Researching Numeracy in the Middle Years

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Numeracy has become a key priority of government policy in recent years generating a number of numeracy-related projects. This paper will provide an overview of the *Middle Years Numeracy Research Project* commissioned by the three employer groups in Victoria in 1999 and report on the design and development of a *Student Numeracy Profile* incorporating rich assessment tasks and involving teacher judgements in the assessment of student numeracy performance. Preliminary analysis of the *Student Numeracy Profile* instrument suggests that it is an effective measure of numeracy at this level with the potential to provide useful insights into instructional strategies for middle years' students.

Numeracy has become a major priority area for all Federal, State and Territory governments in recent years. This is most clearly seen in the *National Goals for Schooling in the Twenty First Century*, which includes the goal "that every student should be numerate and be able to read, write, spell and communicate at an appropriate level" (MCEETYA, 1999). It is also evident in the *National Literacy and Numeracy Plan (DEETYA, 1998)* and the *National Literacy and Numeracy Benchmarks* for Years 3, 5 and 7 (National Numeracy Benchmarks Taskforce, 1997). While literacy has always been a high priority of government, the focus on numeracy is relatively recent. Prior to the 1990s, numeracy was primarily viewed as a sub-set of literacy and largely confined to the non-school sector (that is, industry training, adult education and labour market programs). This heritage is reflected in *Being numerate – What counts?* (Willis, 1990) and *Numeracy in Focus*, a joint publication of the Adult Literacy Information Office and the Adult Basic Education Resource and Information Service (Riordan & Tout, 1995).

While the first use of the term *numeracy*, is generally credited to the authors of the Crowther Report in 1959 (Cockroft, 1982), current Australian usage owes more to the view presented in *Maths Counts* (Cockcroft, 1982, p.11) than it does to the view expressed in the Crowther Report or the more recent *United Kingdom National Numeracy Strategy*, which quite clearly privileges number over other aspects of mathematics.

> Numeracy is defined as more than knowing about numbers and number operations. It includes an ability and inclination to solve numerical problems, including those involving money and measurement. It also demands familiarity with the ways in which numerical information is gathered by counting and measuring, and is presented in graphs, charts and tables (quoted in Rhodes et al., 1998).

A broader, more encompassing view of numeracy is evident in *Numeracy = Everyone's Business* (AAMT, 1997), the Report of the Numeracy Education Strategy Development Conference held in Perth in February 1997, which cites the following policy positions.

> To be numerate is to have and be able to use appropriate mathematical knowledge, understanding, skills, intuition and experience whenever they are needed in everyday life. Numeracy is more than just being able to manipulate numbers. The content of numeracy is derived from five strands of the mathematics curriculum ... as described in the National Statement and Profiles (from *Numerate Students, Numerate Adults*, Department of Education Tasmania, 1995).

> Numeracy involves abilities which include interpreting, applying and communicating mathematical information in commonly encountered situations to enable full, critical and effective participation in a wide range of life roles (from *Literacy and Numeracy Strategy 1994-8,* Department of Education Queensland, 1994).

> Numeracy is the effective use of mathematics to meet the general demands of life at home, in paid work, and for participation in community and civic life. ... the National Numeracy Benchmarks will refer to the contribution that school mathematics and other areas of learning make to the development of students' numeracy. They will incorporate the development of students' understanding and competence with number and quantity (ie, measurement), shape and location and the handling and interpretation of quantitative data. (National Benchmarking Taskforce, 1997)

These views are variously reflected in the statement developed as a consequence of the meeting in Perth.

> To be numerate is to use mathematics effectively to meet the general demands of life at home, in paid work and for participation in community and civic life. In school education, numeracy is a fundamental component of learning, performance, discourse and critique across all areas of the curriculum. It involves the disposition to use, in context, a combination of: underpinning mathematical concepts and skills from across the discipline (numerical, spatial, graphical, statistical and algebraic); mathematical thinking and strategies; general thinking skills; and a grounded appreciation of context (AAMT, 1997, p. 15).

This view suggests that numeracy involves a much broader range of knowledge skills and attributes than can be simply characterised as "basic number facts and skills", that numeracy is simultaneously both bigger than and smaller than school mathematics, and that numeracy has a powerful role to play in facilitating communication and decision making. Perhaps more importantly, it acknowledges that numeracy is *relative to context.* That is, an individual is neither numerate nor innumerate, simply more or less numerate depending on the context in which he/she is expected to operate (Willis, cited in AAMT, 1997). This means that different views of numeracy requiring different assumptions and approaches will be needed for different levels of schooling and contexts (Scott, 1999).

In the early years, the focus is predominantly on the development of counting and number, especially the development of place-value understanding, and the disposition and strategies needed to apply these ideas and skills in relevant contexts. This is evident in *Count Me in Too* (NSW), the *First Steps Program* (WA), and the *Early Years Numeracy Research Project* (Victoria). Although some of these key ideas and strategies need to be consolidated and extended in Years 5-9 (e.g., to support an appreciation of fractions and decimals), numeracy education at this level needs to focus on the development of a broader repertoire of knowledge, skills and dispositions. It needs to equip students to deal effectively with a much larger range of more complex problems involving applications of measurement, data, chance and space. At this stage, cross curriculum links and cross curriculum learning become more relevant in developing strong foundations in numeracy.

Different assumptions and approaches to numeracy at this level are also needed as the socio-cultural context of teaching and learning in the middle years is substantially different to the early years (see Hill & Russell, 1999). Disengagement, low-self-esteem, absenteeism, and poor learning behaviours, concomitant with the pressures of adolescence and school transition, present significant challenges to teachers in the middle years. Trying to uncover what works and does not work in this context is also compounded by the enormous variation in student (and to some extent teacher) knowledge and confidence. Attempts to improve numeracy in the middle years will need to consider not only the contribution that school mathematics might make but also how to impact entrenched classroom cultures, scaffold discourse elements and engage learners more effectively. While existing research in mathematics education provides some guidance, translating these into consistent, coherent advice appears to be more problematic than it does in the early years.

Background and Aims of the Middle Years Numeracy Research Project

In Victoria, as in other Australian States and Territories, there has been a significant increase in government funded literacy and numeracy projects in recent years. The success of the *Early Literacy Research Project (1995-97)* in adopting a coherent, school-wide approach based on the design elements described in the *General Model of School Improvement in Literacy* (Hill & Crevola, 1997), led to the requirement that all future projects be framed in terms of the nine design elements of the model. That is, beliefs and understandings, leadership and coordination, school and classroom organisation, structured classroom teaching program, standards and targets, monitoring and assessment, intervention and special assistance, home, school and community partnerships and professional learning teams.

The *Middle Years Numeracy Research Project: 5-9* (MYNRP) was commissioned by the Victorian Department of Education (now DEET), in partnership with the Catholic Education Commission of Victoria (CECV) and the Association of Independent Schools of Victoria (AISV) in June, 1999. The project is one of a number of other projects commissioned between 1998 and 1999 under the auspices of the DEETYA funded *Successful Interventions: A Secondary Literacy and Numeracy Initiative*. Within this context, the MYNRP was conceptualised by the Victorian industry partners as the second stage of a planned, three-stage research program on numeracy in Years 5 to 9.

As described in the *MYNRP (Stage 2) Project Brief* (DoE, 1999), the aims of the current research project are to:

- inform the development of a strategic and coordinated approach and advice for schools about the teaching and learning of numeracy for students in years 5-9;
- trial and evaluate the proposed approaches in selected Victorian schools; and
- identify and document what works and does not work in numeracy teaching including those students who fall behind.

In addressing these aims, the MYNRP will build upon the work of the *Early Numeracy Research Project* (ENRP), the *Middle Years Research and Development* Project (MYRAD), the *National Numeracy Benchmarks* (DETYA, 1999) and the design elements of the *General Model of School Improvement* (Hill & Crevola, 1997). The MYNRP was specifically required to investigate the role of structured mainstream classroom programs, additional assistance, and the role of parents, mentors, peer support, and professional development, in improving numeracy outcomes at this level.

Key research questions include the following.

- To what extent can numeracy be assessed by the use of structured, rich assessment tasks involving teacher judgements?
- What aspects of current practice appear to be associated with successful and unsuccessful numeracy performance at this level?
- To what extent does the implementation of the *Draft Numeracy Strategy* contribute to improved numeracy performance?
- What characterises the learning-relevant experiences of students at either end of the student numeracy performance spectrum?

The view of numeracy adopted by the Perth conference (AAMT, 1997) has been used to inform the design and implementation of the MYNRP. Although, it is expected that models of

'good' numeracy teaching will principally be found in mathematics classrooms, the project will also explore the contributions made by other curriculum areas and students' 'out-of-school' experience to improved numeracy performance at this level.

Research Design and Methodology

Given the duration and largely explorative nature of the project, it was felt that the most appropriate research design was a quasi pre-pre-post design involving a representative sample and a structured sub-sample. In this case, data was collected from a relatively large sample at the outset to obtain baseline data on student numeracy and some insights into what appeared likely to impact numeracy performance at this level. A smaller, structured sub-sample was selected to participate in a trial phase aimed at finding ways to improve numeracy performance. This sample was selected on the basis of the student numeracy data (high and low) and the extent of evidence concerning supportive school-wide policies and practices (rich and poor) with a view to determining what worked, where and why.

An action research methodology is being used in the Trial schools consistent with a socio-constructivist view of learning (e.g., Lerman, 1998; Crawford & Adler, 1996). This approach is based on the *Maths in Schools* model (Siemon & Ferguson, 1993; Montgomery, 1996) which is premised on the view that success will be greatest where teachers and schools are supported to work on what they believe to be the most appropriate strategy for their situation (Siemon, 1989). This approach was chosen as the research could not know in advance what numeracy-specific strategies would work most effectively in what settings at this level. More particularly, it could not know what would work in combination with the more general strategies suggested by recent middle years research. Specifically, the need for far fewer teachers at years 7 to 9, the importance of sustained and uninterrupted periods of time to engage in meaningful learning experiences, and the need to provide a curriculum that is relevant, negotiated and integrated (see Hill & Russell, 1999; Venville et al., 1998; Cumming, 1996).

To achieve the aims and address the research questions described above, the MYNRP was designed in terms of four broad phases involving the collection of quantitative and qualitative data and the development, implementation, trial and evaluation of a *Draft Numeracy Strategy.* The four phases are briefly described below.

Phase 1: Benchmarking (September-November 1999)

The aim of this phase was to build on the Stage 1 environmental scan (MAV, 1998) by collecting large-scale, sample data on student numeracy performance as well as data related to the design elements under consideration. This phase also included a review of relevant literature and related policies and projects, particularly the *Early Years Numeracy Research Project* (ENRP) and *the Middle Years Research and Development* Project (MYRAD). A formal expression of interest process was used to select a structured, representative sample of 47 schools (27 Primary and 20 Secondary) to participate in the first phase of the project.

The numeracy assessment instruments were developed on the basis of the *National Numeracy Benchmarks for Years 5 and 7* and recognised 'best-practice' models of assessment, that is, 'rich assessment tasks' (e.g., Clarke et al., 1996) and performance assessment (Callingham, 1999; Griffin, 1998). Tasks were sourced to reflect the three strands of the *Benchmarks* and chosen or adapted to ensure they provided an opportunity to demonstrate both content and process outcomes. While the majority of the short tasks were

sourced and/or adapted from *Effective Assessment in Mathematics* (Board of Studies, 1998), task-specific scoring rubrics were developed by the project team. Parallel forms of a written test comprising 5 open-ended tasks were developed for Years 5-6 and Years 7-9 respectively. An extended classroom task aimed at evaluating all student understanding of pattern and relationships, *Street Party*, was sourced from the Tasmanian INISS Project (see Callingham, 1999). Teachers administered the *Student Numeracy Profile* (i.e., a form of the written test and the extended classroom task) over two 40 to 50 minute sessions. Scoring rubrics were provided for all tasks and teachers were asked to assess the student's responses using a computer-readable score sheet. Even though it was a difficult end-of-year period, complete data sets were obtained from just over 7000 students in Years 5 to 9.

Data related to the design elements described in Hill and Crevola (1997) were gathered via an auditing process, that is, school principals were asked to complete a questionnaire and then meet with project team members to verify and/or clarify the school's response as relevant. Schools were invited to submit a portfolio of relevant policies and programs if they desired. Complete data sets were obtained from all 47 schools.

An initial professional development day was held to introduce school contact people to the project and to provide some training in the use of scoring rubrics.

Phase 2: Development of the *Draft Numeracy Strategy* (December 1999 – February 2000)

The aim of this phase of the project was to develop draft advice for trial schools about what appeared to be working in relation to numeracy education in Years 5 to 9. This advice was prepared on the basis of the knowledge and data obtained from Phase 1 and was framed in terms of the nine design elements of the Hill and Crevola (1997) model for school improvement. A Briefing Conference for Trial Schools was held in February 2000 to elaborate the *Draft Numeracy Strategy* and introduce the trial phase of the project including the action planning process to be used. Twenty schools, a sub-set of the original sample of schools, were selected to participate in the Trial Phase on the basis described earlier.

Phase 3: Trial of the *Draft Numeracy Strategy* (March-October 2000)

The aim of this phase of the project is to evaluate the effectiveness of the *Draft Numeracy Strategy* by monitoring the design, implementation and effectiveness of the school-based action plans in relation to student numeracy performance. This will be monitored by the collection of 'missing cohort' data in March and whole cohort data in October using parallel forms of the *Student Numeracy Profile*. The data obtained will enable some degree of within-school comparisons to be made and some limited between school comparisons. School visits, teacher journals, classroom observations and student reflections will be used to monitor the school-based implementations of the *Draft Numeracy Strategy*. Individual case-studies involving student 'outliers' (those identified at either end of the *Student Numeracy Performance* spectrum) will also take place during Phase 3 to explore the specific classroom factors that impact numeracy performance.

Phase 4: Preparation of Advice (September-November 2000)

The aim of this phase of the MYNRP is to revise the *Draft Numeracy Strategy* on the basis of the data and experience derived from Phase 3 with a view to preparing advice that will inform numeracy improvement in the middle years of schooling.

The Student Numeracy Profile

The aspect of the MYNRP that will be reported here concerns the effectiveness and potential of the *Student Numeracy Profile* (SNP) to assess student numeracy performance across Years 5 to 9 and to inform classroom practice. As described above, the two components of the SNP were administered and assessed by classroom teachers using previously supplied scoring rubrics and computer-readable score sheets. The data was analysed using SPSS and *Quest*, a Rasch modelling tool developed by Adams and Khoo (1993). While it is inappropriate to report the aggregate data at this stage, it is appropriate to explore the findings in relation to the SNP itself. Figure 1 shows the *Quest* analysis of item estimates, or thresholds (p = 0.5), for all students across all items.

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                                |
 3.0                            |
                              X |
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                              X |
                              X |
                             XX |    spnb.2 frcc.2
 2.0                         XX |
                            XXXX |    sp8b.2
                           XXXXX |    trvc.2 docm.3
                          XXXXXX |    sp10.2 wlka.2 frca.2 frcc.1 cd  .3
                        XXXXXXX  |    frcb.2
                      XXXXXXXXXX |    sp4 .3 sp9    docm.2
 1.0                  XXXXXXXXXX |    sp8a   wlka.1
                   XXXXXXXXXXXXXX |    sp8b.1 dayb.2 cd  .2 bird.2 medb.1
                    XXXXXXXXXXXXX |    trpb.2 sp4 .2 sp10.1 frcb.1
                XXXXXXXXXXXXXXXXXX |    busb.2 trvb   spna.2 meda.2
               XXXXXXXXXXXXXXXXXXX |    trvc.1 frca.1
                   XXXXXXXXXXXYXX  |    trpa.2 sp5b.2 sp6 .2 wlkb.2 daya
  .0            XXXXXXXXXXXXXXXXXX |    calc.3 docm.1 meda.1
                   XXXXXXXXXXXXXXX |    busa.2 trpa.1 spnb.1
                    XXXXXXXXXXXXXX |    busb.1 sp6 .1 wlkb.1
                  XXXXXXXXXXXXXXX  |    calc.2 sp5b.1 dayb.1
                        XXXXXXXXXX |
                       XXXXXXXXXXX |    trpb.1 sp5a   sp7
                         XXXXXXXX  |    calc.1 bird.1
-1.0                       XXXXX  |    trva
                         XXXXXXX  |
                           XXXXX  |    sp4 .1 cd  .1
                             XXX  |    busa.1
                             XXX  |    sp3c
                              XX  |    spna.1
-2.0                          XXX |    sp3b
                                X |    sp3a
                                  |
                               XX |
                                  |
                                  |    sp2
-3.0                            X |
                                  |
                                  |
                                X |    sp1
                                  |
 Each X represents 26 students (22 cases perfect scores, 26 cases 0 scores)
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Figure 1. Quest analysis of item estimates (Thresholds), all-on-all (N = 6861, p = 0.5).

The coded items on the right refer to a particular part of each task (**sp2** for instance refers to question 2 of the *Street Party* task, possible score 0 or 1). The location of the coded item indicates the point at which students scoring at this level (indicated by the X's immediately to the left) have a 50% chance of satisfying the scoring criterion indicated by the number

following the full stop. For example, **spna.1**, indicates part (a) of the *Draw a Spinner* short task. Its location indicates that those students whose total score relative to the whole population is represented by the X's on the left have a 50% chance of achieving a score of 1 on this part of the task (possible scores 0, 1 or 2).

Of all the items used in the SNP, only one task, *How Far to Walk*, lay outside the boundaries set by the Rasch item fit analysis suggesting that all the others were measuring a similar construct. This outcome is heartening as it suggests it is possible to measure a complex construct such as numeracy using rich assessment tasks incorporating performance measures of content knowledge and process (general thinking skills and strategies). Further trialing is needed to determine the reliability and validity of the SNP over time. Another encouraging feature of the overall item analysis presented in Figure 1 is that the degree of difficulty of the SNP appears to be appropriate for the cohort tested.

The most promising result is that the scaling indicated by the location of the items in Figure 1 suggests that it will be possible to generate a Numeracy Profile with rich descriptions of distinct developmental levels of numeracy performance based on the content and process analysis of the items included in the SNP. This has important implications for the design of structured, numeracy-specific teaching and learning materials which not only support students to acquire the necessary content knowledge and skills but also scaffold a hierarchy of skills, strategies and dispositions concerned with mathematical thinking and problem solving. Callingham (1999) has reported a similar developmental pattern for the *Street Party* task which she has described using the SOLO taxonomy. Further analysis is needed before this can be reported in more detail.

Quality feedback on student understanding has long been recognised as a powerful factor in teachers' decision-making concerning classroom practices (Fennema et al., 1998; Griffin, 1998). A major task within this phase of the project will be to evaluate the impact that feedback, in the form of school and individual reports which are referenced to the emergent numeracy profile, has on the teaching and assessment approaches of Trial schools.

Conclusion

The *Student Numeracy Profile* appears to provide a sound basis for the development of a Numeracy Profile that provides rich descriptions of the key stages in the development of numeracy at this level. While the Numeracy Profile will be informed by further trialing of the SNP, it will be used in the Trial phase as a framework to guide the design and implementation of school-based teaching materials and assessment tasks. It is hoped that such an approach will encourage schools to adopt a multi-disciplinary approach to locally relevant problems or issues as a means of increasing the engagement of middle years' learners (see Venville et al., 1998). During the Trial phase it is also planned to collect data to help frame advice concerning the design elements under consideration. That is, structured mainstream classroom programs, additional assistance, the role of parents, mentors and peer support, and the role of professional development in improving numeracy outcomes. It is envisaged that this will involve a description of the principles of best practice in the development and implementation of numeracy programs within school mathematics, across the curriculum and in the context of a whole school approach.

References

Adams, R. & Khoo, S. (1993). *Quest – The interactive test analysis system.* Melbourne: ACER.

Australian Association of Mathematics Teachers (1997). *Numeracy = Everyone's business.* Report of the Numeracy Education Strategy Development Conference. Adelaide: AAMT/DEETYA.

Board of Studies. (1998. *Effective assessment in mathematics – Levels 4 to* 6. Melbourne: Longman

Cockcroft, W. (1982). *The Cockcroft report.* London: HMSO.

Callingham, R. (1999). Developing performance assessment tasks in mathematics. In J. Truran & K. Truran (Eds.), *Making the Difference.* Proceedings of the 22nd annual conference of the Mathematics Education Research Group of Australasia (pp. 135-142). Adelaide: MERGA.

Clarke, D., Clarke, B., Beesey, C., Stephens, M. & Sullivan, P. (1996). Developing and using rich assessment tasks with the CSF. In H. Forgasz et al (Eds.) *Maths Making Connections.* Proceedings of the 33rd Annual Conference of the Mathematical Association of Victoria (pp. 287-294). Melbourne: MAV.

Cumming, J. (1996). *From alienation to engagement: Opportunities for reform in the middle years of schooling,* Volumes 1 & 3. Belconnen, ACT: Australian Curriculum Studies Association.

Crawford, K. & Adler, J. (1996). Teachers as researchers in mathematics education. In A.J. Bishop et al (Eds.), *International handbook of mathematics education.* The Netherlands: Kluwer Academic.

Fenemma, E., Carpenter, T. & Peterson, P. (1989). Teachers' decision making and cognitively guided instruction: a new paradigm for curriculum development. In N. Ellerton & K. Clements (Eds.) *School mathematics – The challenge to change.* Geelong: Deakin University Press.

Griffin, P. (1998). Outcomes and profiles: Changes in teachers' assessment practices. *Curriculum perspectives, 18*(1), pp. 9-20.

Hill, P. & Crevola, C. (1997). *The literacy challenge in Australian primary schools.* IARTV Seminar Series, No. 69, Melbourne: AIRTV.

Hill, P & Russell, J (1999). *Systemic, whole-school reform of the middle years of schooling.* Keynote, paper. National Middle Years of Schooling Conference, http://www.sofweb.vic.edu.au/mys/other.htm.

Lerman, S. (1998). The intension/intention of teaching mathematics. In C. Kanes, M. Goos. & E Warren (Eds.) *Teaching mathematics in new times.* Proceedings of the 21st annual conference of the Mathematics Education Research Group of Australasia (pp. 29-44). Brisbane: MERGA.

Mathematical Association of Victoria (1998) *Numeracy beyond the early years successful interventions - Numeracy environmental scan.* Unpublished report. Melbourne: MAV.

Ministers Council on Education, Employment, Training and Your Affairs (MCEETYA), (1999). *Adelaide declaration on national goals for schooling in the twenty first century.* Canberra: DEETYA.

Montgomery, P. (1996). The maths in schools professional development program. In H. Forgasz et al (Eds.) *Mathematics Making Connections.* Proceedings of the 33rd annual conference of the Mathematical Association of Victoria. Melbourne: MAV.

National Numeracy Benchmarks Taskforce (1997). *The national numeracy benchmarks.* Melbourne: Curriculum Corporation.

Rhodes, V., Wiliam, D., Brown, M., Denvir, H. & Askew, M., (1998). Designing valid numeracy tests for the primary age range. Paper presented to the Annual Conference of the British Educational Research Association, BERA Education *–line.*

Riordan, D. & Tout, D. (1995). *Numeracy in focus.* A joint publication of the Adult Basic Education Resources and Information Service (ARIS) and the Adult Literacy Information Office (ALIO), No.1.

Scott, D. (1999). Essential Ingredients for Numeracy. *Australian Primary Mathematics Classroom, 4*(1), 4-8.

Siemon, D. & Ferguson, S. (1993). *Maths in schools - A national professional development program submission.* Unpublished manuscript. Melbourne: MAV.

Siemon, D (1989) Knowing and believing is seeing – A constructivist's perspective of change. In N. Ellerton & K. Clements (Eds.) *School mathematics – The challenge to change.* Geelong: Deakin University Press.

Venville, G., Malone, J., Wallace, J. & Rennie, L. (1998). The mathematics, technology and science interface: Implementation in the middle school. In C. Kanes, M. Goos. & E Warren (Eds.), *Teaching mathematics in new times.* Proceedings of the 21st annual conference of the Mathematics Education Research Group of Australasia (pp. 637-644). Brisbane: MERGA.

Willis, S. (1990) Numeracy and society – The shifting ground. In S. Willis (Ed.) *Being numerate – What counts?* Melbourne: ACER.