

ORIENTATIONS TO NUMERACY: TEACHERS' CONFIDENCE AND DISPOSITION TO USE MATHEMATICS ACROSS THE CURRICULUM

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Numeracy can be defined as “having the competence and disposition to use mathematics to meet the general demands of life at home, in paid work, and for participation in community and civic life” (Willis 1992). An important aspect of developing the capacity to use mathematics in everyday life is, for students at school, to use mathematics to meet the demands of other curriculum areas. Just as literacy has become every teacher’s responsibility, so numeracy needs to be seen as integral to every learning area.

This research report describes non-mathematics teachers’ orientations to numeracy, and the development of their sense of identity as mathematicians and as reflective practitioners, as they confront and deal with mathematical problems and opportunities encountered by students across the curriculum.

NUMERACY

Numeracy, quantitative literacy and mathematical literacy have become very much “in-vogue” terms in educational circles (Crowther 1959, Cockroft 1982, Gal 1999, Frankenstein 2001, Steen 2001). Coben (2003) gives an extensive review of this literature, emphasizing that numeracy is a contested term rooted in its social, economic, cultural and historical context.

In Australia Willis’ (1992) described numeracy as “at the very least, having the competence and disposition to use mathematics to meet the general demands of life and at home, in paid work, and for participation in community and civic life”. This definition was later picked up by the Australian Association of Mathematics Teachers (AAMT 1998), emphasizing that numeracy is context specific and relative, that all teachers have a role to play in developing students’ numeracy, and that numeracy is underpinned by mathematical concepts. The Commonwealth Department of Employment, Education, Training and Youth Affairs (DEETYA 1997) also adopted Willis’ view of numeracy, and acknowledged that numeracy was “a fundamental component of learning, discourse and critique across all areas of the curriculum”.

Thus there is a long history of thinking about numeracy as contextual and practical, and as more than just arithmetic. Yet even a cursory glance at curriculum documents and statewide assessments in Australian education, such as the numeracy benchmarks (Curriculum Corporation 2000) and Secondary Numeracy Assessment Program (SNAP) assessment in New South Wales, suggests that this distinction has become blurred, and that numeracy is often seen as little more than school mathematics. Both

have a clear emphasis on fundamental mathematical skills, and very little discussion of the use of mathematics to meet the general demands of life at home or in the community.

This focus on the essential aspects of mathematics appears to embody a naïve view of improving student numeracy. It assumes that ‘mathematics can be learned in school, embedded within any learning structures, and then lifted out of school to be applied to any situation in the real world’ (Boaler 1993, p.12). However, the growing literature on the nature of transfer of learning and the evidence suggests that students do not automatically use their mathematical knowledge in other areas. Lave (1988) found that even experience in simulated shopping tasks in the classroom did not transfer to the supermarket. On the other hand, it appears that people use highly effective informal mathematics in specific situations (Carraher, Carraher & Schliemann 1985, Hogan 1996).

It would be easy to attribute this lack of transfer of mathematical skills to other contexts to a deficient mathematics curriculum and poor teaching, but the quite considerable debate about transfer of skills shows that even if mathematics were taught and learned very well people would not necessarily apply it to new situations (Griffin 1995). Researchers in the area of situated cognition argue that cognitive skills and knowledge are not independent of context, and that activities and situations are integral to cognition and learning (Brown, Collins & Duguid 1989; Resnick 1989).

In order to respond to these issues there has been an attempt to contextualize school mathematics using contexts which appear to be relevant to the students (Cohen 2001). It was hoped that this would help students to see the purpose and usefulness of the mathematics they were learning, and that the mathematics would make sense. However, despite teachers’ best efforts many of these ‘real world problems’ appeared contrived rather than real (Willis 1992); required students and teachers to participate in ‘a willful suspension of disbelief about reality and mathematics’ (Williams 1993); and left out factors relevant to the real situation (Boaler 1993). Further, these attempts still had a primary purpose of teaching mathematics rather than developing numeracy. It would seem that if students are to learn to use mathematics outside the mathematics classroom then that is where they need to experience using mathematics.

For children aged between 5 and 16, a significant part of their life is spent at school, most of it studying subjects other than mathematics. For them, the “real world” includes school, and in particular the time in academic pursuits other than mathematics. Hence if students are to see mathematics as connected to the real world or to become “numerate” in the sense described by Willis and others, they need to use mathematics in a range of contexts, including other curriculum areas.

RESEARCH METHODOLOGY AND THEORETICAL ORIENTATION

The Middle Years Numeracy Across the Curriculum Project commissioned by the Australian Capital Territory Department of Education, Youth and Family Services (ACT DEFYS) attempted to address the somewhat naïve concepts of numeracy

outlined above by placing numeracy firmly in context, as the domain of all teachers. The Project involved researchers working with teachers from several ACT schools to identify and document numeracy opportunities, and to design, develop and implement an effective and transferable model that would support ongoing, school-based engagement with numeracy across the curriculum. This model would help teachers identify the numeracy demands of their teaching area(s), support teachers in implementing strategies for improving student numeracy outcomes and learning across the curriculum, and facilitate productive professional discussion on numeracy within and across all curriculum areas in schools;

The research methodology was based on Research Circles (ANSN 1999), in which teachers came together for periods of time to discuss their work, to observe and evaluate classroom incidents, and document these case studies. Initially the focus was on identifying “numeracy moments”, with the focus later moving to school-wide planning for numeracy across the curriculum.

The Research Circles involved nineteen teachers from eight schools. These teachers taught students in years 5 to 10 in a range of settings, including traditional primary schools (up to year 6), high schools (years 7 to 10) and middle schools (years 6 to 9). The primary school teachers all taught every area of the curriculum, the middle school teachers taught a “core” program of three or four subject areas including mathematics, the high school teachers taught predominantly in one subject area, generally not mathematics.

Each teacher was first asked to write down her perception of numeracy and what she hoped to obtain from participating in the project. Teachers were introduced to the Numeracy Framework (Hogan 2000), which describes being numerate as involving a blend of three knowledges:

1. *Mathematical* knowledge – the skills, techniques and concepts necessary to solve quantitative problems encountered in a real context;
2. *Contextual* knowledge – awareness and knowledge of how the context impacted on the mathematics being used; and
3. *Strategic* knowledge – having the confidence, disposition and skills to find out what needs to be known in order to act numerately.

The Framework suggests that being, or becoming, numerate involves being able to, or learning to, take on three roles:

1. *The fluent operator* - Being (becoming) a fluent user of mathematics in familiar settings;
2. *The learner* - Having (developing) a capacity for the deliberate use of mathematics to learn; and
3. *The critical mathematician* - Having (developing) a capacity to be critical of the mathematics chosen and used.

Following this initial discussion and orientation each teacher developed a classroom-based action research project that would enable her to examine students' numeracy in the classroom. The teachers undertook to record, in as much detail as possible, the circumstances in which students encountered mathematical ideas, the problems they had in understanding the mathematics and/or the context, the action taken by the teacher and what the student did next.

Research continued via group sharing and discussion of observations, refinement of the projects, and formal writing up of the results. The discussion provided a rich array of examples of teachers observing student numeracy, and a constructive forum through which others could provide feedback. It became apparent that the teacher-researchers had begun to look more closely at the students' responses to numeracy demands across the curriculum. They had begun to see that a student's numeracy problem might not be simply a matter of not knowing the mathematics, but might relate to the context, or their inability to continue work on the task once they confront something they can't do. When it was seen to be an issue with the mathematics the teachers were more sensitive to what the mathematical problem might be.

ORIENTATIONS TO NUMERACY

The three orientations to numeracy described below represent idealized cases, rather than specific individuals. In reality no one teacher matched perfectly any of the three types, however in examining the implications of various orientations to numeracy for the development of teacher and student identity it is helpful to describe some idealized type examples.

The separatist: "It's the mathematics teacher's job"

The separatist recognizes that mathematical skills are important. The job of teaching these skills resides squarely with the mathematics teacher. Thus when students struggle to understand a mathematical concept that is encountered within another area of the school curriculum, it is because they have not learnt, or perhaps not been taught, the mathematics well enough. Thus mathematics teachers need to teach mathematics better – "It's not my job".

"These students have not learnt how to construct scales on a graph properly. Even if they were taught scales and graphs in math, they didn't learn it properly, because they can't do it now in science." (Participant observation of student learning)

It may be that the separatist sees numeracy as "not their job" because she, herself, has a fear of, or a negative view of mathematics.

"I feel – part fear, especially of failure, avoidance." (Participant feedback after initial discussions of numeracy across the curriculum)

It may also be that her understanding of her own subject area is inadequate, and that she fails to recognize quantitative aspects of it. In one instance a teacher discussed the inadequacies of computer technology for constructing graphs of titrations in Chemistry, believing that because the graph of pH varied wildly, it was not as

accurate as plotting by hand when universal indicator was used. She perhaps overlooked the possibility that wild variations in pH were the result of inadequate mixing, a contextual problem that was not apparent in hand-drawn graphs. It may even be that she does not have the awareness of “knowing to act” in a given situation (Mason 1998).

It is worth noting that in the extensive literature on student identity as mathematicians (Boaler 1997, Wiliam, Boaler and Zevenbergen 2000) the development of this identity is always related back to experiences in the mathematics classroom. While the environment in the mathematics classroom is undoubtedly a major component in the development of students’ identity as mathematicians, it could be argued that the broader school environment, and in particular the way mathematics is seen and used across the curriculum, may also play a key role. Student identity is complex and multi-faceted; it is, perhaps, somewhat naïve to suggest that the development of mathematical identity is the exclusive domain of the mathematics teacher. Perhaps the “community of practice” (secondary school mathematics) described by Wiliam, Boaler and Zevenbergen (2000) should include the practice of mathematics in other areas of the school curriculum. This is an issue worthy of further research.

The theme-maker: “Mathematics and other learning areas should be integrated.”

The theme-maker recognizes that mathematics has links to other subjects and the real world. She believes that mathematics should be relevant and interesting to the student, and hence develops units of work that incorporate mathematics and other learning areas in parallel, often based around a theme. Assessment activities often involve relatively open-ended, across curriculum projects such as those espoused in the “rich tasks” movement (Education Queensland). She believes that students will learn mathematics better because they are interested and engaged.

“Students were given the following scenario – Astronomers have recently detected a pulsating phenomenon in another galaxy.

Your task as an astrophysicist is to determine what this object is and plan an exploratory expedition to investigate this ‘phenomenon’.” (Participant teaching and learning plan)

This teaching and learning plan outlined how science, social science, art, English and mathematics fitted into this theme of exploring the universe. The mathematics included patterns found in nature such as Fibonacci and its connection with the Golden Ratio, and an introduction to scientific notation and exponents in preparation for the large numbers the students were likely to encounter in their reading.

This view of numeracy is very much to the fore in many of the organizational solutions to some of the issues surrounding the disengagement of students in the middle years of schooling. In such solutions the number of teachers who interact directly with any one student in the first two years of secondary school is minimized, and teachers are expected to teach in three or more curriculum areas, such as mathematics, science and physical education, or English, geography and history. It is

expected that the curriculum will thus be developed around coherent themes, and that the distinctions between the different learning areas will become blurred. However, such an approach runs the risk of enacting a simplistic view of mathematics, and minimizing the contribution that the distinctive elements of seeing the world through mathematical eyes can make to our understanding of ourselves and society (Frankenstein 2001)

The embedder: “Doing mathematics well is essential to learning other learning areas well”

The embedder recognizes that all learning areas include quantitative elements that students need to understand. These quantitative elements are embedded within the context of other learning areas and cannot be divorced from that context. A mathematical view of the world enriches students’ understanding of every other curriculum area. The embedder believes that every teacher is a teacher of numeracy (that is, of mathematics as it is embedded in their area of expertise), and has a responsibility to vigorously intervene in students’ learning of mathematics in that context.

“In a science lesson students read that the human body contains 6 million red blood cells. When I asked students what this number meant very few could write it down and none could visualize what such a number might look like. We spent some time thinking about what 6 million centimeters or 6 million seconds might be. This added to students’ understanding of the science.”

“The class read ‘Day of the Triffids’. We used this as an opportunity to look at scale drawings and made a model of a triffid that reached up the wall of the classroom. Students were then able to get a much better sense of how people in the story must have felt when they saw a triffid.”

The embedder is confident in her use of mathematics as it applies to her own area of expertise, without necessarily being an expert mathematician. She is curious, not only about her own area of expertise, but of mathematics and how it impacts on that area (Simtt, Davis, Gordon and Towers 2003). She is also aware of students’ knowledge both of the learning area and of the mathematical skills and concepts that are necessary to learn it well. She knows to act in a given situation and, when students are confronted by a problem, decides whether the issues are ones of not having the requisite mathematical skills, ones of not understanding the context or ones of not having the strategic knowledge to act effectively. She recognizes that the methods used by students in a mathematics classroom are not necessarily those used by them in other settings. She encourages students to reflect on the mathematics they have used in doing a task – being critical of the mathematics is something that has to be nurtured.

Conclusions

Whose job is to develop students’ numeracy? If the role of school education is, at least in part, to equip the population with the knowledge, skills and strategies to be

thoughtful, productive and critical members of society, then numeracy is everyone's responsibility. Without an awareness of the underpinning role of mathematical ideas in problem solving, in communication and in public debate, it is debatable to what extent an individual can arrive at informed decisions or follow productive strategies. School mathematics alone is unlikely to develop this capacity in our students – it requires conscious effort by all teachers, and a willingness to engage in mathematical thinking in all learning areas. Identifying and capitalizing on numeracy moments not only develops students' capacity to be numerate, it also enriches their learning in other areas of the curriculum.

If learning is to be situated, students need to encounter mathematics not only in their mathematics lessons, nor even in supposedly real-world problems posed during mathematics lessons, but also as it is embedded in the practice of other curriculum areas. They need to be given opportunities to see themselves as learner, critic and fluent numeracy operator within those contexts. Changing teachers' perceptions of numeracy, and helping them to develop the confidence and disposition to embed numeracy in other areas of the curriculum, is critical to developing this community of practice.

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