CONCEPTUALISING AND ENACTING NUMERACY ACROSS THE CURRICULUM

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Numeracy refers to the use of mathematics in non-mathematical contexts. In this paper two approaches to conceptualising numeracy across the whole school curriculum are identified: one based on interdisciplinary inquiry and the other on embedding numeracy into each school subject. The latter approach informed a systematic audit of resources available to Australian teachers for understanding and enacting numeracy across the curriculum. It was found that few resources addressed the need for teachers to recognise and take advantage of the numeracy learning demands and opportunities within the subjects they teach.

BACKGROUND

Numeracy is a term used to identify knowledge, skills and practices related to the use of mathematics in non-mathematical contexts and, in particular, to the use of mathematics in work, home and civic life. Steen (2001) identified seven dimensions of numeracy (using the term quantitative literacy): confidence with mathematics; appreciation of the nature and history of mathematics and its significance for understanding issues in the public realm; logical thinking and decision-making; use of mathematics to solve practical everyday problems in different contexts; number sense and symbol sense; reasoning with data; and the ability to draw on a range of prerequisite mathematical knowledge and tools. Increasing international focus on numeracy, as part of schooling and beyond, is evident in the emergence of testing regimes such as the Programme for International Student Assessment (PISA) and the Programme for the International Assessment of Adult Competencies (PIAAC).

In Australia, the notion of numeracy as an important goal for schooling was confirmed through a national numeracy review (Council of Australian Governments, 2008), which also promoted the view that the development of students' numeracy requires a cross-curricular commitment by schools and systems. This review recommended that:

> …all systems and schools recognise that, while mathematics can be taught in the context of mathematics lessons, the development of numeracy requires experience in the use of mathematics beyond the mathematics classroom, and hence requires an across the curriculum commitment. (p. 7)

Further, numeracy has been identified as one of seven General Capabilities embedded in the Australian Curriculum – the first ever nationally mandated curriculum in this

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country. Numeracy is described within each school subject's curriculum document via the following statement:

> Students become numerate as they develop the knowledge and skills to use mathematics confidently across all learning areas at school and in their lives more broadly. Numeracy involves students in recognising and understanding the role of mathematics in the world and having the dispositions and capacities to use mathematical knowledge and skills purposefully. (Australian Curriculum, Assessment and Reporting Authority, 2014a, p. 13)

A commitment to developing numeracy across the curriculum is also evident in the Australian Professional Standards for Teachers, a set of statements that specify the professional knowledge, professional practices, and professional engagement required of effective teachers (Australian Institute for Teaching and School Leadership, 2014a). Standard 2 states that teachers should "Know the content and how to teach it", and one of the focus areas elaborating on this statement relates to knowledge of literacy and numeracy strategies. Thus proficient teachers should be able to "apply knowledge and understanding of effective teaching strategies to support students' literacy and numeracy development".

However, apart from these curriculum mandates and professional standards statements, Australian teachers are provided with little guidance in understanding and enacting numeracy across the curriculum. This paper reports on preliminary findings of a research project that aims to provide such guidance. The project builds on our previous research, which has developed a methodology for auditing the numeracy demands of the school curriculum and a professional development approach for supporting teachers' planning and pedagogical decision-making in relation to numeracy across the curriculum (Goos, Dole, & Geiger, 2012; Goos, Geiger, & Dole, 2014). This current project will add a new dimension to our previous work by translating what we have learned about teachers' planning, including how they design numeracy tasks, into a more general design framework that teachers can use to adapt existing resources or to create their own.

The first stage of the project, reported in this paper, involved conducting a literature review of "good practice" in teaching of numeracy in schools and an audit of existing resources for teaching numeracy across the curriculum. The following research questions informed this stage of the project:

1. How can numeracy across the curriculum be conceptualised?

2. To what extent do existing resources available to Australian teachers support their understanding and enactment of numeracy across the curriculum?

The first research question is addressed in the next section, which summarises the findings of our literature review. The subsequent section addresses the second question by presenting the methodology and outcomes of the resources audit.

CONCEPTUALISING NUMERACY ACROSS THE CURRICULUM

The literature review revealed that research into numeracy across the curriculum falls into two broad categories: (1) interdisciplinary inquiry that combines mathematics with one or more disciplines into a single program, and (2) identifying the distinctive numeracy demands and opportunities in school subjects other than mathematics.

Interdisciplinary inquiry

Interdisciplinary inquiry refers to tasks, teaching programs or approaches to instruction that connect two or more academic disciplines. While some researchers argue that integrating teaching and learning across disciplines offers greater possibilities for engaging adolescent learners (e.g., Venville, Wallace, Rennie, & Malone, 2002), this approach brings with it challenges that educational institutions often struggle to address when attempting to move away from existing discipline-based approaches. These challenges include the structure of schooling, much of which is designed to protect disciplinary interests, and factors such as discipline-based teacher training, assessment, and parental preferences for a traditional discipline-based curriculum that contribute to maintaining the status quo. Because of these limitations, some people argue against integration and assert that ideas like numeracy should be considered "educational by-product[s] … [that results from] … studying mathematics, physics, chemistry, biology, business studies and various other subjects in which numbers and mathematics concepts find application" (Lee, 2009, p. 218).

Numeracy demands and opportunities in subjects other than mathematics

Numeracy can also be addressed across the curriculum by attending to numeracy demands and opportunities as they emerge when teaching subjects other than mathematics. This does not mean that teachers in other subjects should be required to be expert teachers of mathematics. It does mean that teachers need to be familiar with the inherent numeracy demands of their subject, can recognise a numeracy opportunity when it arises, and have the disposition and pedagogical skill to take advantage of such opportunities. Studies have demonstrated that such opportunities arise in a wide range of subjects, such as science (Quinnell, Thompson, & LeBard, 2013), economics (O'Neill & Flynn, 2013), and the social sciences (Lake, 2002). These subjects not only demand quantitative skills but also offer opportunities to develop critical thinking and active citizenship as important elements of numeracy.

Hogan (2000) argues that being numerate requires three types of knowledge:

Mathematical – understanding of mathematical ideas and techniques
Contextual – capacity to link and use mathematics in life situations
Strategic – identification of key features of a problem in order to make an appropriate choice of mathematics relevant to a situation and recognise the limitations of results.

This framework was used as the foundation for a project that investigated the demands and opportunities in teaching numeracy across the curriculum (Thornton & Hogan, 2003). The findings suggested that teachers can plan for numeracy teaching provided such activity is prioritised and that a numeracy-oriented approach to teaching across the curriculum enriches students' learning in other curriculum areas.

In a series of research and development projects, Goos and colleagues investigated the effectiveness of a teacher professional learning program aimed at enhancing numeracy teaching across a range of school subjects, including history, science, English, health and physical education, and studies of society and environment. This program was based on a multi-faceted model of numeracy that represents a synthesis of research related to effective numeracy practice. The model, which was constructed as an accessible instrument for the purpose of teachers' planning and reflection, incorporates the dimensions of *contexts*, *mathematical knowledge*, *tools*, and *dispositions*, embedded in a *critical orientation* to using mathematics. These are summarised in Figure 1. This model has been used to identify the numeracy demands of non-mathematics subjects in the Australian Curriculum, investigate teachers' understanding of numeracy, and analyse teachers' capacity to recognise and take advantage of numeracy opportunities in the subjects they teach (Goos, Geiger, & Dole, 2011, 2014; Goos, Dole, & Geiger, 2012).

Mathematical knowledge	Mathematical concepts and skills; problem solving strategies; estimation capacities.
Contexts	Capacity to use mathematical knowledge in a range of contexts, both within schools and beyond school settings
Dispositions	Confidence and willingness to use mathematical approaches to engage with life-related tasks; preparedness to make flexible and adaptive use of mathematical knowledge.
Tools	Use of material (models, measuring instruments), representational (symbol systems, graphs, maps, diagrams, drawings, tables) and digital (computers, software, calculators, internet) tools to mediate and shape thinking
Critical orientation	Use of mathematical information to: make decisions and judgements; add support to arguments; challenge an argument or position.

Figure 1. Elements of the numeracy model developed by Goos and colleagues

RESOURCES THAT SUPPORT NUMERACY ACROSS THE CURRICULUM

Audit Methodology

Because the Australian Curriculum maintains strong boundaries between subjects rather than promoting interdisciplinary inquiry, the framework for the resource audit was aligned with the second conceptualisation of numeracy described above – based on identifying the numeracy demands and opportunities in subjects other than mathematics. We were interested in ways in which existing resources supported teachers' *understanding* and *enactment* of numeracy across the curriculum, and so we

constructed an audit framework that captured these qualities. The framework consists of statements sourced from the Numeracy Standards for Graduate Teachers published by the Board of Teacher Registration (2005). Although these Numeracy Standards pre-date the Australian Professional Standards for Teachers (AITSL, 2014a), they have a similar organisational structure in describing Professional Knowledge, Practice and Engagement/Attributes but with explicit reference to numeracy. The Numeracy Standards comprise 22 statements, four of which were selected for the audit framework because they refer to understanding (Professional Knowledge) and enactment (Professional Practice) of numeracy across the curriculum (Figure 2). For the purposes of the audit, they were preceded by the sentence stem "How might this resource help teachers to …?"

Professional Knowledge
PK1: Understand the meaning of numeracy within their curriculum areas.
PK2: Recognise numeracy learning opportunities and demands within curriculum areas.

Professional Practice: Planning
PPP: Take advantage of numeracy learning opportunities within their curriculum context.

Professional Practice: Teaching
PPT: Demonstrate effective teaching strategies for integrating numeracy learning within their own curriculum context.

Figure 2. Framework for resource audit

We limited our search for numeracy resources to those that are (1) readily accessible to Australian teachers and (2) endorsed or produced by the authorities responsible for the Australian Curriculum or the Australian Professional Standards for Teachers, or by teacher professional associations. As a result, we searched the following sources:

1. the numeracy statements for all non-mathematics subjects in the Australian Curriculum: the Arts, English, Science, History, Geography, Economics and Business, Civics and Citizenship, Health and Physical Education, and Technology (ACARA, 2014b);

2. the *Illustrations of Practice* that accompany the Australian Professional Standards for Teachers – an online professional development package comprising video clips of classrooms, teacher interviews, and discussion questions (AITSL, 2014b);

3. the government-endorsed repository of digital resources mapped to the Australian Curriculum and available via Scootle (http://www.scootle.edu.au);

4. teacher professional journals in mathematics and non-mathematics subjects.

Preliminary Results

The first source of numeracy resources was the numeracy statements in each of the Australian Curriculum documents. These statements could help teachers to understand the meaning of numeracy within their curriculum area (PK1). For example, in Geography, the numeracy statement explains that students

"investigate…the effects of location and distance, spatial distributions and the organisation and management of space within places".

The second source of numeracy resources was found to provide little assistance in understanding and enacting numeracy across the curriculum. Only two of the 325 *Illustrations of Practice* were related to numeracy, and only one of these (titled *Embedding mathematics in everything*, see Figure 3) connected mathematics to non-mathematical contexts – but in the form of extra-curricular activities rather than other school subjects. Because this resource illustrates a particular teacher's planning practices as well as his understanding of numeracy and demonstration of effective teaching strategies, it might help teachers develop professional knowledge and practice in all of the ways identified in the audit framework (PK1, PK2, PPP, PPT).

> This teacher works closely with other staff to link mathematics learning to students' experiences. He encourages a collaborative, inquiry-based approach to teaching mathematics, modelling the use of questioning to encourage the use of problem solving with other staff and students. An activity that allows for mathematical investigation, is facilitated by a parent who has an engineering background. The parent visits the school to teach students how to design and construct see-saws using Lego.

Figure 3. Summary of *Embedding mathematics in everything*

For the third source, a search of Scootle using the term "numeracy" returned 235 resources, almost all of which were related to the teaching of mathematics rather than numeracy across the curriculum. Seventeen numeracy resources were identified, all of which were judged to have the potential to help teachers understand the meaning of numeracy within a particular curriculum area (PK1) and, if implemented as directed, to help teachers demonstrate effective teaching strategies for integrating numeracy learning in this curriculum context (PPT). For example, a unit of work in the science curriculum on plants, included activities involving measurement of plant growth, development of a scale for a cross section diagram, and the collection and representation of data in tables and graphs.

The fourth source of numeracy resources was teacher professional journals. A search of 17 journals aimed at teachers of science, English, mathematics, computing, health and physical education, English as a second language, modern languages, geography, art, history, and music, as well as more general journals focusing on early childhood or middle years education, found only 15 articles on the teaching of numeracy across the curriculum. Eleven of these were published in mathematics teacher journals, which are unlikely to be read by teachers of other subjects looking for help in understanding (PK1 and PK2) and enacting (PPP and PPT) numeracy in their own curriculum contexts.

DISCUSSION AND CONCLUSION

Numeracy has been a national educational priority in Australia for over a decade and remains on the international educational agenda because numerate citizens are able to

participate and function more fully in society. Thus, numeracy must be seen as a basic right to be fostered through schooling and beyond. The concept of numeracy across the curriculum, however, is relatively new and so research into how best to promote numeracy capabilities is only beginning to emerge. Two approaches are evident in the literature. One is based on interdisciplinary inquiry that aims to integrate mathematics with other subjects (e.g., Venville et al., 2002), and the other leaves the separate disciplines intact and instead encourages teachers to identify subject-specific numeracy demands and opportunities (e.g., Goos et al., 2014). Both approaches have their challenges. However, it seems that the latter approach would be more feasible for teachers to implement because it avoids the well-documented problems of curriculum integration.

An audit of existing resources available to Australian teachers found very few resources to support teachers' understanding and enactment of numeracy across the curriculum. Most resources that were found did offer some explanation or examples that could enhance teachers' understanding of the meaning of numeracy in their own curriculum context, and many also provided "ready-made" activities for integrating numeracy into the teaching of subjects other than mathematics. However, almost none addressed the need for teachers to recognise and take advantage of the numeracy learning demands and opportunities within the subjects they teach as part of their curriculum planning and pedagogical practice.

While we cannot claim that our numeracy resource audit identified every resource available to Australian teachers, its findings highlighted important gaps. In particular, it seems unlikely that teachers will be able to embed numeracy across the school curriculum without structured assistance in learning how to "see" the numeracy demands and opportunities in all the subjects they might teach. To address this gap, the next stage of our research will translate the numeracy model we developed in previous studies (Figure 1) into a design framework to support teachers in selecting, adapting, and creating resources for embedding numeracy across the curriculum.

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