Challenges to Numeracy Across the Curriculum: Reflections From a Case Study

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It is well accepted and understood amongst the mathematics education community that numeracy is the responsibility of all teachers, across all levels of schooling. However, the way numeracy is understood and actioned across the Early Childhood, Primary and Secondary contexts is different. This paper reports on a case study of secondary school teachers seeking to be more intentional in embedding numeracy across the curriculum. The findings indicate that dialogue and support to see, and make, numeracy connections result in greater cohesion in terms of understanding numeracy and making numeracy more visible for students.

In Australia, the media message about mathematics, as measured via numeracy assessments such as NAPLAN, PISA and TIMSS has highlighted declining performance (Thomson et al, 2013). The response has had two distinct focuses: (1) teaching and learning practices in mathematics which can improve student experiences and outcomes, and (2) how children transfer and apply their knowledge of mathematics. This transfer includes application of mathematics in mathematical problem solving and application in non-mathematics contexts. In a school setting the application of mathematical knowledge in other learning areas is referred to as *numeracy across the curriculum*. Bennison (2015) highlights the importance of all teachers (1) recognising and understanding the importance of numeracy across the curriculum, and (2) being able to identify opportunities for explicit connection to and development of numeracy ideas. In this study we explore ways in which teachers at one school identified and developed opportunities for numeracy across the curriculum, with a specific focus on resources already in use.

Numeracy Across the Curriculum

The Australian Curriculum, Assessment and Reporting Authority (ACARA) includes numeracy as one of seven general capabilities in the Australian Curriculum and defines numeracy as "students recognising and understanding the role of mathematics in the world and having the dispositions and capacities to use mathematical knowledge and skills purposefully" (ACARA 2017). The general capabilities are addressed through the content of the eight learning areas, and content descriptions are tagged with one or more relevant general capabilities. ACARA makes it clear that numeracy is both a part of the mathematics curriculum and an essential component of all learning areas across the curriculum. In other words, numeracy development is a responsibility of all teachers. In version 8.4 of the Australian Curriculum, learning areas were ranked based on the proportion of content descriptions tagged with connections to numeracy; see Table 1 for the ranked list. In version 9, all eight learning areas are viewed equally with each having a clearly defined numeracy statement within their curriculum overview.

The difference between numeracy and mathematics must be clearly conveyed to support schools' engagement with cross-disciplinary, interdisciplinary and transdisciplinary approaches to embedding numeracy across the curriculum (Coffey & Sharpe, 2021). Without this clarity, measuring and reporting student numeracy outcomes required to meet the political agenda can promote the idea amongst teachers that numeracy is simply a skill-based pursuit (Goos et al., 2019).

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Table 1

Learning Areas Ranked by Highest Proportion of Content Descriptions Tagged with Numeracy

1	F-6/7 Humanities and Social Sciences	7	Science
2	7-10 History	8	The Arts
3	7-10 Geography	9	Health and Physical Education
4	7-10 Civics and Citizenship	10	English
5	7-10 Economics and Business	11	Languages
6	Technologies	12	Work Studies

Numeracy requires students to make sense of non-mathematical contexts through a mathematical lens, use critical judgement, and investigate possible solutions to real world problems (Geiger, Goos and Forgasz, 2015). In actioning this, teachers need to provide opportunities where students develop a depth of understanding of the specific application of mathematics within their subject area. This can be achieved either through *numeracy moments* or *numeracy opportunities*. Numeracy moments are encounters (often ad hoc) with mathematics in other learning areas where the learning intention is not reliant on the mathematical connection. In contrast, numeracy opportunities are planned uses of mathematics that are integral to the learning intention; see Goos et al. (2019) for examples of numeracy opportunities.

A teacher's understanding of numeracy depends on the combination of the different types of knowledge held by the teacher and their own personal beliefs (Muir, 2008). Strong content knowledge by itself does not ensure that a teacher can embed numeracy in ways that are meaningful for students (Muir, 2008). Embedding numeracy across the curriculum can be challenging. Teachers need to understand how students learn, appreciate the applications of mathematics, recognise mathematical possibilities in non-mathematics subjects, and be willing to collaborate with colleagues (Goos et al., 2019). An additional complexity, with a directive that all teachers should embed numeracy in their teaching, is that it may cause may anxiety for some teachers, particularly if their own mathematical experiences have not given them the confidence and aptitude to identify or seek out numeracy moments or opportunities.

To capture the complex demands of numeracy across the curriculum, Goos, Geiger and Dole (2010) developed a model designed to reflect the nature of numeracy in the 21st century. The model builds on previous understandings of numeracy. Early work by Goos (and later with colleagues) used the Australian Association of Mathematics Teachers definition of numeracy: "to be numerate is to use mathematics effectively to meet the general demands of life at home, in paid work, and for participation in community and civic life" (AAMT 1997, p.15). More recent work by Goos et al. (2019) places *context* at the heart of numeracy and acknowledges the key roles of *mathematical knowledge*, *tools*, and *dispositions*. These four dimensions are embedded in a *critical orientation* to using mathematics, highlighting the potential of numeracy connections to promote opportunities for meaningful connections to real-world issues. The model of numeracy in the 21st century can be used as a framework when teachers are planning for numeracy opportunities.

In this paper we share insights from a cohort of teachers seeking to be more intentional in their approaches to numeracy across the curriculum by planning for, enacting and reflecting on numeracy moments in non-mathematics learning areas.

Research Design

This study employed a case study approach to explore the ways in which a targeted approach to numeracy across the curriculum was received and enacted in a secondary school context. Case study, as discussed by Yin (2009, p.1211), enables an "intense focus on a single phenomenon within its real-life context", and as such can encompass both qualitative and quantitative methods of data collection. The ‘case’ in this study was an urban secondary school (Years 7–12), in a predominantly middle-class area with more than 1300 enrolled students.

Following the school’s own scoping survey, the project team, in collaboration with the Head of Mathematics and some of the mathematics faculty at the school, unpacked the school’s own data about perceptions of numeracy. An information session was held for teachers in the mathematics faculty on numeracy and numeracy across the curriculum. This session included discussion around the faculty’s strengths and priorities and informed the co-design (with the Head of Mathematics and the project team) of upcoming professional learning workshops.

Goos (2020) infers a three-step approach to developing numeracy across the curriculum that was used to guide the work with the school, with particular emphases on steps 1 and 2.

1. Exposure to exemplar activities—*knowing* about numeracy.
2. Trying out initial ideas—*doing* in relation to numeracy.
3. Continued interaction (developing knowing and doing)—numeracy as part of *being*.

As part of this project, the school identified a focus on Health and Physical Education (HPE) and Design and Technologies (DT) as a starting point for their approach to numeracy across the curriculum. These middle-years teachers participated in a series of professional learning workshops. The workshops focussed on unpacking expectations of, and current practices associated with numeracy, introducing the 21st century numeracy model (Goos et al., 2014), and illustrating ways to embed numeracy (‘*knowing*’). The workshops also encouraged teachers to identify and reflect on numeracy moments, and supported teachers to plan for, enact, and reflect on numeracy opportunities (*‘doing’*). These workshops were held across three terms and were facilitated by the project team.

The main data collected in this study were teacher surveys and reflections on both numeracy moments and numeracy opportunities to identify teachers’ current experiences of numeracy across the curriculum, the main resources they use, and also their confidence in and experiences as users of mathematics. Where feasible, teachers recorded and watched back their own lessons to support their reflections. All teachers completed:

- An initial survey and reflection prior to the start of the project (in term 1),
- A second survey and reflection after their first ‘have a go’ activity (in term 3), and
- A final survey and reflection after their lesson incorporating a planned numeracy opportunity (in term 4), ideally after reviewing their own recording of the lesson.

The initial survey was anonymous so that teachers would feel comfortable sharing negative perceptions or confidence rankings without fear of being identified. Responses to subsequent surveys were identifiable. In the final survey, 360° cameras were made available so teachers could record their lessons. The research team processed and made the video recordings available, but teachers reviewed them independently to reduce any perceived scrutiny of them. In this paper we present and discuss findings from the first two project stages (up to term 3).

The Context

In the school’s initial preparation for a focus on numeracy, all middle school teachers (Years 7-10) were surveyed and asked about their perceptions of numeracy. Of particular relevance to this project is the variation in responses from teachers regarding their current understanding of the numeracy demands of the subjects they currently teach. The results from an anonymous survey distributed by the Head of Mathematics at the site indicates a variety in teacher perceptions (n=60 middle school teachers) of what numeracy is, as well as a range in teacher self-reported confidence in understanding of the numeracy demands of their learning area. Confidence ranged from very good or good (n=14, n=20), fair (n=17), through to poor or very poor (n=8, n=1); this cohort of 60 teachers includes the mathematics faculty.

When reflecting on the challenges specific to this site, which informed the project, the Head of Mathematics noted:

> From a site perspective, numeracy across the school is important as it can allow students (and teachers) to improve dispositions towards Numeracy and use mathematics effectively and critically in their personal & civic life. There is often a misrepresentation of what numeracy is (the fact NAPLAN—Numeracy is essentially a mathematics exam doesn't help) by teachers and the general public, so being able to change those perceptions is important. Like literacy, it is hoped that we can recognise numeracy as everyone's responsibility and not an "opt-out". It is also hoped that by being able to recognise numeracy opportunities within their learning area, students have multiple exposures (a High Impact Strategy) to different mathematics from a variety of topics. This could potentially have a symbiotic relationship through which other learning areas' numeracy opportunities are mapped, meaning in mathematics, we bring other areas into ours.

The participants in this study were all teachers at the case study site teaching HPE (n=12), Food Technologies (FT; n=2, part of the D&T middle school curriculum teaching team), and DT (n=4) in the middle years (Years 7 to 10). Three of the teachers (HPE) also teach mathematics, one of whom would be considered out-of-field based on their teaching qualification. The last teacher indicated they would have liked to study mathematics as part of their qualification, but it wasn't an option. Three other teachers also indicated that they opted to study some mathematics as part of their teacher training and indicated that they enjoyed maths. Seven of the 18 participants indicated that they don't really enjoy mathematics (5 HPE and 2 FT). The data for the 2 FT teachers is included where relevant in the 'overall' data but excluded from cohort-specific data as one teacher did not complete all parts of the survey.

Findings: Stage 1

Aside from the three HPE teachers currently teaching mathematics, seven other teachers (three of whom don't particularly like mathematics) indicated they have taught it in the past (two at the case-study school and five at other schools). Of these seven teachers only three said they make pre-planned numeracy connections. The most common response from the participants (8 out of 18) was using a mixture of both planned and ad hoc. A further five said they typically plan, and four indicated they typically make ad hoc in-the-moment connections.

Teachers were asked what they personally wanted to get out of the project. Their responses predominantly indicated pedagogical content knowledge (PCK) related to numeracy (n=8), along with numeracy resources (n=3), improved outcomes for students (n=3), mathematics PCK (n=2), and mathematics content knowledge (n=1). Interestingly, four responses exclusively referenced mathematics rather than numeracy (n=10), and two people did not mention either mathematics or numeracy. Categorised in terms of the five dimensions of the model of numeracy for the 21st century, four respondents mentioned wanting students to enact numeracy in context, and one talked about tools for numeracy.

All participants were asked to rate their confidence (with 10 being the highest) in explaining a range of mathematics topics. Table 2 summarises the responses from all 18 participants (HPE, DT and FT), noting that some did not rate some topics and two participants (1 HPE and 1 DT) did not rate any topics. A breakdown by learning area is also shown for interest, noting that little can be inferred about differences between the two cohorts given the small sample sizes. Fifteen teachers gave rating for 75% or more of the topics listed in Table 2 (with 13 teachers giving ratings for all topics). These average confidence for each teacher was computed and ranged from 2.9 to 8.8 (out of 10).

Table 2

Participants' Mean Confidence Scores (Self-Rated) where 1 is Low and 10 is High

How would you rate your confidence in explaining the following aspects of mathematics:	Overall (n=18)	HPE (n=11)	DT (n=3)
Fractions, decimals and percentages	7.50	7.64	8.67
Ratios and proportions	7.20	7.09	8.33
Measurement: units, instruments and accuracy	8.13	8.00	9.33
Perimeter, area, and volume	7.80	7.36	9.33
Geometric figures: definitions and properties	6.40	6.27	8.00
Geometric figures: symmetry, motions, transformations, congruence, similarity	5.13	4.91	7.00
Coordinate geometry	6.07	5.50	8.67
Algebraic representation	6.07	5.40	8.67
Evaluate and perform operations on algebraic expressions	5.64	5.10	8.67
Solving linear equations and inequalities	5.77	5.11	7.67
Representation and interpretation of data in graphs, charts, tables	8.27	8.27	7.67
Simple probabilities: understanding and calculations	7.20	7.09	6.67

Table 3 outlines the commonly used resources identified by the teachers—included verbatim. Teachers have been grouped according to their average self-rated confidence from Table 2. The three groupings used are:

- *Low confidence:* the average confidence of each teacher in this group is 3.0 or less
- *Mid confidence:* the average confidence of each teacher in this group is 5.0 to 7.5
- *High confidence:* the average confidence of each teacher in this group is 7.5 or more.

Table 3

Participants' Preferred Resources, by Confidence Grouping

Group	The resources you use that you find the most helpful:
Low (n=1)	None listed
Mid (n=8)	*My own resources:* [identified but no examples given] *Digital resources:* live it up, internet articles; data collection tools *Physical resources:* maps; pre-set out route cards, embed into PowerPoints *Knowledge:* Understanding the different calculations that I'm working through so I can explain them; previous knowledge and colleagues.
High (n=6)	*My own resources:* PowerPoint notes highlighting numeracy connections *Physical resources:* Videos, diagrams, diaries and match play booklets; a myriad of resources from books to websites *Digital resources:* Arduino open-source web site, A.C recourses website *Other:* Prior assessments; contextualized numeracy, highlighting the numeracy in my curriculum

When asked what support was available at their school to make better numeracy connections across the curriculum, one respondent in the low confidence group said that other colleagues were their main support. In the mid confidence groups, there were six responses: one 'not a lot', two 'not sures' including one who said they had neither been offered nor sought out any support, and three who indicated support from across the faculty and/or from mathematics teachers. The high confidence group gave responses such as colleagues in the mathematics faculty (n=2), electronic and Power BI (n=1), not sure (n=4), two of whom indicated they were new to the school and one other stating "The maths faculty are very open with helping when it comes to these numeracy moments". The range in responses suggests that while support is available, it is not visible or accessible equitably among teachers.

Findings: Stage 2

Ten teachers from Stage 1 participated in Stage 2, 8 HPE and 2 DT (Table 4).

Table 4

Participants' Chosen Numeracy Moments in Stage 2

Describe the numeracy connection:	Type	Numeracy Continuum connection:
DT: Year 7's are building a model of a COLA and had to scale the building and furniture to ensure that the model didn't look "weird".	M*	Using fractions, decimals, percentages, ratios, rates
DT: Changing a design sketch into a life size pattern and allowing ease and seam allowance.	O	Estimating and calculating with whole numbers
HPE: Design and perform dance movement patterns	M	Recognising and using patterns and relationships
HPE: During an inquiry process, the students needed to collect a lot of data ... I spent some time with them describing the importance of identifying themes, comparing the data sources across the variety of sources to recognise patterns to then draw conclusions.	O	Recognising and using patterns and relationships
HPE: Teaching Outdoor Ed where students needed to work with time and distance when planning route cards.	M	Estimating and calculating with whole numbers
HPE: Stage 1 Physical Education—Biomechanics; we have discussed and explored speed, velocity, displacement, distance and projectile motion. These make connections from theory to a practical setting and how these aspects can be utilised effectively.	O	Using spatial reasoning
HPE: Stage 2 PE lesson looking at analysing and evaluating training programs using HR, GPS data and game statistics.	M	Using fractions, decimals, percentages, ratios, rates
HPE: Heart rate and training zone; recording your heart rate in beats per minute. Record pulse for 15 seconds then multiply it by 4.	M	Using fractions, decimals, percentages, ratios, rates
HPE: Yr. 10 Human Movement, analysing HR data; calculating % by looking at max heart rate then we looked at calculating different % of their heart rates and linking them into which energy system was dominant at different points of the game.	O	Using fractions, decimals, percentages, ratios, rates
HPE: We analysed a tennis match plotting depth of shots, first serve percentage and then percentage of points won when the first serve went in. We then had students calculate the number of hours they spend on court training at various intensity levels and used a formula to calculate overall workload for that period of time.	O	Using fractions, decimals, percentages, ratios, rates

Note. M=numeracy *Moment*, O=numeracy *Opportunity.*

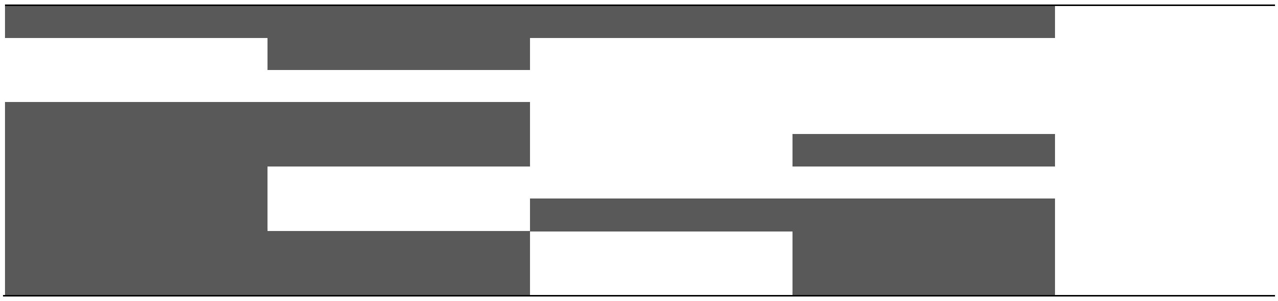
In Stage 2, teachers were asked to identify a significant numeracy moment and plan for an explicit elaboration or discussion in class in relation to the mathematics. Teachers were asked to reflect on the experience. Table 4 summarises their numeracy moments and associated mathematical content (their words). The most common connection to the numeracy continuum was with using *fractions, decimals, percentages, ratios and rates* (n=5, 1 DT and 4 HPE), followed by *estimating and calculating with whole numbers* (n=2, 1 DT and 1 HPE), *recognising and using patterns and relationships* (n=2, 2 HPE) and *using spatial reasoning* (n=1, HPE). No connections were made in the planned numeracy moments to *using measurement* or *interpreting statistical information.*

Teachers were also asked which elements of the numeracy for the 21st century model aligned to their numeracy moment. Table 5 shows a visualisation where each row corresponds to a participant, and grey shading indicating an identified connection. Connections were primarily to knowledge, contexts and tools, with only two to dispositions, and none to critical orientation. This has parallels to work reported by Goos, Geiger and Dole (2014), in which only four of 18 teachers participating in numeracy professional development self-identified critical orientation as part of their trajectory through the numeracy model, and only then at the end point.

Table 5

Visualisation of Connections Each Teacher Made to the Model of Numeracy for the 21st Century

Mathematical Knowledge	Contexts	Dispositions	Tools	Critical Orientation



Eight of the 10 teachers felt their numeracy connection was embedded throughout the lesson. When asked to reflect on how the lesson went and if they noticed anything different about their students, the general feeling was that students seemed to have greater attention to detail and were engaged, as they felt the mathematical connection was "relevant context to their learning" (HPE teacher) and/or "they had a strong interest to make connections" (HPE teacher). This was noted in upper year levels too but more strongly amongst the students already opting for mathematics and physics courses.

No concerns were raised about a lack of student content knowledge other than one comment that students seemed to need a lot of support "analysing a wider range of data and recognising the relationships different pieces of evidence have to each other" (HPE teacher). Only one negative response about student engagement appeared across the ten reflections: in the heart rate lesson, the teacher reflected that some students were really reluctant to "do maths in PE … really avoided it".

While the reflections indicated that most lessons didn't go exactly as planned, all teachers indicated they would do their lesson again with modifications that, in general, related to making the mathematical connections clearer. We share one teacher's reflection (data comparison lesson) below as this signals a shift in the importance given to planning numeracy connections.

> Ok—it wasn't specifically planned, I only noticed there was a need for the discussion. It was only a 5–10-minute teaching moment where I spoke through how to do it, but I didn't have any examples. …. Unfortunately, time got away and I ... forgot to come back to this activity, but I think it could have been quite valuable. [I noticed that] some seemed to be more actively accessing their data and reading with a more critical lens. Rather than just

seeing the data and then drawing some basic information from it that is easy to comprehend (which seemed to be an issue), some definitely reduced this…. This could have [been] great value if more specifically planned with examples to support and an engaging activity, rather than 'chalk and talk' impromptu.

Summary and Conclusion

In Australia, students with low socio-economic status have experienced declining performance in mathematics (O'Keeffe & Paige, 2021), creating challenges for students when presented with critical numeracy experiences. Educational policy highlights the importance of numeracy across the curriculum, however there is still huge variation in the ways numeracy is defined and understood within the sector. The challenge of including more numeracy across the curriculum is multi-faceted. Whole school approaches to numeracy are reliant on clear and consistent messages about what numeracy is and whose responsibility it is. In this study, we saw better alignment between teachers' understanding of numeracy after targeted workshops aimed at challenging teachers to think differently about numeracy. Through dialogue and support to see and make numeracy connections rather than feel obliged to teach mathematics, these teachers and their students had predominantly positive experiences in making numeracy across the curriculum a priority in their learning areas.

Teachers in this study connected their numeracy moments primarily with mathematical knowledge, contexts and tools which is consistent with what they personally aimed to gain from being in the project. The limited connections to student dispositions and critical orientation suggest that more work needs to be done to support these teachers in developing a richer picture of numeracy beyond transfer of mathematical knowledge to other learning areas.

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