

## Exploring Teachers' Numeracy Pedagogies and Subsequent Student Learning across Five Dimensions of Numeracy

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This paper reports the case of two teachers with respect to the positioning of numeracy in a reform curriculum and subsequent student learning across five dimensions of numeracy. By analysing the conversations of these two teachers, their underlying beliefs about numeracy and its value and role in the curriculum were able to be explored. These beliefs were further reflected in the learning outcomes of the six students in this study. The paper describes examples of how the five dimensions of numeracy were evident in the thinking and practice of both the teachers and their students.

Recent curriculum reform in Tasmania has been guided by a consideration of the knowledge, skills, and attributes required of students living in the twenty-first century. Tasmania's Essential Learnings Framework (Department of Education, Tasmania [DoET], 2002) places thinking skills and strategies at the core of the curriculum and encourages the connection of knowledge and concepts across the curriculum. It emphasises the importance of being numerate rather than purely of knowing and doing mathematics. An ability to understand and apply mathematical concepts is valued alongside the development of students' abilities to problem solve, reason, communicate, and reflect upon their learning.

### *Teachers and Students Negotiating Curriculum in the Classroom*

Innovative and reform curricula are filtered through teachers' beliefs and practices (Wilson & Lloyd, 2000). Although researchers are aware of the broader contexts and policy-driven environments that influence curriculum construction, it is the curriculum that is enacted in the classroom that drives the research from which this study is taken. Teachers add a pedagogical dimension to curriculum to create daily learning experiences for their students. It is that knowledge that equips teachers to "lift the curriculum away from texts and materials [and] to give it an independent existence" (Doyle, 1992, p. 499).

The role of the student in curriculum is also acknowledged. Students determine their own level of engagement and interest in classroom activity and therefore exert some control over their learning and knowledge construction. Snyder, Acker-Hocevar, and Snyder (1992) suggest that "curriculum enactment" appropriately describes the process of implementation and educational experience that teachers and students jointly undertake as they negotiate and determine what the curriculum will be like in each classroom.

With respect to the teaching of mathematics, teachers' knowledge, beliefs, and practices play a significant role in the learning of their students (Hill, Rowan, & Ball, 2005). It is therefore important to look at the beliefs and practices of teachers in relation to the learning of students in Tasmania's curriculum context. This study aims to deepen understanding of the construct of numeracy through considering two ideas:

- The way in which two teachers position numeracy in a values-focused curriculum, and
- The way in which their students experience numeracy.

## Theoretical Framework

Numeracy has become an essential capability for any individual who wishes to participate fully in a democratic society and to apply not only knowledge and skills, but also critical reasoning capabilities, to learning and to everyday life. “Whereas mathematics is a well-established discipline, numeracy is necessarily interdisciplinary ... numeracy must permeate the curriculum. When it does ... it will enhance students’ understanding of all subjects and their capacity to lead informed lives” (Steen, 2001, p. 115). The concepts and skills required to meet the numeracy demands of everyday life are defined and examined under various names, including quantitative literacy (Steen, 2001), mathematical literacy (Organisation for Economic Cooperation and Development [OECD], 2006), critical numeracy (Johnston, 1994), mathemacy (Skovsmose, 2004), and numeracy (Australian Association of Mathematics Teachers [AAMT], 1998). Each definition has particular theoretical underpinnings, whether it be an emphasis on the psychological, social, or cultural nature of learning, or as is the case of more recent terms, such as mathemacy and criticalmathematical [sic] literacy, whether it be informed by critical theory where the role of politics and power within social and cultural contexts is placed at the fore.

Green (2002), in considering the role of literacy in the English classroom, and the wider curriculum, acknowledges the different discourses of language, meaning, and power that play a role in the development of literacy. He advocates the synthesis of these dimensions in forming a three-dimensional model of literacy where “the most worthwhile robust understanding of literacy is one that brings together the “operational”, “cultural”, and “critical” dimensions of literate practice and learning” (Green, 2002, p. 27). Although Green acknowledges the political nature of literacy as a social practice, he calls for a balance between all the important dimensions of literacy with the aim being to support students in meaning-making in context.

It is equally important for mathematics educators to acknowledge the different dimensions that are necessary for the development of competent and effective numeracy practice. Mathematical language, skills, and functions are required for students to make sense of, and critically evaluate, the contexts in which the mathematics is embedded. The socio-cultural and critical aspects of knowledge construction enable the selection of appropriate mathematical tools and informed critique of both mathematics and society. This study acknowledges the important contribution each element brings to a comprehensive definition of numeracy. Numeracy is about making meaning of mathematics, at whatever level of mathematical skill. It is not inferior to mathematics, but rather is about understanding and using mathematics, in all of its representations, for making sense of the world, for considering critically information presented, and for making informed decisions.

The view of numeracy adopted in this study is underpinned by social constructivist theory. Shepard (2001) expounds the principles of social constructivism as drawing from contemporary cognitive, constructivist, and socio-cultural theories. Although valuing the sense-making and active process of mental construction that individuals undergo to construct their own knowledge, the importance of the social and cultural interactions is not neglected.

Table 1 contains a summary of five dimensions of numeracy, based upon the aforementioned principles together with a comprehensive review of the literature as it pertains to numeracy education. In particular, the work of AAMT (1998), Steen (2001) and

Queensland School Curriculum Council (1999) was considered in presenting a comprehensive balanced view of numeracy extending across foundational mathematical concepts and skills, strategic thinking, disposition, recognition of context, and critical practice. Numeracy is a complex construct with many aspects, beyond mathematical skill, contributing to a high level of numerate behaviour.

Table 1  
*Dimensions of Numeracy*

Aspects of knowledge construction	Dimensions of numeracy	Description
FOUNDATIONAL	Mathematics	The foundational understanding and use of the language, concepts, and skills of mathematics, as they relate to number, measurement, space, data and chance, and pattern and algebra.
PSYCHOLOGICAL	Reasoning	The use of (i) mathematical thinking strategies to question, identify, represent, explain, and justify mathematical approaches relevant to a given context, and (ii) general thinking strategies to support the problem solving process, from lower level cognitive processes, such as recall and application, to higher level critical thinking processes involved in evaluation, judgment, decision making, and creativity.
AFFECTIVE	Attitude	The confidence and disposition to choose and use mathematical understandings wherever required. Willingness to take risks and persevere in approaching new mathematics and new contexts.
SOCIO-CULTURAL	Context	The ability to select and apply the appropriate mathematical tools for sense-making in a given context and understanding how the context impacts on the mathematics. Contexts related to school and everyday life, public and social issues, and an awareness of mathematics connected to history and culture.
CRITICAL	Equity	Awareness that mathematics can be used inappropriately, can be represented to promote bias, and can therefore promote inequities in society. The ability to question assumptions and use mathematics in an analytical and critical manner to make decisions and resolve problems and investigations.

## Method

The research reported in this paper was part of a larger qualitative study designed to investigate the positioning of numeracy by teachers of middle grade classrooms (Grades 5-8) in Tasmania's reform environment and student experiences of numeracy in these classrooms. The larger study adopted a collective case study approach with five participant teachers and their students. All the teachers had an interest in numeracy and planned and implemented units of work informed by Tasmania's Essential Learnings curriculum framework (DoET, 2002). In addition, a representation of middle years' grades was sought across a range of schools. The research used a combination of interview, observation, document, and photographic data to provide insight into the unique positioning of numeracy as enacted in the classroom by each teacher and the experiences of their students.

In this study the case of two Grade 8 teachers, interviewed together, and six of their students is reported. Teacher interviews were semi-structured and lasted approximately 40-50 minutes. They were designed to gain an insight into teacher beliefs and practices with respect to current curriculum reforms; views concerning the place of numeracy within these reforms; and their planning, teaching, and assessment practices.

After completing the unit of work with the 34 Grade 8 students, six students were invited to participate in an individual in-depth interview. These six students were chosen by the teachers, in consultation with the researcher, as representing a spread of mathematical ability. The student interviews were semi-structured and were 30-40 minutes in length. The students brought relevant work samples to the interview to support discussion about the tasks they completed.

As a qualitative study, cluster analysis (Miles & Huberman, 1994) was used to code the teacher and student interviews. They were analysed according to the five dimensions of numeracy as detailed in Table 1 of the theoretical framework. Excerpts from both the teacher and student interviews are included in this study to illustrate each of the dimensions of numeracy as they were exhibited.

## Context of the Study

### *The School Setting*

Tanglefoot School, an independent girls' school, was the setting for the study. Although part of the wider Tasmanian educational community, as an independent school, Tanglefoot did not fall directly under control of the state government education system. The Essential Learnings Framework (DoET, 2002) was included in Tanglefoot's Middle School Handbook as the underpinning framework that informed a curriculum incorporating three main aspects: traditional subject disciplines, interdisciplinary units of work, and six week mini-courses providing options in academic, life skills, and recreational areas of student interest.

At Tanglefoot School the discipline of mathematics was a core subject for students in the middle school. It involved the explicit teaching of the five strands of mathematics: number, space, measurement, chance and data, and algebra, in addition to thinking, acting, and communicating mathematically. Each Grade 8 class had four 50-minute mathematics lessons timetabled each week with students' numeracy capabilities encouraged through the discipline of mathematics. At times, however, students were also required to draw upon their knowledge and skills developed in mathematics for use in other subject areas and in their interdisciplinary units of work. This was the situation with the unit of work observed during the case study.

### *The Unit of Work: Live 8*

Ange and Jen (pseudonyms), the two Grade 8 teachers at Tanglefoot School, worked collaboratively to implement a five week integrated unit of work, *Live 8*, inspired by music concerts held across the world in 2005, by prominent musicians, to highlight the issue of world poverty. Ange and Jen were motivated by a belief that the *Live 8* concerts would provide the Grade 8 students with an engaging, real-world context in which to learn about the contrasting nature of developed and under-developed countries and issues related to the broader concept of poverty. The unit of work brought together the disciplines of Mathematics and Studies of Society and the Environment (SOSE) with the aim of enhancing students' numeracy capabilities, their abilities to work collaboratively, their skills in information literacy and communication, and ultimately their understandings of the concept of poverty. The context of poverty was used to develop further the students' skills in graphing and data analysis. The unit of work culminated with the girls completing

a major assignment requiring them to investigate one country and compare it to life in Australia. Students were specifically asked to consider aspects such as population, mortality rates, literacy levels, income, government systems, economies, water supply, and aid programs.

## Results

### *The Teachers: Ange and Jen*

Ange, the teacher of Mathematics and Science for the middle school had been teaching for seven years and commenced at Tanglefoot School in 2003. Jen, the teacher of English and SOSE, had been teaching for three years. Tasmania's Essential Learnings Framework (DoET, 2002) informed Ange and Jen's teaching since it had been incorporated into Tanglefoot's construction of middle school curriculum in 2003. Ange and Jen were interviewed together, with Ange playing a predominant role and Jen contributing where she felt comfortable and where she wished to add a comment.

Ange and Jen felt that the Essential Learnings (ELs), Tasmania's curriculum, supported "real-life learning goals" and "[sat] nicely with integrated units of work". They gave examples of where they had planned for mathematical learning in previous integrated units of work. In addition, Ange and Jen spoke of the inclusive nature of the ELs catering for the "different learning needs" of students and allowing students to "go in and show exactly what they do know and what they can achieve", contributing to development of students' "self-esteem". Their personal views were aligned with the school's construction of curriculum and they also had autonomy over how they implemented integrated units of work with their students.

Ange and Jen expressed a view toward numeracy that did not place the role of numeracy across the curriculum above the role of mathematics as a "discrete subject". Ange, in particular, spoke of the importance of mathematics for providing some students with "pathways" for their future learning and that the ELs enabled a focus to "get the girls interested in maths" and learning to be numerate across disciplines. The following section details how the two teachers' conversations about their teaching practice could be described according to the five dimensions as state earlier in the Theoretical Framework.

*Mathematics.* The foundational role that mathematics plays in developing numeracy was evident when Ange described numeracy. "I think numeracy is applying, the application of those mathematics skills into different areas". Her content knowledge was evident through many of the comments she made as she discussed her teaching. For example, aspects of the content of algebra and number were mentioned in describing the importance of teaching and assessing for numeracy.

As the SOSE teacher, Jen mentioned the importance of students having the opportunity to apply their knowledge of concepts related to culture, community, society, and the environment to build their understanding of important mathematical concepts.

In SOSE we use numeracy in graphing, reading tables, analysing statistics and things like that. I make sure they can relate it to [life] ... If they have to apply it they can actually grasp the concept.

*Reasoning.* In discussing the role of numeracy in the middle school curriculum, Ange referred to the language of "thinking" as forming an important part of student assessment. Both teachers referred to the middle school assessment booklet (Tanglefoot, 2005) on numerous occasions and the important role it had in informing their teaching and

assessment practices. In this booklet, strategies such as posing questions, recalling strategies and relationships, conjecturing, justifying, explaining, and drawing conclusions were listed as important elements of working mathematically.

The teachers talked about wanting to see evidence of how the students were thinking and problem solving. Ange highlighted the value of students “showing their working out” as it helped the teachers to “really know how they [the students] are going” as opposed to “working in class out of books”. She felt that text books did not provide her with information on how students were thinking when solving problems.

*Attitude.* The importance of a positive disposition toward numeracy in contributing to positive numeracy outcomes, although not explicitly mentioned by either of the two teachers, was implicit in their comments. Ange mentioned her aim to “get the girls interested in maths” through the teaching of numeracy. Jen said she wanted to “make sure the girls can relate to it” and tried to engage the students with tasks that would be of interest to them. For Ange and Jen, the role of numeracy, as mathematics in context, was the key to developing this engagement, “interest”, and positive disposition.

*Context.* Both Ange and Jen expressed a belief that numeracy was very much about using mathematics in context. They saw numeracy as “something that is taught in lots of subjects” and involving the “application of mathematical skills into different areas”.

Jen gave examples from when she spent a short time teaching Grade 7 mathematics, not her usual teaching area, where she would provide the students with opportunities to “try to apply that knowledge too... to real-life situations”. The contexts valued by the teachers were authentic, real-world contexts, as evidenced in this comment by Ange.

I think that is the way that maths will probably be going in the future. It is going to be real-world context and I think that is important. ... and I think the ELs, with Being Numerate as a focus, will sit quite nicely with integrated units of work. Hopefully that will develop over the years.

When talking about their teaching they provided examples of contexts they had used with students. Contexts such as crime, health, design, and decorating were mentioned.

*Equity.* Ange discussed how important it was for mathematics education to cater for “the needs of all students”. She described numeracy in its role across the curriculum as being the way “to get the people who struggle”. Although neither Ange nor Jen expressed in the interview aspects of numeracy teaching that would equip students with the ability to consider information critically, or consider inequities in society, the *Live 8* unit of work implemented after the interview provided an example of their underlying beliefs in this area.

### *The Students*

The six students interviewed in this study were asked to describe and discuss specific graphs they had completed during the unit of work. In particular, the graphs included in students’ major assignments on poverty formed the focus for the interviews. The students were happy to participate in the interview and were forthcoming in telling the stories of their graphs. The conversations started with specific mathematical content displayed in the graphs but as the interview progressed the comments encompassed broader issues about how the graphs helped them understand poverty. The following excerpts provide examples of the students’ learning across the five dimensions of numeracy.

*Mathematics.* All the students demonstrated specific mathematics understandings in explaining their graphs and used the mathematics to help them when comparing their

country of investigation to Australia. They also used the language of mathematics, specifically as it related to chance and data, and number. The range of their responses is evident in the following excerpts.

The big difference in the way that Afghanistan live to the way Australia live, like the average income, people in Australia can earn \$30,000 a year easily, and in Afghanistan it is \$280 a month (emphasised). [Student 5]

The gini index for Australia is 35.2 and then for Rwanda it is 28.9. Basically with the gini index, zero is all the money in the country is completely fairly distributed and 100 means completely unevenly distributed. [Student 6]

It shows that pretty much everyone in Australia can read that are over the age of fifteen, but in Nepal they don't have much literacy, or options to read. The literacy rates for men are just over 60% and the females just over 25%. [Student 3]

Some students also mentioned how their previous mathematics learning had helped during this unit of work, as exemplified by Student 6's comment about frequency tables.

We have done frequency tables before in maths and it helped here because I understood. With graphs I always forget which way the x and y axes go. It helped me to remember and how to set it out and what they're for. [Student 6]

*Reasoning.* The thinking strategies of students were identified when they were describing their graphs. Student 4's comments about literacy rates in Sudan was typical of the students as they became engaged in the discussion and moved beyond the mathematics in their graphs to the reasons for the results and considering other information they had researched about their country.

Ah well the literacy rate. Here I suppose it shows that the females, as in probably most countries in that region or area are less educated than males, probably because of priorities in the system and religious beliefs. The literacy in Australia is obviously amazingly higher than Sudan but in Sudan they have a program, I can't remember but they give free education and I think it is for the first six years and the government is focusing on eliminating illiteracy in the country. [ Student 4]

The ability of the students to make comparisons and explain their work was shown by one student when she demonstrated a distinct engagement with the issue by her surprise and shock.

When I looked at this it really shocked me a bit because you don't really realise how much money goes in and out of your house and for Australia \$800 a week is really a lot of money and when I saw Somalia which is one dollar it was really amazing. The graph when you look at it you can really see the difference between the two countries. [Student 2]

At times the students' thinking moved to a focus on the impact of poverty on the context of their particular country of investigation.

The other countries, since they are so rich they shouldn't worry about it because they have a lot of money and the aid programs are good, but they probably need to do more to help the country out like bring in more food supplies and more fresh water. [Student 3]

Comparing the data makes it more personal and thinking about children there who can't read and write when they're fifteen and stuff like that. [Student 1]

*Attitude.* Students' personal disposition toward numeracy became evident when they were discussing their work. Five of the six students expressed a preference for using mathematics in real-life settings. Student 6, for example, focused on the application of skills in engaging her in learning.

It is more interesting and you actually put it to use rather than just learning it so we actually put it there and have to come back to the skills we've learnt and stick it on. I prefer to use it in real life because it's interesting and it's so much better because it is for something you're learning about and not learning how to do it. [Student 6]

By “stick it on” the student here was referring to applying the mathematics. Three of the six students mentioned the value of having to find the relevant information for themselves and making decisions about how to represent their data.

Students' willingness to persevere and engage with the task was exemplified in different ways. Examples include a comment by one student about the time put into gathering correct statistics, and by another student about the discussions she had with family members.

Well it was actually quite hard to compile all the correct statistics and data. I had to go to several different websites and collect different numbers for each year and then I had to put them all together. [Student 4]

I talked to my sister about it on the phone and she is in London, so it helped me to understand how *Live 8* was working and what was happening and that had an influence on the way I did my assignment. [Student 5]

*Context.* The context of student learning, in this case the country of investigation and wider issues of poverty, featured prominently when students were explaining their graphs. As discussed above in the dimension of “Attitude” students expressed a preference for applying their learning of mathematics to real-life contexts. There were many times, in explaining their graphs, that the students focused on the context of their country.

They're one of the poorest countries in the world and most of the people live under the poverty line and children under five die of malnourishment before they reach the age of five. [Student 3]

They are probably not living past the age of 50 because of all the violence, heaps and heaps of people were killed, and the water and disease and stuff like cholera and dysentery. [Student 6]

Student 5 also noted the value of situating her learning in the context of the country that formed the focus of her investigation, and the importance of comparing living conditions in that country to life in Australia.

It was good to realise how much of a difference there is to the way we live to the way other countries live, because if we hadn't done this we wouldn't have known. It has made us more aware of the way we live to the way for example that Afghanistan lives. [Student 5]

*Equity.* In this particular unit of work, the mathematics enabled the students to question societal structures. Student 1 described the tensions between the importance of wealthier countries providing financial support and the difficulty in ensuring the money goes to where it is needed.

I think that the richer and more developed countries in the world need to offer money and support, like they are at the moment but I also think like in Africa they have got corrupt governments and so they give them money and all that sort of thing but often the government takes it for themselves rather than using it to help the people. I think something needs to be done about the governments, but even if their government is overthrown they are still going to need support from richer countries. [Student 1]

Student 2 focused on the basic needs and important resources needed in underdeveloped countries.



Just getting aid into countries and helping get clean water and clean food and resources and I think all the countries like America and Australia and Asia should really put in to help out these countries that are not as well off because Africa is a struggling country and I think they really do need some help and we are being a big selfish with our resources. [Student 2]

All six students considered personal contributions that they felt would, in some small way, assist in alleviating poverty. The following excerpts represent the range of suggestions, from supporting local fundraising opportunities and raising awareness, to considering a career in overseas aid work.

I think a lot of countries do help out, but people in general could help more. Like everyday people, we do try to help and we may see an ad on tv about sponsoring children or fundraising but I think we need to focus more on ourselves and what we can do. [Student 4]

Well ever since I was little I have wanted to make a difference in those kinds of places, like I want to study medicine and help out there. ... I was thinking of going and being a doctor of an anaesthetist or paediatrician in somewhere like Somalia or probably in Iraq. [Student 2]

## Discussion and Conclusion

Although the two teachers in this study were not explicit about what contributes to high level numeracy, when discussing their teaching practice the five dimensions of numeracy were evident in their discourse and impacted upon the learning outcomes of their students. The positioning of numeracy, as a cross-curricular construct in the curriculum, informed Ange and Jen's teaching practice. They saw the foundational role of mathematics as crucial for students when tasks required them to apply their understanding of mathematical concepts in subjects other than mathematics and in integrated units of work. The teachers encouraged their students to show their reasoning when solving problems and when discussing their work in order to inform Ange and Jen's assessment of student learning.

Real-world contexts were described by the teachers as important for the learning of students. These included a combination of school and everyday contexts that the girls could relate to and also wider social, cultural, and political contexts. These real-world contexts were viewed as being central to the development of positive student attitudes toward numeracy. Planning for numeracy outcomes in interdisciplinary settings was seen by the teachers as supporting not only the learning of mathematics, but also of other important concepts. Students were encouraged to use mathematics to consider and reflect upon society and its structures and inequities.

By analysing the conversations of these two teachers, their underlying beliefs about numeracy and its value and role in the curriculum were able to be explored. These beliefs were further reflected in the discourse of the six students in this study. The students were able to identify appropriate mathematics in describing their work. Their mathematical understandings also enabled them to engage positively with the context, to consider many issues related to the context of the country they investigated, and finally to move toward an informed critique of poverty.

As Australia grapples with the re-conceptualisation of curriculum it is crucial that the place of numeracy is considered. This study has considered the positioning of numeracy by two teachers in a reform environment and the numeracy experiences of their students. It has described examples of how the five dimensions of numeracy were evident in the thinking and practice of both the teachers and the students. The results demonstrate the possibilities for student learning across all the dimensions of numeracy, when mathematics

is purposefully embedded within interdisciplinary frameworks. Further analysis of the data that forms the larger research project, from which this study was reported, will contribute further to understanding the complex nature of the construct of numeracy.

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