A Working Understanding of Numeracy in the Secondary Setting

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This paper reports on a recent qualitative case study that explored the numeracy understanding and practices of a secondary school teacher who did not have formal teaching qualifications in mathematics. Results of the study suggest that although teachers may be able to confidently articulate a definition of numeracy, their working understanding, application of numeracy concepts and propensity to facilitate student learning opportunities in numeracy are less certain.

Numeracy has long been a focus for education in Australia and is recognised as a core skill required by students across all learning areas (Council of Australian Governments [COAG], 2008; Ministerial Council on Education Employment Training and Youth Affairs [MCEETYA], 2008). The importance of numeracy as a lifelong skill has been acknowledged at a national level by its inclusion in the Australian Curriculum as a cross-curricular capability that involves students developing the knowledge and skills to use mathematics across all learning areas at school (Australian Curriculum Assessment and Reporting Authority [ACARA], 2012) and the inclusion of strategies to support student numeracy knowledge and understanding as a part of national teacher accreditation requirements (Australian Institute for Teaching and School Leadership, 2011). The relevance of numeracy as a teaching focus has been embraced by the primary and middle school sectors as evidenced by the amount of research and professional learning available in these areas, but there appears to be comparatively little to support the development of student numeracy by non-mathematics teachers in the secondary school setting.

The findings discussed in this paper are from a small project initiated to provide proof-of-principle for a larger study that will be the foundation of a doctoral thesis. The project's purpose is to develop an understanding of how secondary teachers currently incorporate numeracy ideas into their non-mathematics classrooms, and to highlight the opportunities for further research in this area and the need for professional learning programs that address the specific circumstances of secondary school teachers in relation to developing their students' numeracy. This paper reports on the initial interview and observation phases of the project and examines the pedagogical reflections and practices of a secondary school Geography teacher.

Numeracy in the Secondary Classroom

The recent introduction of the Australian Curriculum has emphasised the importance of equipping students with generic skills such as numeracy, which will enable them to participate in a complex, globalised world (ACARA, 2013). In Australia's case, we are faced with two battles: keeping our curriculum flexible and responsive by incorporating the skills and knowledge our students will need in an unknown future (MCEETYA, 2008), and reversing the decline in student achievement in numeracy over the past decade (Thomson, De Bortoli, & Buckley, 2013). The issue of poor performance is not isolated to Australia or even to numeracy, as literacy achievement amongst our students has also declined

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(Thomson, et al., 2013), and we cannot rely on the natural renewal of teaching staff via teacher preparation programs to respond to this trend. An Australian study indicated that a third of beginning secondary teachers did not feel at all prepared to teach numeracy compared to less than 10% of respondents who felt unprepared to teach literacy (Milton, Rohl, & House, 2007). Milton et al. (2007) also noted that even amongst students with mathematics as their specialist teaching area, only 70% gave a positive response in regards to their preparedness to teach numeracy. There does not appear to be similar research on the views of experienced teachers, however there is no evidence that the results would be significantly different or that the situation for beginning teachers might have improved since 2007.

The role of the teacher in determining student success has attracted the attention of researchers and employers (Askew, Rhodes, Brown, Wiliam, & Johnson, 1997; Australian Association of Mathematics Teachers [AAMT], 2002; COAG, 2008; MCEETYA, 2008; Rowe, 2003). This has led to a range of initiatives aimed at teacher professional learning such as the federally-funded Smarter Schools project (Department of Education, Employment and Workplace Relations, 2012), however large-scale projects and research that have a numeracy emphasis have predominantly focused on the primary sector (e.g., Askew, et al., 1997; Clarke et al., 2002). Similar studies in the secondary school sector are much smaller in size and scope, and although research is growing in this area there is limited literature available to inform practitioners and other interested parties about teaching numeracy in secondary schools, especially by experienced teachers.

Numeracy is identified in the Australian Curriculum as a general capability that involves students developing "the knowledge and skills to use mathematics across all learning areas at school and in their lives more broadly" (ACARA, 2013, p. 16). All teachers share the responsibility of contributing to the numeracy development of their students with a wide range of educational needs accordingly (AAMT, 1998; Milton, et al., 2007). However, there is little agreement of what numeracy is (Steen, 2001) and while there is broad understanding that numeracy is important, the current context of national standardised testing may be influencing what numeracy is understood to be and what teachers can to do teach it (Hogan, 2012).

Numeracy is context dependent (Beswick, 2008) so it falls to teachers outside the mathematics classroom to model its use in order to develop numeracy understanding amongst their students in contexts outside the mathematics classroom. Using mathematics well is central to all learning areas, and teachers need to consider how to properly acknowledge and respond to the numeracy demands of their curriculum by employing strategies that enable students to learn effectively (Thornton & Hogan, 2005). Central to this is, of course, the necessity that teachers themselves are able to recognise and confidently apply the mathematical knowledge, skills and ideas that underpin the numeracy intrinsic to their subject area (Thornton & Hogan, 2004).

Confidence in teaching numeracy amongst teachers was briefly acknowledged earlier in this paper; however, it is important to distinguish the different influences on teachers' understanding of numeracy that may contribute to how they approach it in the classroom. A recent study showed that although teachers are confident in their understanding of what numeracy is, they lack confidence in planning, teaching, assessing and creating appropriate learning environments for the development of numeracy in their students (Goos, Dole, & Geiger, 2012b).

Teachers' beliefs about numeracy and whether they can be effective teachers of numeracy are related to their knowledge and understanding of numeracy (Bennison &

Goos, 2013), but their beliefs and practices can be influenced by professional learning (Beswick, 2008). As Australia moves towards a nationwide curriculum that incorporates numeracy across all learning areas, it is an opportune time to examine current practices and build upon existing knowledge and understanding of numeracy teaching practice amongst secondary school teachers to inform targeted professional learning.

The Study

Methodology

This paper examines the experience of one teacher in the context of a larger multiple case study focused on the experiences of secondary school teachers whose specialist teaching areas were not mathematics. The participants worked in the same comprehensive 7-12 high school in a provincial centre in New South Wales that practices academic streaming from Year 8 for all learning areas except Physical and Health Education. The school's student population is from a mid to low socioeconomic community with a predominantly Anglo-celtic cultural background. The school was selected as the author, a past staff member, had a good working knowledge of the school's recent educational foci.

There were four participants in the study and this paper focuses on Robert (a pseudonym) as the data extracted from his case was representative of other participants' experiences in teaching, curriculum development and professional learning, but in Robert's case his observed lesson demonstrated a broader range of the complexities of teaching numeracy in a classroom situation than the other participants' observed lesson.

Robert taught in the Human Society and its Environment faculty and had a background in political science and international relations, qualifying him to teach Geography, Business Studies and Legal Studies to Year 12. Robert came to teaching after a career in the transportation industry and raising his young family. At the time of the project he had 6 years teaching experience including time spent in a partially selective metropolitan school in western Sydney. His professional philosophy for teaching at the school was to lift his students out of the poverty cycle that is endemic in the local community and he saw literacy and numeracy levels as key determinants of students' post-school outcomes. Robert studied high–level mathematics during his own schooling and expressed confidence in applying mathematical knowledge and strategies in his private and professional life. It should be noted that Robert had previously worked closely with the author in formal workplace contexts and less-formal contexts such as extended school excursions.

Data Collection and Analysis

The study spanned one school term (10 weeks) and data were gathered from several sources. The participants each took part in a semi-structured interview of approximately 40 minutes, a 50-minute lesson observation and an unstructured interview of approximately 30 minutes following the observation. Participants were provided with a list of prompts (interview questions) prior to the initial interview to give them adequate time to consider how they engage with numeracy in daily practice and to gather documents to support their responses. The interview questions provided stimuli for discussion about the participants' knowledge of and confidence in embedding numeracy into their lessons and programs, to examine the extent of support provided by the relevant state-based curriculum documents and to audit past experiences of professional learning in numeracy.

There were no criteria as to what was required of the observed classes in terms of content or academic level. The author made written field notes that recorded on-task student-teacher interactions and student-to-student discussions with particular attention to numeracy-based interactions, and took copies of student worksheets and the participants' whiteboard notes. It should be noted that students present in observed lessons were considered to be participants for ethical reasons, however their input towards the data was limited to project-related interaction between themselves and with the teacher participant. The class discussed in this paper was a Year 9 Geography class described by Robert as being a moderately achieving class where, as a junior class, he had more flexibility in delivery of content compared to senior classes. He anticipated being asked to present a numeracy-focused lesson, however it was made clear that was not a requirement of the study prior to the observation taking place.

The follow up interviews were conducted within a week of the lesson observation. In this context, participants engaged in a professional dialogue about the numeracy demands of the lesson that had been observed and were provided with feedback with reference to current research in numeracy. This discussion included informal professional learning on deconstructing mathematics-based problems using Polya's (1957) Heuristic and Newman's Error Analysis (as cited in Watson, 1980). Initial analysis of research themes was conducted immediately after each episode of data collection, and further analysis was carried out to identify curriculum content descriptions and numeracy elements evident in the observed lessons.

Numeracy in the Geography Classroom

Understanding Numeracy

In the initial interview Robert defined numeracy as "being able to use maths in other contexts" and placed a high value on strong numeracy skills. He described many scenarios in both professional and personal settings where numeracy skills could be employed, however they were limited to examples where the underlying mathematical knowledge was arithmetic or measurement. He identified geometry-based skills as requisite knowledge in Geography but associated them with mathematics rather than numeracy. Robert frequently used the term *mathematics* but then corrected himself to *numeracy* except in the case of describing geometry knowledge and skills.

Robert regarded himself as an "incidental teacher of numeracy" in that his lessons do not have a specific numeracy focus but he does facilitate student learning opportunities in numeracy as they arise. He described meeting the curriculum's outcomes for numeracy as difficult and the curriculum "not explicit enough in its links with numeracy to know whether [he's] meeting [the students'] needs". He considered himself as having a solid foundation in teaching literacy (which had been a school-wide focus for three years), and said that numeracy was an "'also ran' in the school and the wider profession". Robert described his access to and confidence in developing subject-specific resources to support student literacy outcomes as substantial but was not aware of any subject-specific resources for numeracy nor would he be confident in developing them himself.

He was frustrated by the lack of availability of professional learning in numeracy, although he acknowledged that his focus is predominantly on Geography and literacy, both of which he said had, "many courses and programs and resources on offer". After some prompting (and with the benefit of first-hand experience of the school's history in professional learning for numeracy on the part of the author) he recalled a one-hour after-

school staff meeting where, "the focus was on lifting the school's standardised testing results" rather than the classroom-based ideas and techniques Robert viewed as "the key to making professional learning memorable and time worthy".

Teaching Numeracy

The lesson observed was about latitude and longitude and was the first lesson in 10-lesson unit of work on mapping skills. The lesson was structured as a brief, teacher-led introduction of approximately 10 minutes, a sustained period of students working independently or collaboratively on workbooks followed by a whole-class, teacher-led discussion on the issues raised in the task during the last 5 minutes of the lesson.

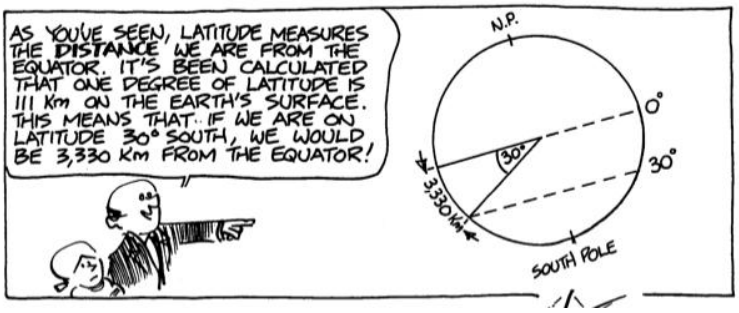

Figure 1: Student workbook text sample (source unknown)

The task required students to read text that was presented as a comic (see Figure 1) and interpret diagrams in order to answer written questions (see Figure 2). The lesson incorporated the use of mathematics-specific language (e.g., rotate, parallel, perpendicular), descriptions of angles in relation to vertical tilt and elevation/depression, spherical geometry, time, cardinal directions and addition of fractions. Robert responded to students' mathematical literacy demands with a range of strategies he later described as being in his "literacy bag of tricks", such as engaging the students in a game of Hangman to identify the formal term for circles with a common centre.

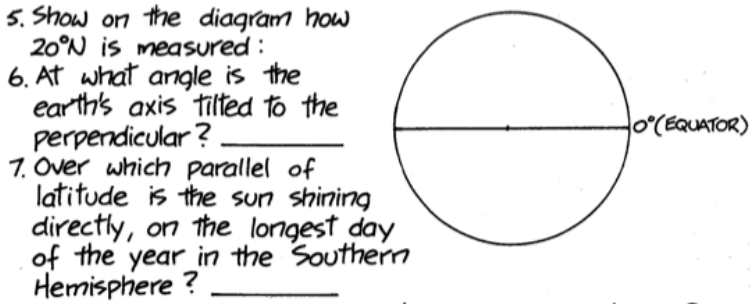

Figure 2: Student workbook question sample (source unknown)

The students asked a number of questions about the work that had strong links to numeracy. For instance, one student asked about the location of the international date line, and Robert pointed out the (labelled) international date line and prime meridian on a globe, and said that they were "opposite each other because they're 180° apart". Robert also made connections with previously learned concepts in Geography and mathematics. One such instance was when a student asked for a protractor to answer Question 5 in the workbook as shown in Figure 2, Robert asked whether students were required to draw every diagram

perfectly when in a mathematics class, or would a neat sketch be appropriate in a scenario such as this.

Robert also demonstrated some concepts physically. For example, in order to answer a student's questions about the seasons, he nominated that student as "The Sun" and as Robert held a globe and rotated it, he walked around the student and described the affect of Earth's position in relation to the sun. He subsequently drew a diagram of Earth's orbit around the sun on the whiteboard with the solstices and equinoxes marked accordingly.

Robert had anticipated that students would engage with the task as it was presented in an appealing format and he had made adjustments for the students whose low literacy comprehension would otherwise lead to them not understanding the text and disengaging. After the lesson he stated that compared to his usual lessons, he was more alert to the numeracy content he was delivering as he was conscious of being observed, although he also stated that he forgot the author was there half way through the lesson. He described the lesson as typical in regards to the nature and frequency of students questions about numeracy-related content, but he described his practice as "enlightened" in that he was more confident in his teaching methods in relation to numeracy due to his participation in the project and consequent realisation that he was able to explicitly use his own mathematical knowledge and understanding to further student outcomes in numeracy.

Discussion

Robert's experiences described above highlight several areas for consideration, as they appear to impact upon his practice and approaches to teaching numeracy. How teachers understand numeracy both in practice and as a policy definition was a theme identified in the wider project as well, and will be discussed in this section.

Previous research (Beswick, 2008) has discussed how a person's understanding of numeracy depends on a range of factors, such as past experiences or occupation. Thus, numeracy can mean different things to different people. In Robert's context numeracy had two definitions. Firstly, numeracy was seen as a skill required by all students and could be defined by a well-constructed statement reflective of his school's policy on numeracy that make links to mathematics and real-world applications. Secondly, Robert had a working understanding of numeracy that was framed in terms of what he does in class i.e., he would list activities dependent on numeracy, for instance scale, mapping skills and population pyramids.

Robert's initial focus on computational and measurement aspects of numeracy were typical of the participants in the study. As Robert engaged in more discussions about numeracy with the author, it was revealed that Robert saw a delineation between numeracy and mathematics, despite articulating a definition of numeracy that specifically referred to mathematics and reflected school policy definitions of numeracy (Hogan, 2012). What Robert was unable to articulate was the range of numeracy-based skills in his pedagogical content knowledge. Skills such as developing students' knowledge of how geographic space is represented and the ability to reason and make decisions demand the numeracy skills of spatial awareness and problem solving, yet Robert interpreted these things as being different to numeracy. The tendency to overlook skills such as estimation or problem solving as numeracy-based has been researched before and is not limited to Geography or teaching (Zevenbergen & Zevenbergen, 2009).

Problem solving was an area of numeracy that was completely overlooked by Robert in the initial phase of the project, however towards the end of the project he articulated a

broader understanding of the scope of numeracy, especially in relation to spatial patterns and analytical skills. These areas in particular are increasingly being identified as opportunities to develop what Geographers refer to as spatial literacy, or the ability to understand spatial relationships and the ability to reason and make decisions about spatial concepts (Maude, 2010; McInerney, 2008).

Robert recognised that the state-based and Australian curriculum documents for Geography provide broad definitions of numeracy and indicators of when numeracy may be evident in a learning task, but expressed disappointment that there are no examples of how numeracy could be developed in his learning area. The lack of guidance in recognising numeracy demands of subjects other than mathematics, and the absence of direct references to additional opportunities for developing students' numeracy capabilities has been recognised in recent research (Goos, Dole, & Geiger, 2012a) and while Robert was appreciative of curriculum documents that were not prescriptive in terms of teaching and learning practices he described frustration in regards to providing learning tasks that explicitly attend to student numeracy skills due to a lack of knowledge and resources.

Robert expressed an improved level of confidence in helping students identify where mathematical skills and ideas might help them in the context of Geography towards the end of the project. He also made the observation that he was only able to help students with numeracy as he personally possessed a high level of mathematical understanding and had the disposition to use mathematical ideas in the context of Geography - an observation consistent with past research (Goos, Geiger, & Dole, 2010; Perso, 2006).

Conclusion

This paper sought to discuss the working understanding of numeracy of a secondary school teacher. The project highlighted the difficulties faced by secondary school teachers in meeting their requirement to provide numeracy rich learning environments as numeracy ideas are not explicit in the curriculum documents that provide a framework for student learning experiences. Consequently, opportunities to develop student numeracy capabilities are dependent on the numeracy understanding and mathematical capacity, confidence and disposition of the classroom teacher to develop numeracy learning occurrences.

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