What can other areas teach us about numeracy?

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Education professionals, regardless of their specialist area, are broadly aware of the importance of numeracy. Internationally, definitions of numeracy (known elsewhere as mathematical literacy or quantitative reasoning), describe "an individual's capacity to formulate, employ and interpret mathematics in a variety of contexts... reasoning mathematically and using mathematical concepts, procedures, facts, and tools to describe, explain and predict phenomena... recognising the role that mathematics plays in the world and to make the well-founded judgements and decisions needed by constructive, engaged and reflective citizens." (Organisation for Economic Co-Operation and Development, 2014, p. 37), or more locally, numeracy is "the knowledge and skills to use mathematics confidently across all learning areas at school and in their lives more broadly... It involves students 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 [ACARA], 2012, p. 25).

Descriptions such as "incorporating the use of mathematics to meet the demands of day-to-day life" roll off the tongue of many a teacher, but their working understanding of what numeracy is may be limited to "counting and measuring" or "maths", or more optimistically "problem solving with numbers" or "the ability to use maths in real-world scenarios". Aspects of numeracy such as logical reasoning, spatial thinking and visual representation are not at the forefront of teachers' perception of what numeracy is, perhaps due to the historical acceptance of arithmetic skills being the limit of the mathematical knowledge required for everyday routines (Australian Association of Mathematics Teachers [AAMT], 1998), and the current regime of NAPLAN may also be influencing what numeracy is understood to be and what can be done to teach students about it (Hogan, 2012). The follow-on effect of this is these non-arithmetic areas may not be accessed by students in classrooms.

Perceptions and experiences

It could be argued that providing teachers with a range of numeracy-based discipline-specific resources would better enable them to integrate the use of numeracy skills within their subject as we have seen in the case of literacy —but this would risk numeracy becoming even more of a curriculum add-on than it already is for many teachers. If the focus instead is directed towards developing teachers' awareness and confidence of what numeracy is, perhaps emphasising and incorporating activities that will build students' fluency, strategies and confidence in using mathematical knowledge, skills and ideas in the context of every day living would be more practical and achievable.

However, the stalling point in incorporating numeracy for many teachers seems to be a lack of awareness of how and where numeracy is evident in their curricula—perhaps a remnant of their experience with school mathematics in years gone by.

It has been my experience whilst observing lessons and discussing numeracy with secondary (non-mathematics) teachers that opportunities to develop students' numeracy outcomes are evident throughout secondary classrooms but many of these opportunities seem to be overlooked. Teachers appear to be unfamiliar with the scope of numeracy tasks beyond the arithmetic basics, and it could be argued that many of the examples provided in contemporary curriculum documents (see ACARA, 2014 amongst others) are add-ons rather than tasks that use mathematics skills to support the learning of other subjects' content and so do not demonstrate how teachers can incorporate numeracy into their lessons in a meaningful way,

A teacher's confidence in incorporating numeracy-based skills and ideas appears to be correlated to their individual achievement and knowledge of the scope of numeracy beyond arithmetic. This in itself would be dependent upon the context of their own life experiences, applications and confidence in applying contextually appropriate mathematical strategies, knowledge and ideas (Beswick, 2008; Scott, 1999). This is echoed in my own observations: teachers are well equipped to respond to numeracy ideas within a task, although it seems that without the indicators of formal notation or mathematics-specific language, teachers are unaware of the many and varied opportunities to embed numeracy into their lessons. Combine this with the general confusion (or misrepresentation) between mathematics and numeracy and there is no surprise that many teachers have limited appreciation for their own capacity for numeracy, and consequently maximising opportunities within their subject to enhance outcomes for their students.

This is not to say that teachers who did not study mathematics at a tertiary level are not equipped to adequately address student numeracy learning needs, it merely recognises the challenge they face in identifying the broad scope of numeracy-rich opportunities in their lessons. Drawing from their own life and professional experiences, teachers outside of the mathematics faculty arguably have a good understanding of the role of number-based numeracy skills within their subject area. The arithmetic ideas of counting, measuring and perhaps even interpreting data could readily be applied in context under the banner of their subject content knowledge, as could skills like multiplying fractions in Food Technology or estimating distance in Physical Education as well as specific knowledge such as using equations in Science or drawing scale diagrams in Industrial Technology. However, being able to identify opportunities to further students' numeracy development is not necessarily a part of the typical repertoire of skills of secondary teachers.

A history and an example

As a passionate numeracy educator I have been involved in teacher professional learning in numeracy across my school, most commonly in the form of a faculty- or whole-school staff meeting during the less-than optimal after school time slot (Christensen, 2005) and held during the lead up to national standardised student testing. A typical session would involve describing numeracy according to the many policy documents available, reviewing the school's outcomes in numeracy according to examination results, working through examples of generic numeracy-based questions drawn from a standardised test, and perhaps (time allowing) an open discussion in general terms about how teachers can help students, but with no real strategies, examples or evidence considered.

The model described above reinforces the perception of numeracy as an add-on and offers little incentive for teachers to reflect on their practice. The next week, all is forgotten and teachers are left frustrated and disillusioned, wondering how to affect real change for their students. Fed up with this recurring scenario, I have embarked on a research project that hopes to identify how to best work with teachers to enhance student numeracy outcomes.

One of my project participants, Robert (a pseudonym), chose to be a part of my research because he feels that his students are lacking the kind of skills that protect them from the poor life outcomes associated with low numeracy levels such as high mental illness rates, incarceration and underemployment (Parsons & Bynner, 2005). Robert teaches at a rural, comprehensive high school in NSW and is a specialist geography teacher, with a background in political science, tourism and trade. He has described his personal understanding of mathematics as 'better than average' having achieved highly in his own school experience of mathematics, and feels that his knowledge of mathematical language, formal notation skills and solid understanding of core mathematical ideas are of direct benefit to his teaching practice. Robert described his past experiences of professional learning in numeracy as presentations made during staff meetings immediately before NAPLAN testing, and that he had not taken much from those sessions as they did not provide him with strategies to help students.

One of the first discussions I had with Robert touched on his belief that trying to incorporate numeracy into an already packed curriculum would lead to superficial learning that devalues both numeracy and the topic of study: a statement made to me often in my years delivering professional learning. We then went on to examine a unit of work he was writing where he had identified a task where students would need to draw on their mathematical knowledge, but he was not sure if there were opportunities to actually develop their numeracy skills.

The unit of work investigated the Indonesian Buddhist Temple Borobodur and was presented as an electronic booklet containing text and images with links to visual media. The text was aimed at Year 9 and 10 students and was explicitly supported with literacy strategies described by Robert as part of the school's cross-curricular program for literacy improvement. The task that Robert had identified as requiring mathematical skill was the construction of a timeline depicting the temple's long history. Students were to read a passage of text (see breakout box, p. 31) and then answer the following questions:

1. How long did it take to build Borobodur?
2. How long was it covered in ash?
3. Create a timeline (drawn to scale) to show the significant events mentioned in the history of Borobodur.

What was immediately apparent to me as a mathematics specialist was the need to scaffold the timeline questions so all students could access the task regardless of their experience or expertise, just as Robert had done for other tasks in the booklet that required strong literacy skills. As the task presented students with a problem to solve, I introduced Robert to Polya's problem solving method (Polya, 1957) as a suite of teaching and learning tools for solving mathematical problems. We rewrote the questions so that they would present to students as smaller problems to solve:

1. List the significant events mentioned in the history of Borobodur in date order.
2. Create a timeline using an appropriate scale for your events.
3. How long did it take to build Borobodur?
4. How long was it covered in ash?

The inclusion of the fourth question above gave rise to a discussion about inferred questions and I introduced Robert to using Three Level Guides (Stewart-Dore, 1990) as a text analysis tool. He was familiar with the concept and felt he had seen it before, but was not aware of its name, nor its application beyond a strictly literary context. With that, a fifth question was added:

5. Approximately how many times did Mount Merapai erupt during the time that Borobodur lay abandoned?

The Borobudur Temple compounds are a UNESCO World Heritage listed monument. It is located in the Kedu Valley, in the southern part of Central Java, at the centre of the island of Java, Indonesia. Borobudur is one of the greatest Buddhist monuments in the world. It was built between 750 AD and 842 AD. It was built to honour Buddha and is a place where many Buddhist pilgrims come to pray. The name Borobudur is believed to have been from the Sanskrit (an ancient language of India) words vihara Buddha uhr, meaning the Buddhist monastery on the hill. The temple rises imposingly from the surrounding landscape, inspiring all travellers who come to visit it. Once a year Buddhists in Indonesia celebrate Vesak (informally known as Buddha's birthday) at Borobudur.

Around the beginning of the 11th century AD, the temple was abandoned and fell into disrepair as a result of the declining influence Buddhism and the growth of Islam in Indonesia. It was eventually abandoned, becoming covered by volcanic ash from nearby Mt Merapi. Worldwide knowledge of its existence was generated in 1814 by Sir Thomas Stamford Raffles, then the British ruler of Java, who was advised of its location by native Indonesians. Restoration work however, did not begin until 1975. Borobudur was inscribed on the World Heritage list in 1991.

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Borobudur Temple Compounds is an outstanding example of Indonesia's art and architecture from between the early 8th and late 9th centuries that exerted considerable influence on an architectural revival between the mid-13th and early 16th centuries.

...

Mt Merapi is an active volcano located only 30 kilometres away. Merapi is one of the most active volcanoes in Indonesia. Smoke is visible from the volcano most days of the year and it erupts significantly approximately every 10 to 15 years.

Introducing another question where students had to take data from the text and use it to solve a problem with no exact of definitive answer fulfilled Robert's intention of embedding numeracy into the unit of work in a meaningful way. By using numeracy skills to develop a timeline of events, students were better able to appreciate Borobodur's importance in Indonesian history and culture.

He was keen to include more numeracy-based ideas in the unit of work, but felt that there were few other activities in the booklet that would engage students in using their numeracy skills without being tokenistic. This is

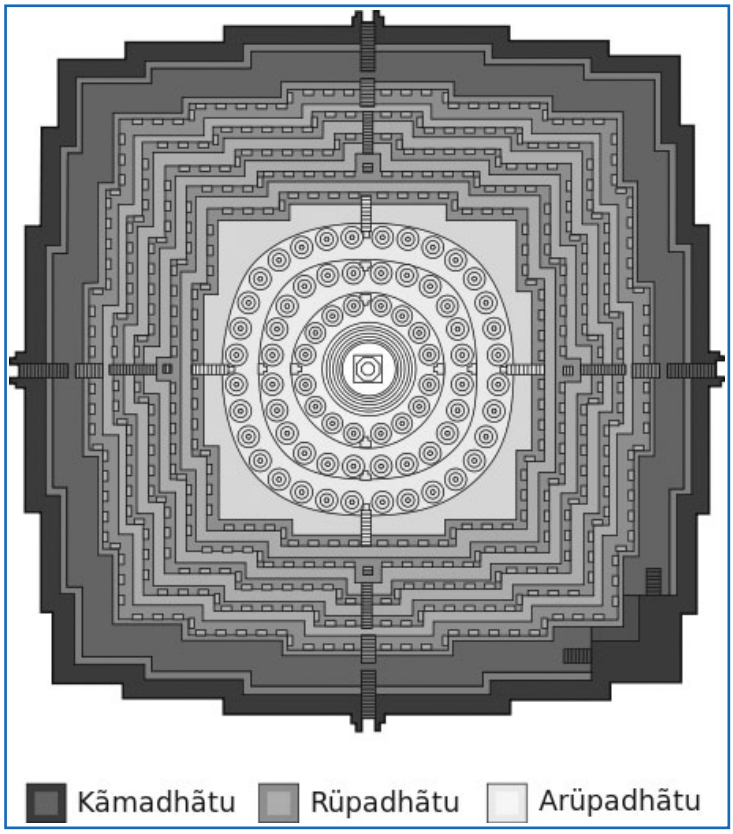

Figure 1. Plan view of Borobodur Temple (Kartapranata, 2009).

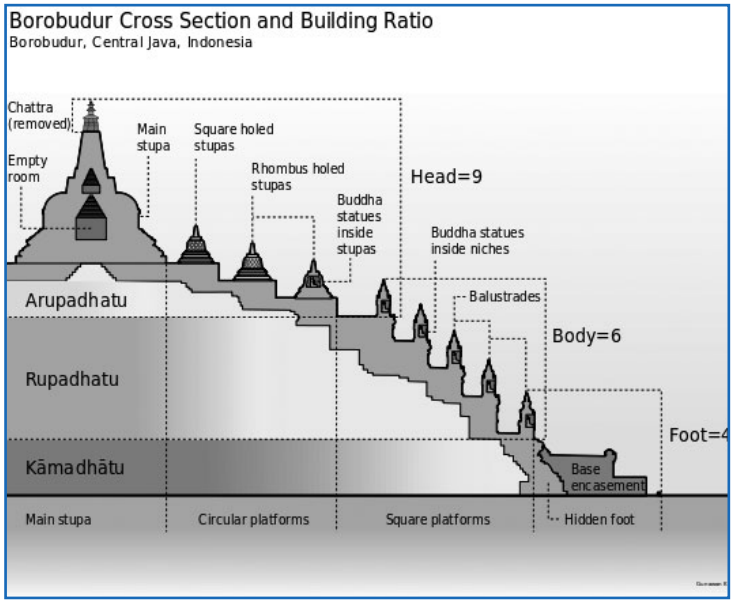

Figure 2. Cross section of Borobodur Temple (Kartapranata, 2011).

reflective of the broader notion discussed earlier in this article that teachers seem to have a narrow perception of what numeracy is. He commented that he, "wanted to maintain a high expectation of the quality of student work without compromising the numeracy or geography elements of the task". He was well aware of the potential for calculation-based activities given the ample data provided on tourist statistics, the number of statues and measurements for the relief panels, but he thought that including questions that required students to reach for their calculator deviated from the purpose of the task and did not show the relevant mathematical ideas or the skill of using mathematics in different contexts in a particularly flattering light.

As we further reviewed the content unit of work, it became apparent that Robert was unaware of the many opportunities in the booklet to enrich the students' understanding of geography-based knowledge with numeracy-based skills and understanding. For instance, Robert had included information on the design features and symbolism of Borobodur and provided plan and cross-section views of the temple (see Figures 1 and 2). A quick discussion on the geometric features of the diagrams led Robert to include some questions that he hoped would help students recognise the cultural importance placed on art and design, and would also reinforce the use of mathematically correct language which would contribute to improving students' literacy outcomes

1. What do you think is meant by building ratio?
2. What do you notice about the circular and square shapes in the plan view?
3. What kinds of symmetry does Borobodur have?
4. Lightly draw in any lines of symmetry on to the plan view.

Looking at the art and design elements of the temple through a lense of symmetry and geometric patterns opened up an opportunity for students to examine history and culture while using mathematical skills in an authentic way.

Robert's teaching and learning practice has a strong focus on literacy as his school has provided extensive professional learning in specific literacy strategies that are research-driven and evidence-based (Wallace, Power, Holloway & Harkness, 2012). Robert wanted to incorporate specific mathematical terminology, as he believed this would help students in becoming mathematically literate. He included some common terms such as circumference and pyramid and had used words instead of abbreviations for units of measurement. His fondness for using specific mathematical terms was deepened with the suggestion of including less common but contextually relevant terms. For instance, the temple was described in the text as having, "four staircases facing east, west, north and south". Deliberately adding another mathematical term to make the sentence read as, "four staircases facing the cardinal directions (north, south, east and west)" meant students could see a very specific, technical term in a context that was relevant yet possibly unfamiliar. Robert made the final edits to the workbook trusting that he had increased the quality and quantity of opportunities for students to improve their numeracy outcomes.

Discussion and conclusion

The process of working on a numeracy task that was not written specifically to address a school goal was a first for both myself as a teacher-researcher and Robert as a co-researcher, and reflected positively on Robert's dedication to enhancing student numeracy outcomes as well as his openness and general attitude to numeracy as more than a curriculum add-on. The discussion points that arose from our brief but detailed analysis of the unit of work rested around the themes of the value of numeracy in non-mathematics classrooms, the self-perception and awareness of the non-mathematics teacher and lessons we can learn from the journey of embedding literacy across the curriculum.

Robert's apprehension about devaluing the tasks set for his students was both a reflection of his initial understanding of what numeracy is and his high standard for maximising classroom time. His reluctance to include arithmetic calculations "just for the sake of it" indicated that he saw calculators as a tool rather than a skill, at least in this scenario, and his impetus to push students' numeracy understanding beyond "mindless busywork" reflected this. Robert's sensitivity to the time restraints in meeting syllabus requirements was also a significant factor in seeking professional learning as he felt the status afforded to numeracy in school curricula was perfunctory and he wanted to achieve more as a professional.

Robert's adaptations of the unit of work were in many cases modelled on strategies he was familiar with from his extensive training in literacy, and in at least one case Robert intended to use a literacy strategy for the specific purpose of improving students' numeracy. Borrowing from our cousins in the literacy domain is not new, and in fact there are many literacy strategies that can assist students in learning the complexities of mathematical English (Carter & Quinnell, 2012). What we can take from Robert's participation in this undertaking is that his experience as a teacher of literacy assisted his journey in developing skills as a teacher of numeracy. In conjunction with

his desire to learn, opportunity to apply new skills immediately to a realistic problem and being involved in professional learning that was informal and offered guidance rather than instruction, the model applied in this scenario was consistent with best practice in adult education (Brookfield, 1986).

The ease at which Robert incorporated numeracy tasks within the unit of work may reveal a relationship between the mathematical background of a teacher and his or her engagement in numeracy-rich activities. Robert's high personal mathematical knowledge and confidence in applying mathematical ideas within his subject area allowed him to quickly recognise tasks that would be easy to modify for the purposes of enhancing student numeracy, but initially only within the context of working collaboratively with a numeracy specialist. It seems that teachers, possibly irrespective of their own achievement level in school-based mathematics, can benefit from specific attendance to identifying the links between their personal and professional numeracy expertise and the pedagogical aspects of embedding numeracy tasks into their lessons, supported by a framework of peer learning. It seems evident that mathematics educators play a significant role as facilitators for guiding our colleagues in identifying contextually relevant numeracy-based skills and ideas within their subject area.

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