciplines influence a technological development	1.12 AS 91055 Internal 4 credits Demonstrate understanding of basic concepts used in manufacturing
		1.13 AS 91056 Internal 4 credits Implement a multi-unit manufacturing process

As Tables 1 and 2 illustrate, the standards related to Technological Practice provide scope for developing a technological outcome or model that could involve significant inclusions from mathematics, science and engineering. However, it is evident that information is absent in the explanatory notes to standards, and largely so in resources available on-line, that specifically recognise that these standards are suitable for STEM cross-curricula learning. The argument could be made that technology developments, by their nature, are likely to involve some form of cross-curricula learning. However, given that the *New Zealand Curriculum* encourages cross-curricula learning, it is surprising that explicit recognition of this is not provided within these standards.

In relation to Tables 1 and 2, three additional Technology standards have been shaded because of their potential for use in an integrated-STEM course context. Two of these standards relate to

Level 1 and one standard to Level 2. No achievement standards at NCEA level 3 were identified as being relevant. Information related to the three standards is provided below.

Table 2. Level 2 NCEA Generic Achievement Standards

Curriculum Strand		
Technological Practice	**Technological Knowledge**	**Nature of Technology**
2.1 AS 91354 Internal 4 credits Undertake brief development to address an issue	2.5 AS 91358 External 4 credits Demonstrate understanding of how technological modelling supports risk management	2.9 AS 91362 Internal 4 credits Demonstrate understanding of the nature of technological outcomes
2.2 AS 91355 Internal 4 credits Select and use planning tools to manage the development of an outcome	2.6 AS 91359 External 4 credits Demonstrate understanding of the role of material evaluation in product development	2.10 AS 91363 External 4 credits Demonstrate understanding of sustainability in design.
2.3 AS 91356 Internal 6 credits Develop a conceptual design for an outcome	2.7 AS 91360 External 4 credits Demonstrate understanding of redundancy and reliability in technological systems	2.11 AS 91364 Internal 4 credits Demonstrate understanding of advanced concepts related to human factors in design
2.4 AS 91357 Internal 6 credits Undertake effective development to make and trial a prototype	2.8 AS 91361 Internal 4 credits Demonstrate understanding of sociocultural factors, and how competing priorities are managed, in technology	2.12 AS 91365 Internal 4 credits Demonstrate understanding of advanced concepts used in manufacturing
		2.13 AS 91366 Internal 6 credits Undertake development and implementation of an effective manufacturing process

NCEA Level 1 Generic Technology:

AS91051 (Standard 1.8, 4 credits, internally assessed): Demonstrate understanding of how different disciplines influence a technological development.

Overview:

> This standard requires students to identify the knowledge and practices drawn from different disciplines associated with a technological development. While students could focus on an outcome that they have developed themselves, it would generally be necessary for the understandings required for this standard to come from beyond their own practice. (NZQA, 2017)

Explanatory Note 4 describes possible disciplines as including, but not limited to … "technology, psychology, mathematics, management, law, science, social science, the arts, architecture and ethics."

Although the overview statement gives emphasis to students' understanding coming from learning "beyond their own practice," the writers believe that such a standard provides scope for "experiential learning" by its inclusion in the assessment of the project development component of an integrated-STEM course. This could be done by a direct assessment by teachers of the important integrative links made by students along with the inclusion of a reflective statement by students of how the different knowledge areas have been drawn together. Unfortunately, as already mentioned, there are no equivalent discipline-integrative standards at Levels 2 and 3 to complement the standards in the Technological Practice strand.

The other two standards of interest are:

- *AS91052* (Level 1, Standard 1.9, 4 credits, internally assessed): Demonstrate understanding of the ways a technological outcome, people, and social and physical environments interact; and
- *AS91361* (Level 2, Standard 2.8, 4 credits, internally assessed): Demonstrate understanding of sociocultural factors, and how competing priorities are managed, in technology.

While these standards are integrative in nature, and in some circumstances could involve cross-curricula learning, the main purpose of these is directed to students' understanding of other forms of influence on a technological development (social and physical environments and the impact of socio-cultural factors).

As noted earlier, the analysis has operated from the basis that the course under consideration has the hypothetical title: *Technology with Mathematics and Science—Developing Design Solutions*. The question arises as to whether similar scope for cross-curricula assessment occurs if either Mathematics or Science were the principal subject (*e.g., Science with Mathematics and Technology—Developing Design Solutions*). Unfortunately, if an analysis is made of the current achievement standards in Mathematics and Science, there appears to be no equivalent practice strand, or combination of standards, for developing an integrated-STEM course where mathematics or science are the primary subject in the STEM combination. The following standards within Chemistry, Physics and Biology hint at the possibility of relevance for an integrated-STEM approach to learning, but would need further revision and development to be more obviously relevant.

Biology, Level 3, AS 91602: Integrate biological knowledge to develop an informed response to a socio-scientific issue. (3 credits)

Chemistry, Level 2, AS 91163: Demonstrate understanding of the chemistry used in the development of a current technology. (3 credits)

Chemistry, Level 3, AS 91389: Demonstrate understanding of chemical processes in the world around us. (3 credits)

Physics, Level 2, AS 91169: Demonstrate understanding of physics relevant to a selected context. (3 credits)

Physics, Level 3, AS 91522: Demonstrate understanding of the application of physics to a selected context. (3 credits)

Of the standards listed above, it is clear that the Chemistry standard (Level 2, AS91163) comes closest to meeting an integrated-STEM course development, but on its own is not sufficient in scope or credit value (it is only 3 credits) for meeting the kind of course and learning that is the focus of this paper.

Discussion

The principal focus of this paper has been on cross-curricula course design and assessment in relation to integrative-STEM education at the senior secondary level in New Zealand. For comparative purposes, four subjects within the social sciences were also studied. The two dominant national educational provisions related to curricula at this level are the requirements and opportunities provided to schools and students by the *New Zealand Curriculum* (Ministry of Education, 2007) and the assessment framework of achievement and unit standards available within NCEA. From the analysis of various curriculum and assessment documents consulted by the writers, several general conclusions have been reached relating to cross-curricula course design and assessment.

- The *New Zealand Curriculum* provides support for the development of cross-curricula courses in its front-end description both as a way of preparing students for life-long education (e.g., developing skills such as problem solving, critical thinking, synthesis, transfer, and metacognition) and as a means of widening students' understanding of the value and importance of making connections from different areas of their study.

- In contrast, the cross-curricula assessment opportunities provided by NCEA to date appear to lag behind the encouragement and intent of the *New Zealand Curriculum*. While the present analysis has focused largely on integrative-STEM education, the writers have been struck—albeit from less thorough excursions into opportunities available from non-STEM subjects—by the limited attention to assessment of cross-curricula learning in the available range of NCEA achievement standards. (The writers acknowledge the possibility that more assessment opportunities may exist than we have encountered in our purposeful sample survey of social science achievement standards to date.)

- In relation to integrative-STEM course design, where Technology is intended to be the principal subject (e.g., Technology *with* Mathematics and Science), only one achievement standard (*AS91051, Level 1, Technology,* 4 credits: Demonstrate understanding of how different disciplines influence a technological development*)* overtly addresses curriculum integration. If a subject other than Technology is the principal subject in a STEM combination, again only one integrative achievement standard was found (*AS91163, Level 2, Chemistry,* 3 credits: Demonstrate understanding of the chemistry used in the development of a current technology*)*. However, what is apparent to the writers is that all of the standards available in the Technological Practice strand (at all three levels) are able to be adapted to STEM course design. Remarkably, no reference to this possibility is provided in the wording or explanatory notes associated with any of the relevant standard specifications, nor is it explicitly apparent in the associated documents that have been consulted.

Clearly, the last point can be addressed through a future revision of achievement standards in Technology that would include appropriate STEM signals to schools and students in standard specifications and associated documents. Standards equivalent to AS91051 (Technology 1.8), but at a more advanced level, could also be introduced at Levels 2 and 3. However, the relatively limited recognition of STEM possibilities appears to suggest that cross-curricula course design has not been at the forefront of the thinking of those who have been involved with the design and review of assessment standards. It is now time that such thinking was given greater prominence to take advantage of the learning opportunities that are available under the *New Zealand Curriculum*. This thinking should be extended to include the development of assessment standards that recognise integrative-STEM education where the principal subject is mathematics, science or engineering; similarly, and more generally, the thinking should be extended to the development of assessment standards across the NCEA spectrum.

Unfortunately, the previous paragraph makes the necessary changes to NCEA seem straight forward; tweak a few changes and things will be workable! However, such changes are anything but simple. Standards have been designed largely subject by subject within the different fields and sub-fields recognised by the Ministry of Education (MOE) and the New Zealand Qualifications Authority (NZQA). Sitting between the *New Zealand Curriculum* and assessment for NCEA lies a very important step for teachers—to design courses of learning that marry NCEA achievement standards with the New Zealand Curriculum. An important belief of the writers is that course design should be led by the purpose and rationale for a course, not by what is available in the existing range of achievement standards. This does not mean that assessment standards should simply be tagged on at the end of the course design process; because of their importance they need to be woven into the course design process early on. The content of achievement standards gives important indications to teachers and students of what, within the curriculum, is deemed important to assess. However, the wide range of possible (and exciting) course developments that could be introduced through cross-curricula teaching and learning inevitably leads to situations where some of the important content/skills engendered by such design cannot be validly assessed through existing single-subject achievement standards. Standards do not exist for assessing such learning; more importantly, the dynamics of cross-curricula design should not be constrained by the limitations provided by the single-subject structures that have heavily influenced the design of NCEA. New thinking is needed.

One of the writers, under the theme of "curriculum fragmentation," has consistently argued that NCEA does not give enough attention to the development of integration and transfer of important knowledge and skills *within* subjects, let alone across disciplines (Hall, 2000; 2005; 2016). The following extract captures the problem:

> … the more you break down a subject (course) into separate assessment components for assessment purposes, the more you need to address the assessment of the knowledge and skills that show that students understand the important relationships and connections within the curriculum. (Hall, 2016, p. 1)

In the same paper, Hall posed the following question: "Where in the current design of NCEA is there a systematic consideration of the linkages between the different parts of the NZ curriculum, both within curriculum areas/subjects and across such divisions?" (p. 6). Suggestions were provided by Hall for dealing with the issue of fragmentation within subjects brought about by the structural features of NCEA. A more radical suggestion is provided here for dealing with cross-curricula assessment of learning. Instead of attempting to work through the extensive process of revising existing standards, or creating new ones, to do what seems impossible — to come up with standards that cover all, or nearly all, possibilities in cross-curricula design — take a leaf out of the IBD and require students at, say Levels 2 and 3, to undertake a formal cross-curricula study as part of their learning programme.

A model for doing the latter, if a student elected to do an integrated-STEM project, exists through the Technological Practice strand; this should be complemented by an assessment of each student's understanding of how different disciplines influence a technological development (e.g., Achievement Standard 1.8 in Table 1). More generally, an approach similar to that employed by Visual Arts could also be considered. For example, Visual Arts 2.4 (AS91320, 12 credits) requires students to "Produce a systematic body of work that shows understanding of art making conventions and ideas within design." This engages students in "making individual, related works that form a series or sequence to show generation and development within the art making process.

This involves editing, selecting and ordering work." The notion of a "systematic body of work" is one that could be adapted generically to a range of cross-curricula projects. The task for MOE/NZQA is to come up with a generic specification of the standard(s) that would enable a range of different subject combinations to be covered. The task of schools would be to guide students towards undertaking self-selected projects that are suitable and manageable, and that provide students the opportunity to demonstrate cross-curricula learning consistent with the intellectual qualities that characterise the educational goal of life-long learning: critical analysis, synthesis, transfer, problem solving, independent and co-operative learning, creativity, and metacognition.

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