From Curriculum to Workplace Requirements: Do They ‘Match’?

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This paper examines correspondences and disjunctions within a national curriculum and between various aspects of its delivery, and how these align with the mathematical needs of the workplace. This is investigated in the context of the New Zealand school mathematics curriculum; the Numeracy Development Project; the senior school assessment régime, and the numeracy requirements of toolmaking. In theory, the numeracy aspects of the various curricula and the workplace should form a logical learning progression in numeracy. The content was consistent across the various curricula, however, the assessment régime was not particularly congruent with gaining the thorough knowledge (mastery) required for workplace practice.

Numeracy is recognised as an important part of our society as it impinges on most aspects of peoples’ lives and particularly on their ability to perform efficiently and effectively in the work place. Most western governments now specifically recognize and promote numeracy learning. Official statements of numeracy reflect a broad consensus on its importance and that mathematical problems should be “embedded in real-life contexts … [which are] superior to … school-type word problems and context-free computational problems involving the same numbers and operations” (Carraher, Carraher, & Schliemann, 1985, p. 21). This is evident, for example, in the New Zealand school mathematics curricula statement (Years 1-13) which calls for contexts for numeracy where students are expected to be able to go beyond accurate calculation and are to “learn to estimate with reasonableness, … [and] understand when results are precise and when they must be interpreted with uncertainty.” (Ministry of Education [MoE], 2007, p. 26). Mathematics, including numeracy understandings and skills, is seen as having “a broad range of practical applications in everyday life, in other learning areas, and in workplaces ” (p. 26) which can all provide suitable learning contexts.

Despite this focus there is an extensive literature on ongoing concerns over low levels of numeracy. For example, David Blunkett, a former minister of education in the United Kingdom, described the fact that 7 million adults in England lack even basic numeracy skills as a “silent scandal” (Coben et al., 2003, p. 36). The problem, however, is as much part of tertiary education, for example, university students studying engineering (Belward, Mullamphy, Read, & Sneddon, 2007; Henderson & Broadbridge, 2009), medicine (Sheridan & Pignone, 2002) and bioscience (Tariq, 2002), as it is in general adult numeracy, schools and industry.

While numeracy contexts between vocations may appear to be dissimilar, there is a core of numeracy concepts and skills common to many professions and vocations (e.g., nursing, toolmaking and chemical spraying). Marr and Hagston (2007) list the following which employ numeracy: calculation (with and without calculators); mental calculations and estimations; calculation and interpretation of percentage; use of ratio and proportion; use and interpretation of scale drawings, plans and diagrams; measurement (length, volume, weight, temperature, speed); display and interpretation of data (use and interpretation of graphs, charts and tables); recognition of patterns and anomalies with measurements and data sets, and communication of mathematically related ideas. To this list can be added the higher level thinking of ‘problem solving’, which makes use of

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numeracy skills in successive stages to solve (multi-step) problems in the workplace and in education contexts.

Concern over numeracy competency led many governments to set up numeracy development programmes during the 1990's to enhance both school and post-school numeracy education. New Zealand's initial response to such concerns was the introduction and evolution of the Numeracy Development Projects [NDP] (2000 – 2010) for Years 1-8 aimed at improving individuals' (staff and students) mathematical conceptual understanding and calculation skills. Then the curriculum revision of 2007 explicitly absorbed content elements of the NDP and aligned the two. The same occurred in the development of the mathematics national standards (MoE, 2009) where, for example, NDP assessment materials and approaches are stated as being suitable for assessing standards in numeracy. Thus, the NDP Number Framework (MoE, 2008a) is now paralleled in the numeracy components of the *New Zealand Curriculum* (*NZC*) (MoE, 2007) and the national standards (MoE, 2009), theoretically culminating in the NCEA school-focussed Level 1 (Year 11) numeracy Achievement Standard (AS) and the workplace-focussed mechanical engineering Unit Standard (US). These are intended to work in conjunction with each other and thus provide smooth numeracy learning progressions, in both content and assessment, from primary (Year 1-8) through to secondary school (Year 9-11) and thence to the workplace.

The NDP has a hierarchy of eight stages of strategy and linked content with the highest stages: Stage 7 (Advanced Multiplicative [AM]) – Early Proportional Part-Whole) and Stage 8 (Advanced Proportional [AP] - Part-Whole) (MoE, 2008a) addressing some of Marr and Hagston's (2007) core content. For example, NDP *Book 7* (MoE, 2008b) "decimals and percentages" (p. 3) and *Book* 8 (MoE, 2008c) "finding estimates of percentages and decimals" (pp. 25-26); "ratios" (p. 42), and "rates" (p. 43).

In a review of NDP, Young-Loveridge (2010) states that there is a clear indication from the New Zealand documents, for example, *NZC* and *Mathematics Standards for Years 1 to 8* (MoE, 2009), that students should be AP thinkers by the end of Year 8. However, only "12% of year 8 students" (Young-Loveridge, 2010, p. 29) reached this level. In addition, Linsell (2010) and Thomas and Tagg (2006) expressed concerns about whether the development of numeracy skills continues during the secondary school years. This is reflected in a review of a Year 12 Level 2 Algebra examination paper which stated that "many of the candidates who did not achieve showed poor basic numeracy skills" (MoE, 2010, p. 2). Thus, the percentage of students who go on to achieve mastery of AP thinking while in secondary school, prior to further study or entry to the workplace, is not known.

This paper examines the numeracy components of various New Zealand curricula, their assessment, and how they align with the numeracy needs of toolmaking (a branch of mechanical engineering often using fine measurements such as thousandths of a millimetre and producing machine parts). This is done to explore the adequacy of the formal education system to meet the numeracy needs of the workplace.

Method

The nature of curricula materials, learning progressions and assessment was examined using document analysis while interviews with toolmakers explored their views of the curricula and the workplace use of numeracy skills.

The document data from various curricula, assessment schedules, examination papers and support materials up to 2010 were examined for connections and disjunctions with respect to numeracy. The examination focused on investigating what was currently intended to be taught, what was actually assessed, including the type of problems students were given to solve, and to what extent they could solve them.

The interview data from semi-structured interviews with six experienced toolmakers and toolmaking educators (see Table 1) explored their perspectives on how numeracy skills were evidenced in curricula, how they were necessary for, and applied in toolmaking, and the preparedness of beginning toolmakers.

Table 1
Participant toolmakers' ages and which perspectives they represent

Participant pseudonym	Age in years	Secondary school perspective	Toolmaking curricula perspective	Toolmaking training perspective	Business perspective
Lawrence	65	Yes	Yes	Yes	Yes
Pablo	50	Yes	No	No	No
David	45	Yes	No	Yes	No
Fraser	40	No	Yes	Yes	No
Michael	65	No	Yes	Yes	No
Lyle	60	No	No	Yes	Yes

The six participants formed a purposive sample (Sarantakos, 1993) selected to represent the various perspectives of "key informants" (p. 183). Of the participants only Laurence, from an English background, was not trained in New Zealand and Lyle was the only one still working at toolmaking.

The toolmakers' interview data was examined for evidence of congruence and disjuncture between curricula and practice, plus any common concerns (raised by all participants) evident in the responses.

Findings

This paper explores the adequacy of the formal education system to meet the numeracy needs of the workplace by examining disjunctions between the numeracy components of various curricula, their assessment, and their alignment with the needs of toolmakers. Here the curriculum related data is considered first, followed by the assessment related data and then the toolmakers' interview data.

Curriculum alignment

The numeracy content was closely aligned between all the curricula (up to 2010). The alignment was evident in both the official curricula (*NZC*, AS, and US) and related documents (national standards, NDP and text support materials).

All the NDP numeracy skills are present in the *NZC* and are pertinent to toolmaking. There is a clear connection between NDP content and skills and the toolmaking numeracy requirements, for example, the appearance of percentages and ratios in NDP *Book 8* (MoE, 2008d), in the *Learning Guide* (Glaeser, Curry, & Mortlock, 2010) for toolmaking and in *AS 90151: Solve straightforward number problems in context* (NZQA, 2007e).

Also the mechanical engineering curriculum US 21905 (NZQA, 2010b) emphasises numeracy and arithmetic skills applied in practical contexts (often involving geometry and trigonometry). The content of US 21905 is paralleled in an associated student workbook

(Competenz, 2007) which indicates that basic numeracy skills are an integral part of toolmaking. For example, the understanding of decimals, fractions, percentages (and their equivalents) and conversions of units (ratios) and their use in more complex problem contexts.

This close alignment of curricula content and materials was as expected due mainly to: the revision of the school curriculum in 2007 which incorporated many NDP elements, and the consequential development of 'national standards'. While the alignment between the various curricula was very close the alignment between the curricula and their assessment was, however, not as close, particularly for NCEA.

Assessment alignment

The 2006 NCEA examination paper for AS 90151 (NZQA, 2007a) contained questions on calculating a s traightforward percentage increase and decrease; calculating a straightforward fraction remainder; reading a recipe for information and calculating a weight; calculating the original amount before *Goods & Services Tax* was added; calculating the original amount before depreciation; calculating a percentage increase using scientific notation, and explaining using appropriate calculations which of two investment schemes, one of which involved compound interest, was better. The content and context questions in this examination paper all have their counterparts in NDP, *NZC*, and most in the toolmaking curricula except, for example, the *Goods & Services Tax* context. However, these questions only assess a subset of the total content and only any two of nine questions correct were required to score Achieved (NZQA, 2007a). Thus, a student with an Achieved grade may actually have mastery of very little of the AS content.

A similar situation is evident with 2006 exemplars made available where Achieved only required two questions out of eight correct (see Table 2). A student gaining Achieved could only answer a few questions correctly potentially giving rise to considerable variation between students in what content had actually been 'mastered'.

Table 2
Summary of 2006 exemplars for AS 90151: Solve straightforward number problems in context (NZQA, 2007b, 2007c, 2007d)

Student	Questions and potential 'pass' level								Grade
	Achieved					Merit		Excellence	
	1	2	3	4	5	6	7	8	
1	a	a	-	-	-	-	-	m	Achieved
2	a	-	-	a	-	m	m	-	Merit
3	a	-	a	a	-	m	m	e	Excellence

Similarly, these exemplars show that we cannot be sure that even a person who has gained Merit or Excellence is able to demonstrate understanding of concepts and skills (mastery) across all the content assessed. Indeed, it is impossible to know exactly what numeracy concepts and skills were understood by a student who scored Achieved without examining the student's examination script in detail. In the case of Merit or Excellence the situation is much the same with the emphasis possibly shifting to the inability to identify the gaps in terms of what was actually examined.

This suggests a potential disjunction between the aims of *NZC* (and NDP) with a focus on mastery and the numeracy AS in how it is assessed (and therefore possibly what content is actually taught).

Toolmakers' perspectives

In the interviews with the toolmakers the relevance of the toolmaking (and other) curricula to toolmaking practice was confirmed, as was the importance of all of the curriculum numeracy content and skills. All mentioned the need to perform 'simple' calculations (e.g., Laurence; David; Pablo; Fraser) and estimations and approximations (David) 'all the time'. They emphasised, for example, conversions between fractions, decimals and percentages (Laurence; Michael), conversion from millimetres to metres to centimetres (Laurence), and conversion from square millimeters to square meters (Fraser).

While the toolmakers used calculators often this did not replace or diminish the need for sound mental arithmetic skills (Lyle). In fact, all the toolmakers emphasized the importance of being able to apply mental arithmetic skills "all the time" (e.g., Fraser), in contexts that involved problem solving using multi-step, lateral thinking. Indeed problem solving and finding multistep solutions were seen as essential skills for toolmakers because often they do not know "what's coming in the door next" (Lyle) and there is "no formula that pops into your brain straight away" so you have to "sit down and think about a way of doing it ... a method" (Lyle). The way of "doing it" may involve performing a mathematics calculation or solving a problem not previously encountered, or inventing a 'toolmakers' technique suited to the unique challenges required by the project's design.

Significant concern was expressed about the readiness of many beginning toolmakers who lacked base numeracy knowledge and skills where numeracy mastery of NDP Stage 8, the numeracy AS and mechanical engineering US numeracy content was desirable. For example, basic numeracy knowledge of, and skills with percentages, fractions, ratios and decimal place value were "lacking in [students coming] out of high school. Very definitely. It is, it's a real problem" (Michael), and knowing the equivalence of 0.6 and 60% would be something "we would love them to have … but they don't always have it" (Michael). Fraser, referring to having to re-teach basic decimal knowledge and conversions said that, "the students still forgot this skill very quickly and could not apply it in a real context."

While specific entry requirements for toolmaking were not set Michael felt that being able to divide an amount into simple ratios was "enough to begin an apprenticeship". This, however, cannot be taken as a given and the toolmakers comments on students' preparedness suggest an inadequate school preparation in numeracy for toolmaking.

Alongside this was a view that much of school mathematics was not relevant to toolmaking in both content and the largely context free approaches in schools. For example, Fraser commenting on the usefulness of studying more advanced mathematics, said he advised apprentices that they should "scrub half of what [you're] told [in school mathematics]". In terms of context, Pablo felt that young people did better in the workplace when they can "actually see … a practical application and they use that application regularly so [therefore] they can see a reason for it" whereas at school, there "might be a reason but you can't see it". In summarizing his point of view, Pablo emphasised the importance of "actually practically using [mathematics]". The importance of context in empowering students was also mentioned by David who spoke of secondary students performing a series of different calculations in designing a seating area for a deck where "they [didn't] even see it as a maths problem" and by Laurence who emphasised the importance of contextual application when teaching apprentices: “I think it’s got to be applied maths, completely … totally applied maths to what they’re actually doing”.

Discussion

The *NZC,* NDP and AS 90151 provided a consistent progression (up to 2010) for numeracy content, skills and understandings from primary school to the workplace with the numeracy components of both these curricula being seen as relevant by the toolmakers. This suggests a strong alignment of curricula with workplace practice. However, the NCEA assessment was not well aligned with the expected outcome of this progression.

Two disjunctions relating to the NCEA assessment were identified. Firstly, the grade indicated nothing about which specific skills the student can actually perform as not all numeracy curriculum content was examined and as similar ‘grades’ did not necessarily imply that students possessed similar skills or knowledge there may be significant variation in what students understand. Typically, an Achieved candidate was given eight to ten opportunities to demonstrate their skills and knowledge and they needed to get two (or perhaps, three) problems correct. Without studying the student’s paper we can identify neither the aspects of numeracy where the candidate showed proficiency nor the other aspects where they do not. Secondly, the mastery of all skills is crucial for success in the workplace but the extent of the competence required for Achieved was very minimal, and even high performing (Excellence) students could have significant gaps in their knowledge and may not understand Advanced Proportional thinking.

The potential impact of these disjunctures was evident in the toolmakers concerns centred around students’ preparedness to begin apprenticeships in terms of meeting basic numeracy requirements and their limited ability to apply them. The negative attitudes of the toolmakers to much of school mathematics, due to lack of students mastery of basic skills and the apparent lack of context in school mathematics, appears similar to Marr and Hagston’s (2007) report that some people regard classroom mathematics as being “useless, abstract, and taught without relevance” (p. 9).

Workplace proficiency requires toolmakers to have more sophisticated numeracy understandings including higher level thinking skills and the ability to deal with multi-step problem situations. These are more usually associated with the NCEA Excellence level descriptor for AS 90151 - “Devise a strategy and solve a number problem” - rather than that of Achieved - “Solve straightforward number problems in context” (NZQA, 2010a, p. 1). However, being able to develop a solution pathway and apply several skills in sequence to solve problems cannot take place until thinking skills are developed and basic numeracy skills mastered. The development of basic numeracy skills and strategies is a focus of NDP and *NZC* but neither of these is particularly evident in AS 90151.

Hence the emphasis placed on basic numeracy skills in toolmaking teaching resources (Competenz, 2006) and the mastery approach focus of *NZC* and NDP. In addition by the time apprentices qualify as toolmakers, they need mastery of higher order thinking skills plus detailed knowledge of the toolmaking context.

Thus, there would appear to be a strong case for further emphasis on numeracy development in secondary schools leading to mastery of all numeracy content and the need to focus on higher thinking skills.

Implications

The key aspect for curricula development emerging from this study is the need to maintain a focus on mastery of numeracy materials up to and including Advanced Proportional ideas and content. While it appears that all essential toolmaking numeracy skills are contained in the numeracy AS, significantly higher levels of mastery are required to better meet the needs of the workplace.

There are two potential possibilities here: one is to extended the numeracy strand into a Level 2 (and 3?) numeracy AS focusing on both numeracy and thinking skills which incorporate more contextual applications, for example, measurement and a variety of workplace situations. Currently numeracy competency is not developed in the more 'advanced' mathematics ASs in NCEA Levels 2 and 3 as these have no explicit numeracy content or assessment of it, nor any direct link to the numeracy needs of many professions/vocations. The other possibility is to assess for mastery of all the numeracy AS material rather than the current assessment regime with its partial cover of content and minimalist requirement for Achieved.

A numeracy programme that is based on *NZC* principles, focussing on mastery of numeracy concepts and skills, and meeting the actual needs of individuals' learning and the workplace, would be much more suitable for all students.

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