

Reflections on the Middle Years Numeracy Research Project – Is It a Case of Too Much Too Soon, For Too Many?

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This paper will provide an overview of the *Middle Years Numeracy Research Project* conducted in Victoria from 1999 to 2000. Results from the final stage of the project indicates that teachers working in professional teams in a coordinated and purposeful way do make a difference to numeracy outcomes for the majority of students. However, evidence from individual interviews with a sample of ‘at-risk’ students suggests that schools still face a significant challenge in recognising and dealing with difference at this level. Implications for further research and current practice are discussed

Although there have been a significant number of numeracy-related projects in all Australian States and Territories in recent years, relatively few have focussed on the middle years of schooling or collected large-scale data on student numeracy performance based on the *National Numeracy Benchmarks for Years 5 and 7* (Curriculum Corporation, 2000). Possible reasons for this include uncertainty about what constitutes numeracy in the middle years, the relative lack of numeracy-specific research at this level, and higher profile given to early identification and intervention in the early years (for example, Commonwealth of Australia, 2000).

The Victorian *Middle Years Numeracy Research Project* (MYNRP) was essentially commissioned to identify and document what works and does not work in numeracy teaching in Years 5 to 9 particularly in relation to those students who ‘fall behind’.

The key research questions to be addressed in this paper are listed below.

1. What does the initial data indicate about student numeracy performance in the middle years of schooling?
2. To what extent were Trial Schools successful in improving numeracy outcomes?
3. What characterises the numeracy learning experiences of ‘at-risk’ students?

Numeracy or mathematical literacy has been variously described in the literature and public policy domain (for example, AAMT, 1997; Dossey, 1997; Scott, 1999; Willis, 1990, 1997; and the Commonwealth of Australia, 2000). For the purposes of the MYNRP, numeracy in the middle years was seen to involve:

- core mathematical knowledge (in this case, number sense, measurement and data sense and spatial sense as elaborated in the *National Numeracy Benchmarks for Years 5 and 7*);
- the capacity to critically apply what is known in a particular context to achieve a desired purpose; and the
- actual processes and strategies needed to communicate what was done and why (Siemon, Virgona & Corneille, 2001)

Research Design and Methodology

Given the duration (18 months) and largely explorative nature of the project, it was felt that the most appropriate research design was a quasi pre-post design involving a

representative sample and a structured sub-sample. In the first phase of the project (September-December, 1999), data was collected from just under 7000 Year 5 to 9 students in 47 schools using rich assessment tasks (see Siemon & Griffin, 2000; Siemon & Stevens, 2001). This data was collected to provide baseline information on student numeracy performance and some insights into what appeared to be impacting numeracy performance at this level. The following year, a structured sub-sample of 20 schools was selected to participate in a year-long trial phase aimed at identifying ways to improve student numeracy performance. This sample was selected on the basis of the initial student numeracy data (high and low) and the extent of evidence concerning supportive school-wide policies and practices (rich and poor). All students in Years 5 to 9 in the structured sub-sample of schools were given a parallel version of the initial assessment tasks in November 2000 (n=2899).

The student numeracy data was analysed using SPSS and Quest, a Rasch modelling tool developed by Adams & Khoo (1993). The item analysis confirmed that it is possible to measure a complex construct such as numeracy using rich assessment tasks that incorporate performance measures of content knowledge and process (general thinking skills and strategies) across a range of topic areas using teachers-as assessors. The overall item analysis provided evidence that the degree of difficulty of the tasks chosen was appropriate for the cohort tested. A detailed analysis of the distribution of items also supported the development of an eight-level scale, referred to as the *Emergent Numeracy Profile* (Siemon & Griffin, 2000). All other data was analysed qualitatively by means of content or category analysis. That is, by an examination of the response sets for patterns, relative frequencies and/or relationships to demographic and/or student numeracy performance data.

Main Findings

The following summary of the main findings is derived from the *Report on the Middle Years Numeracy Research Project* (Siemon, Virgona & Corneille, 2001). The findings were based on the analysis of the school surveys, student numeracy performance data, individual interviews of a selected sample of students, Trial School Action Plan Reports, teacher journals and surveys, and the relevant literature. Due to space limitations only those findings that relate to the key research questions listed above will be considered in this paper.

1. What Does the Initial Data Indicate about Student Numeracy Performance in the Middle Years of Schooling?

As the Phase 1 data collection represents the first large-scale attempt to evaluate numeracy not only in terms of the *National Numeracy Benchmarks for Years 5 and 7* but also students' capacity to interpret, apply and justify their mathematical thinking, it is difficult to gauge the significance of the results presented in Table 1. Given that the majority of mathematical content was representative of Victorian Curriculum Standards Framework (CSFII) Levels 2 to 4 for a Year 5 to 9 sample that might be expected to be operating at CSFII Levels 3 to 6, the overall performance could be viewed as disappointing. The results reported here need to be interpreted with some caution due to the relatively small number of tasks used. However, they suggest at the very least that there is considerable scope for improvement in student numeracy performance in the middle years of schooling, particularly in relation to multiplicative thinking and rational number

(see Siemon & Griffin, 2000).

Table 1

Phase 1 Mean Scores Student Numeracy Performance by Year Level

Total Phase 1	Year 5	Year 6	Year 7	Year 8	Year 9
Mean Logit Score: 51.2 (53.9%)	47.8 (50.3%)	52.9 (55.7%)	50.1 (52.7%)	52.0 (54.7%)	53.1 (55.9%)
Std. Dev. 11.2	10.5	11.0	10.9	11.1	11.8
N = 6859	1314	1318	1467	1484	1276

All differences between means for consecutive Year levels are significant. ($p < .001$ for Years 5-8, $p < .05$ for Year 8-9). The significant 'dip' in numeracy performance between Years 6 and 7 is consistent with similar data reported in relation to literacy performance in the middle years of schooling (Hill & Russell, 1999). While there are many other contributing factors, such as the transition from primary to secondary school and a range of social and emotional issues associated with emerging adolescence, evidence from the teacher surveys suggests that at least some of the variance may be due to the relatively lower expectations of Year 7 students by their teachers.

There were some interesting differences with respect to location where it appears the overall 'dip' between Year 6 and 7 performance was largely driven by the significant difference in the performance of Year 6 and 7 students from metropolitan schools ($n = 4303$, mean logit scores: 53.9 and 48.4 respectively). By contrast, in regional and/or rural schools ($n = 2556$) there is no 'dip' in performance at this level. In fact, the performance of Year 7 students (mean logit score: 53.7) is significantly better than their Year 6 counterparts (mean logit score: 51.6). Possible reasons for this cannot be explored here but it may have something to do with 'social connectedness', that is, how comfortable a Year 6 student feels about moving from their familiar, generally much smaller primary environment to a new secondary school (Siemon, 2001b).

The distribution of students across the eight *Emergent Profile Levels* in each of Years 5 to 9 supports the phenomenon observed in the First International Mathematics and Science Study (eg, Keeves & Radford, 1969) of the 'seven-year gap' in mathematics performance of students in the middle years of schooling. This suggests that in any one, 'mixed-ability' class from Year 5 to 9 there is as much variation in performance as there is in the whole of Years 5 to 9 (Siemon, 2001a). While this does not shed any light on how to optimise learning opportunities in the middle years of schooling, it does suggest that something quite radical needs to be done if the learning needs of individual students are to be adequately addressed.

2. To What Extent Were Trial Schools Successful in Improving Student Numeracy Outcomes?

Teachers and targeted programs make a difference to student numeracy outcomes in the middle years of schooling. There was a significant improvement in Trial School student numeracy performance means from Phase 1 to Phase 2 for 18 of the 20 schools. All of the increases in student numeracy performance from Phase 1 to Phase 2 by year level are significant ($p < .05$). However, it would appear that the 'transition dip' was 'deepened' (see Table 2). As for Phase 1, there were significant differences between Years 5 and 6, Years 6 and 7, and Years 7 and 8 in the Phase 2 data ($p < .001$). In contrast to Phase 1, there was no

significant difference between Year 8 and Year 9.

Table 2

Phase 1 and 2 Mean Scores Student Numeracy Performance by Year Level for Trial Schools

Trial School	Year 5	Year 6	Year 7	Year 8	Year 9
Phase 1 (Nov 1999)					
Mean Logit Score: 46.5 (48.9%)	40.4 (42.5%)	46.9 (49.4%)	45.3 (47.7%)	50.0 (52.6%)	49.8 (52.4%)
Std. Dev. 12.9	12.98	11.4	12.2	11.8	13.7
N = 2899	540	513	690	603	553
Trial School	Year 5	Year 6	Year 7	Year 8	Year 9
Phase 2 (Nov 2000)					
Mean Logit Score: 52.6 (55.3%)	49.4 (52%)	54.6 (57.4%)	51.0 (53.7%)	53.5 (56.3%)	54.7 (57.6%)
Std. Dev. 11.8	10.0	10.7	11.3	13.5	13.5
N = 2899	540	513	690	603	553

The item analysis suggests that the tasks associated with the most significant improvements in numeracy performance could be summarised as tasks involving a capacity to read and interpret everyday mathematical representations. There was also considerable improvement on tasks that required students to monitor and regulate their cognitive behaviour. The ability to interpret data relevant to context, perform mental calculations and recognise, describe and use patterns were also areas where student numeracy performance improved. However, the 'hotspots' identified by the Phase 1 data (see Siemon & Griffin, 2000) remained relatively 'hot' despite the overall improvement in these aspects as well as others.

Not surprisingly, given the general increase in student numeracy performance, there was a significant shift in the relative proportions of students at each level of the *Emergent Numeracy Profile* from Phase 1 to Phase 2 (see Table 3). This is illustrated by the fact that in November 1999, just over 61% of the students in Years 5 to 9 were performing at or above Level D on the *Emergent Numeracy Profile*, while in November 2000 this proportion had risen to just under 80%. The mean shift across all Year levels was 1.52 Profile levels (Siemon, Virgona & Corneille, 2001).

Table 3

Proportion of Trial School Students by Profile Level for Phase 1 and 2

Total	A	B	C	D	E	F	G	H
Ph1 Trial N=2899	10.6%	10.3%	17.7%	15.9%	18.1%	16.7%	8.7%	2.0%
Ph2 Trial N=2899	3.7%	5.9%	10.5%	15.8%	20.0%	22.3%	15.2%	6.6%

It is clear from the improvements in student numeracy performance achieved by all Trial Schools that teachers and targeted programs make a difference and, in particular, that a whole-school approach to numeracy improvement is a key element in achieving success.

Some of what characterised the practice of those schools that made the most improvement in student numeracy performance and/or sustained relatively high levels of student numeracy performance will be referred to in the discussion below.

3. What Can We Learn from Students Identified as 'At Risk' About Their Experience of Learning School Mathematics?

To explore students' experience of learning school mathematics two students who were nominated as 'typically weak' or 'at risk' by their school were interviewed and asked to respond to an attitude survey (n = 40). The following propositions were derived from the responses to the interview and survey for the students who 'fall behind'.

- These students believe that mathematics is important and relevant.
- They generally want to learn and be able to apply mathematics.
- Mathematics is not perceived to be as 'boring' or irrelevant as is often assumed.
- They are prepared to accept some of the responsibility for learning
- Addition and measurement were nominated as the 'easiest' areas of mathematics. Multiplication, division, fractions, and decimals were nominated as the 'hardest'.
- The most critical element in their learning from the students' perspective is the quality of teacher explanations, in particular, the capacity of teachers to connect with their level of understanding and communicate effectively.
- Traditional, text-only based approaches are seen as a major impediment to engagement and successful learning.
- Success is crucial to engagement.
- Students would prefer more one-on-one assistance within the context of the whole class lesson.
- Students prefer mathematics classes to be activity-based (that is, games, manipulatives, investigations), deliver success, involve problem solving, and be conducted in a constructive and positive manner.
- 'Relevance' appears to be about connectedness, it is not necessarily about immediately applicable, 'real-world' tasks, although this is important. It is, at least in part, about being able to access what is seen to translate to further opportunities to study mathematics, 'real' maths, and access to 'good' jobs (Siemon, Virgona & Corneille, 2001).

For these students, the quality of teacher explanations was seen to be one of the most important factors affecting their learning of mathematics. However, this also depends on the students' disposition to engage in this enterprise. Students 'at risk' clearly value the use of a broader range of more inclusive practices. But, their responses to the interview questions suggest that disengagement may have as much to do with their perceptions of how they are treated by their teachers, as it does with the particular nature of the teaching practices used. In particular, it appears that the extent to which efforts are made (and seen to be made) to communicate respectfully with students in a way which recognises and accepts 'where they are at' is a key factor in whether or not middle year students are prepared to engage in the task of learning mathematics. Engagement is also very closely related to past success. Students are willing to engage in the task of learning and applying mathematics to the extent that they believe they understand what is required of them and they experience some success.

Discussion

The Action Plans and Final Reports of those schools that made the most improvement in student numeracy performance and/or sustained relatively high levels of student numeracy performance were found to be remarkably convergent. The distribution of strategies confirming the usefulness of the Hill and Crévola (1997) model for school improvement. Analysis of the Final Reports from these schools suggested that improvements in numeracy outcomes were largely achieved as a consequence of a concerted focus on recognised ‘best practice’ in the teaching and learning of mathematics. For instance, features reported included:

- regular and systematic use of open-ended questions, games, authentic problems, and extended investigations;
- teaching strategies focused on connections and developing students’ strategies for making connections;
- active engagement of students in conversations and texts that encourage them to reflect on their learning and explain and justify their thinking; and
- learning activities chosen in relation to learners’ needs and interests (Siemon, Virgona & Cornelle, 2001).

However, the reports also acknowledged, and this was strongly supported by the teacher surveys, that powerful constraints mitigate against a sustained implementation of more effective practice at this level. From the teachers’ perspective, a major impediment to more effective practice was the sheer amount of perceived content that they felt obliged “to cover”. From the students’ perspective, particularly those that ‘fall behind’, it was evident that many did not have access to the key underpinning ideas and strategies needed to achieve some measure of success.

Quite clearly, more time and space needs to be found to ensure the ‘big ideas’ of mathematics and the connections between them are the principal focus of school mathematics at this level. There are many issues which impact the transition from primary to secondary school (for example, Cumming, 1996; Barber, 1999). However, the significant dip in student numeracy performance between Years 6 and 7 suggests, among other things, that serious and urgent consideration needs to be given to what mathematics is taught and how it is taught at this level. Traditional approaches based on linear sequences of topics may not be the most effective way to engage young learners, many of whom need additional and special assistance.

Student engagement has become a major focus of recent research (for example, Clarke, 2001; Barber, 1999; Otero, 1999; Cumming, 1996). The observations here are supported by a large-scale study by Marks (2000) who identified three factors as strong predictors of student engagement in the middle years: a “positive orientation to school, as reflected in school success” (p.173); authentic instructional work that

involves students intellectually in a process of disciplined inquiry to solve meaningful problems, with relevance to the real world beyond the classroom and of interest to them personally (p.158);

and systems of social support. That is,

a positive school environment ... normed for respect, fairness, safety, and positive communications ... in which students experience high levels of expectations and receive help from teachers and peers” (p.174).

The distinction observed by Marr (2001) in relation to talk in adult numeracy classrooms, that is, the *opportunity to speak* and the *means to speak* is also relevant to the

issue of student engagement. While schools and teachers need to ensure students are given the *opportunity to engage* through the selection of appropriate content and the use of a variety of teaching approaches, this on its own is insufficient. Students also need access to the *means to engage*. That is, how to read, write and speak mathematically to participate in the conversation and text of mathematics (Pimm, 1987). So, although there is a case for focusing on key underpinning ideas, such as part-whole relationships, place-value and multiplicative thinking, teachers also need to deal directly and overtly with the ways in which mathematics is represented and communicated. From the students point of view the most important contribution teachers can make is to communicate mathematical ideas and texts effectively *with them*, on a one-to-one basis where needed, to enable them to take their place in the mathematics learning community. This message is overwhelming and cannot be ignored.

While speaking and listening are key ingredients in building shared meaning for mathematical ideas and texts, quality speaking and listening can only occur where there is sufficient trust, knowledge and confidence to share and work at what is known and how it is known. Above all, where there is sufficient time to focus on meaning as opposed to just 'doing'. Again, this has important implications for the design and delivery of school mathematics programs. It would appear that for too many students and teachers there is simply too much to do and not enough time to do it. While many students will be able to learn from the experience of doing, this depends on having access to a network of related ideas which inform and are shaped by the doing. Without the linking, connecting ideas and the means to access and elaborate those ideas, the doing becomes a boring, repetitive and unproductive exercise. Teachers and students need time to elaborate and explore ideas. This does not mean a reduction in expectations but a shift in expectations and targets from a large range of relatively disconnected ideas to a very much smaller, far more connected set of 'big ideas' supported by descriptions of the sort of conversations that teachers might be expected to have with students as they work on those ideas.

One of the clear implications that can be drawn from the student numeracy performance data and the student interviews is that early diagnosis and intervention is critical. Targeted professional development is needed to support teachers identify numeracy-related learning needs and provide the scaffolding needed to support students' learning. While existing research in mathematics education can be used to support some of this (for example, Clarke et al, 2000), further research is needed to identify and elaborate the key growth points and scaffolding needed to support the development of numeracy-specific ideas and strategies at this level.

The relative lack of stability in student numeracy performance over the course of the middle years of schooling and the suggestion that students are 'back on track' by Year 9 suggests that formally differentiating the curriculum before students achieve some sense of responsibility for their own learning can only exacerbate these differences. While further work is needed on more appropriate organisations for learning in the middle years, it would appear that the use of flexible grouping within mixed ability classrooms supported by specialist one-on-one intervention within classes is a more appropriate option in dealing with difference in relation to school mathematics and/or numeracy. Further work is also needed to explore the efficacy of vertical and/or cross-curriculum or integrated curriculum arrangements in relation to improved numeracy performance.

It is clear from the work undertaken in relation to this project that there is an urgent need to identify, describe and resource more effective ways of supporting teaching and learning for numeracy in the middle years of schooling. Structured professional

development programs to support and enhance the work of teaching school mathematics at this level are a logical first step in improving numeracy outcomes. However, sustained improvement will also require a serious review of how school mathematics is represented and positioned within the context of teaching and learning at this level.

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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 .
- Barber, M. (1999). *Taking the tide at the flood: Transforming the middle years of schooling*. National Middle Years of Schooling Conference, <http://www.sofweb.vic.edu.au/mys/what.htm> .
- Clarke, D. J. (2001). *Perspectives on practice and meaning in mathematics and science classrooms*. Dordrecht: Kluwer.
- Clarke, D., Sullivan, P., Cheeseman, J. & Clarke, B. (2000). The Early Numeracy Research Project: Developing a framework for describing early numeracy learning. In J. Bana & A. Chapman (Eds.) *Mathematics education beyond 2000* (Proceedings of the 23rd annual conference of the Mathematics Research Group of Australasia). Sydney: MERGA.
- Commonwealth of Australia (2000). *Numeracy, A priority for all: Challenges for Australian schools*. Canberra: Department of Education, Training and Youth Affairs.
- Cumming, J. (1996). *From alienation to engagement: Opportunities for reform in the middle years of schooling*, Volumes 1 and 3. Belconnen, ACT: Australian Curriculum Studies Association.
- Curriculum Corporation. (2000). *National numeracy benchmarks for years 3, 5 and 7*. Melbourne: Curriculum Corporation.
- Dossey, J (1997). Defining and measuring quantitative literacy. In L. Steen, L (Ed.) *Why numbers count – Quantitative literacy for tomorrow's America*. New York: College Entrance Examination Board.
- Hill, P., & Russell, J. (1999). *Systemic, whole-school reform of the middle years of schooling*. The National Middle Years of Schooling Conference, <http://www.sofweb.vic.edu.au/mys/other.htm>.
- Hill, P., & Crevola, C. (1997). *The literacy challenge in Australian primary schools*. IARTV Seminar Series No. 69. Melbourne: IARTV.
- Keeves, J., & Radford, W. (1969). *Some aspects of performance of mathematics in Australian schools*. Melbourne: ACER.
- Marr, B.E. (2001), *Enhancing mathematical discourse: A study of small-group interactions in an adult numeracy class*. Unpublished Masters thesis, RMIT University
- Marks, H.M., (2000), Student engagement in instructional activity: Patterns in the elementary, middle, and high school years. *American Educational Research Journal*. Vol. 37, No. 1, pp. 153-184.
- Otero, G. G., (1999). *Learning ain't what it used to be, Student engagement strategies for 21st century schools*. Paper presented to the National Middle Years of Schooling Conference.
- Pimm, D. (1987). *Speaking mathematically: Communication in mathematics classrooms*. London: Routledge.
- Scott, D. (1999). Essential ingredients for numeracy. *Australian Primary Mathematics Classroom*, 4,(1), 4-8.
- Siemon, D (2001a). Bridging the gap in the middle years. *Proceedings of the Mathematics K-10 Symposium*. Sydney: NSW Board of Studies
- Siemon, D. (2001b). Supporting numeracy in the middle years. *Learning Matters*, 6(3),14-18.
- Siemon, D., & Griffin, P. (2000). Researching numeracy in the middle years of schooling. In J. Bana (Ed) *Mathematics education beyond 2000* (Proceedings of the 2000 Conference of the Mathematics Education Research Group of Australasia). Sydney: MERGA
- Siemon, D., & Stevens, M. (2001). Assessing numeracy in the middle years – The shape of things to come. In *Mathematics shaping Australia – Proceedings of the eighteenth biennial conference of the Association of Mathematics Teachers*, Adelaide: AAMT (CD Rom).
- Siemon, D., Virgona, J., & Corneille, K. (2001). *Report on the Middle Years Numeracy Research Project: 5-9*. www.sofweb.vic.edu.au/mys/research
- Willis, S. (1978). Which numeracy? *Unicorn*, 24(2), 32-42.
- Willis, S. (1990). Numeracy and society – The shifting ground. In S. Willis (Ed.) *Being numerate – What counts?* ACER: Melbourne