The Effects of Number Knowledge at School Entry on Subsequent Number Development: A Five-year Longitudinal Study

Marj Horne
Australian Catholic University
<m horne@patrick acu edu au>

A sample of 572 children from 70 schools was assessed for number knowledge at the beginning of schooling and at the end of each year for the first five years of school During the five years children's mathematical understanding developed at different rates and many moved position relative to their peers While just under two thirds of the students who began with their number understanding below the median were still below the median at the end of Grade Four (the fifth year of school), this means about a third moved from the lower group to the upper half of the class Nearly 13% had moved into the upper quartile, demonstrating that mathematical behaviour on entry to school was not necessarily the strong predictor of future performance as has been shown in other studies

In the last two decades there has been much interest in preschool and the first years at school as setting up the base for the future Researchers from both sides of the Atlantic have argued for a more explicit numerical approach in early childhood education (Fuson, Richards & Briars, 1982; Gelman & Gallistel, 1986) Recent US publications on mathematical development (e g , Kilpatrick, Swafford, & Findell, 2001) have included specific chapters on the years prior to school In the UK the attention on numeracy development has been directed to schools but also to the pre-school level (e g , Montague-Smith, 1997)

These early years programs can make a real difference to the society Peisner-Feinberg, Burchind, Clifford, Culkin, Howes, Kagan and Yazejian (2001) followed 733 children from age 4 through 8 and found modest long term effects of child care on the child's patterns of cognition and social emotional development through at least first grade This effect was stronger for children defined as having at-risk backgrounds While this study followed children for only a few years, a recent long term study (Reynolds, Temple, Robertson & Mann, 2001) described benefits for low-income children up to the age of 20 following an early childhood intervention These benefits were educational (as measured by the level of educational achievement), and social, including the reduction in juvenile arrest Thus early childhood intervention can make a difference in the early childhood years but also for individuals as adults and to the society itself These studies have not looked specifically at mathematical development but rather cognition in general

Thus the evidence indicates that quality pre-school can make an overall difference to outcomes and that with a mathematical focus, children at risk can be better prepared for school with improved mathematical development during the first years of school Even so, the place of mathematics/numeracy in preschool and childcare has not been as strongly debated as literacy (McNaughton, 1999)

Specific mathematical outcomes are now present in the Australian guidelines (Commonwealth of Australia, 2001a, 2001b) The Education Department in Tasmania has worked to develop Numeracy guidelines including specific objectives for children under the age of 5 These are just examples of development in recent years

Given this attention there is a question that arises concerning the impact of children's mathematical cognition at entry to school on their subsequent numeracy learning Young-Loveridge (1991) found that just below 80% of children who began school in the bottom half of their cohort were still in the bottom half of the cohort after four full years at school Another study found more than half the difference in numeracy skills at age 9 could be explained by the skills at age 5 on entry to school (Bennet, Desforges, Cockburn & Wilkinson, 1984) However this difference in competence can be influenced by active intervention Fuson (1992) found that intervention at preschool level in mathematics made a difference in the development of mathematical understanding during the first years of school and a planned program of games and focused activities during preschool and during the first year of school brought lower achievers up to achievement standard by the end of Grade 1 (Griffin, Case & Siegler, 1994)

I must acknowledge that I believe that early mathematical experiences can contribute to students' subsequent mathematical development, and thus I would like to see some careful introduction of mathematical concepts at a preschool level, through rich and focussed mathematical experiences where teachers use appropriate and engaging questions that stimulate children's thinking and the development of their mathematical language

Acknowledging my beliefs I set out to look at the data from the Early Numeracy Research Project (ENRP) (list all Clarke et al, 2002) to see the effect numeracy skills at the start of Grade 0 (the Preparatory or "Prep" year) had on the attainment in the same areas of numeracy nearly five years later at the end of Grade 4 This in many ways is similar to the longitudinal study conducted by Young-Loveridge (1991) in New Zealand She followed a cohort of 68 children from 18 different primary schools beginning school at age five in 1985 for over four years until the age of nine in 1989, and monitored their numeracy

The question is whether the longitudinal data gathered from March 1999 to November 2003 supports these previous findings that the children who begin school with the poorer mathematical understanding tend to remain in the same position relative to their peers unless there is some intervention

Method

The ENRP was a large scale, three-year long study involving all teachers and children in Grades 0 to 2 in thirty five trial schools in Victoria, Australia These thirty five trial schools were matched with a sample of children from thirty five reference schools to provide a control group Of particular interest here are the 572 children who began in the project at the start of Grade 0 and were still in project schools at the end of Grade 4, thus forming a longitudinal cohort All of the students in the project were assessed in a one-on-one interview near the beginning and end of each school year, March and November respectively The assessment was based on nine mathematical domains but for this paper only the four number domains Counting, Place Value, Addition and Subtraction Strategies and Multiplication and Division strategies have been used As a result of the interview, for each of these domains the children were assigned a growth point from 0 to 6 (0 to 5 for Place Value) Details of the interview and the growth points can be found in the project report (Clarke et al, 2002) and other papers (Rowley, Clarke, Clarke, Gervasoni, Horne & McDonough, 2002) While the growth points themselves do not form an interval scale, based on over 5000 children's interviews, interval scales were created to enable data to be combined and parametric statistical procedures to be used (Horne & Rowley, 2001)

The student data for this study included all students in both reference and trial schools for which data was available in Grade 0 and at the end of Grade 4, and as such is representative of students at these grade levels across the state A small group of students in trial schools who were given special additional assistance were removed from the sample

The data were analysed in a number of ways Firstly the interval scale data, which had previously been collected for each of the four number domains, was combined to give each student a number score for the start of Grade 0 (March 1999), the end of Grade 0 (November 1999) and the end of Grades 1, 2, 3 and 4 (November 2000, 2001, 2002 and 2003 respectively) Using the entry data, the lower half and upper half of the longitudinal cohort (with the exception of students on the median) were identified for both the trial and the reference schools The trial and reference school data were considered separately since there was evidence that children in the trial schools and reference schools performed differently (Rowley et al, 2002) From the Grade 4 data for both the trial and reference schools the median scores were identified Using these markers the percentage of students in the lower group at the beginning of Grade 0, who were still in the lower half group at the end of Grade 4 was identified

Secondly the same procedure was followed to divide the group at the start of Grade 0 into four using quartiles From this it was possible to track the movement of children relative to their peers across the five years of the project by using cross-tabulations

Thirdly correlation coefficients were calculated to investigate the stability of the number scores and to find the percentage of the variance of the scores at the end of Grade 4 which could be explained by the entry behaviour

Finally a similar procedure was done using the end of Grade 0 data as the baseline

Results

In the lower group in March of Grade 0 in reference schools (87 students of the 174 who were with the project for the full five years) 64 4% were still in the lower half at the end of Grade 4 but 12 7% were in the top quarter This was in schools where there were no particular efforts at remediation apart from teachers’ standard approaches

For the trial schools, of the lower half of students in March of their Grade 0 at school (156 of the 398 who were with the project for the five years), 64 7% were still in the lower half at the end of Grade 4 and 12 2% were in the top quarter These figures for both trial and reference schools were very similar and show that with the normal classroom approaches used by a range of teachers, students make differential gains and many students who arrived at school demonstrating very little mathematical knowledge placing them in the bottom half of the class gained knowledge to move them ahead of many of their peers into the top half and even the top quarter of the class

In order to look at this in more detail the students were, with the exception of those who were on the median score, assigned to quartiles Table 1 shows the relative positions of the children at the start of Grade 0 compared to the end of Grade 4

It is of particular interest that there were 18 students, five in the reference schools and 13 in the trial schools, who began school in the lowest quartile for number (10 5% of the lowest quartile) who by the end of Grade 4 were in the top quartile Similarly there were 15 students, three in the reference schools and 12 in the trial schools, who began school in the top quartile who by the end of Grade 4 had progressed more slowly than their peers and were then in the lowest quartile (9 7% of the upper quartile at the start of Grade 0) Overall in reference schools, 36 2% only were stable in the same quartile with respect to their peers and in trial schools the equivalent figure was 39 0% On the other hand 22 4% and 26 6% respectively moved across two or more quartiles

Table 1
Students' Movement Across Quartiles from the Start of Grade 0 to the End of Grade 4

Reference Schools	*n*=174	1st	2nd	3rd	4th
		Quartiles at end Grade 4			
Quartiles at the start of Grade 0	1st	24 (42 1)	14 (24 6)	14 (24 6)	5 (8 8)
	2nd	11 (36 7)	10 (33 3)	6 (20 0)	3 (10 0)
	3rd	8 (17 8)	13 (28 9)	10 (22 2)	14 (31 1)
	4th	3 (7 1)	6 (14 3)	14 (33 3)	19 (45 2)
Trial Schools	*n*=387				
Quartiles at the start of Grade 0	1st	51 (44 7)	24 (21 1)	26 (22 8)	13 (11 4)
	2nd	26 (28 3)	31 (33 7)	15 (16 3)	20 (21 7)
	3rd	8 (11 8)	18 (26 5)	25 (36 8)	17 (25 0)
	4th	12 (10 6)	24 (21 2)	33 (29 2)	44 (38 9)

Table 2 shows the correlations between performances at the start of Grade 0 and at the end of each other year The reference and trial school groups have not been separated as differences between group means should not affect correlations involving individual children and calculations done showed very little difference The movement across the quartiles indicates that the relative position with respect to their peers in mathematics is not as stable now as has been indicated in some past studies (Young-Loveridge 1991) Correlations have been used in the past to provide an index of stability

Table 2
Correlation Coefficients for Number Knowledge Comparing All Testing Periods

n=572	End Gr0	End Gr1	End Gr2	End Gr3	End Gr4
Start Gr0	0 58	0 50	0 45	0 43	0 41
End Gr0		0 67	0 62	0 59	0 54
End Gr1			0 73	0 70	0 63
End Gr2				0 77	0 71
End Gr3					0 78

The progression of the students in the group who began school below the median and the group who began above the median in relation to their peers is shown in Figure 1

These figures are quite low indicating that only 16 8% of the variance in number at the end of Grade 4 can be explained by the number behaviour at the start of the Grade 0 year Indeed only 36 1% of the variance at the end of the Grade 0 year can be explained by the entry behaviour suggesting that perhaps the children's performance at the end of their Grade 0 year, following their first year at school, may be a better indicator for predicting the future performance The amount of variance in the end of Grade 4 scores explained by the score at the end of Grade 0 is 29 2%, which, while an improvement, does not come close to the 53% found by Young-Loveridge (1991) when looking at similar correlations

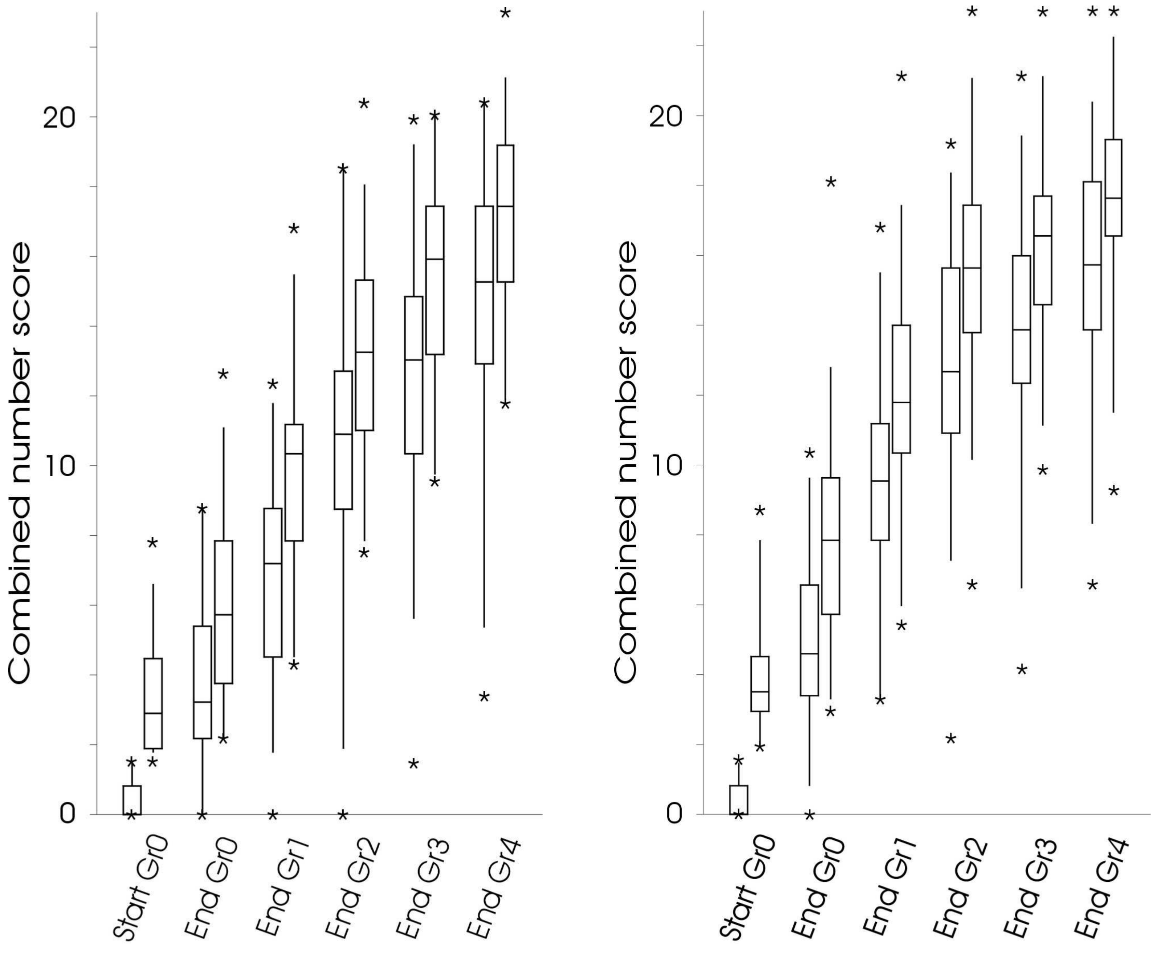

Figure 1 Lower and upper groups over time in reference and trial schools

The box and whisker plots show 95% of the data, with the maximums and minimums being shown by asterisks For each time period the boxplot for the low group is shown to the left of the boxplot for the high group The data are combined for the trial and reference schools

From the graphs in Figure 1 the spread of the children in both the lower and higher groups can be seen to change year by year There is a ceiling effect on the interview assessment which shows in Grades 3 and 4, though it is noticeable that very few children have reached the ceiling in all four domains The growth in trial schools had clearly slowed down in Grades 3 and 4, but the teachers at this level were not involved in any special programs and few of them had taken part in the ENRP professional development

Although the stability is not high the students' scores at the end of their year 0 may still be a better predictor This would allow for the effect of them settling in to the school environment In the group who form the lower group in November of their year 0 in reference schools (87 out of 174) 67 8% were still in the lower group at the end of their second year while 8 (9 2%) had moved to the top quartile In trial schools of the group forming the lower part in November of their year 0, (206 out of 387) 63 6% were still in the lower group while 33 (16%) were in the top quartile This is very similar to the figures for the Start of Grade 0 to the end of Grade 4 so using the later data made little difference, although the amount of explained variance did increase Table 3 shows the movement across quartiles from the end of Grade 0 to the end of Grade 4

Table 3
Movement Across Quartiles from the End of Grade 0 to the End of Grade 4

		Quartiles at end Grade 4			
Reference Schools	*n*=172	1st	2nd	3rd	4th
Quartiles at the end of Grade 0	1st	20 (55 6)	10 (27 8)	5 (13 9)	1 (2 8)
	2nd	14 (29 8)	14 (29 8)	11 (23 4)	8 (17 0)
	3rd	8 (17 4)	10 (21 7)	18 (39 1)	10 (21 7)
	4th	4 (9 3)	9 (20 9)	8 (18 6)	22 (51 2)
Trial Schools	*n*=384				
Quartiles at the end of Grade 0	1st	41 (53 9)	21 (27 6)	9 (11 8)	5 (6 6)
	2nd	40 (33 6)	35 (29 4)	28 (23 5)	16 (13 4)
	3rd	12 (12 9)	19 (20 4)	32 (34 4)	30 (32 3)
	4th	4 (4 2)	20 (20 8)	29 (30 2)	43 (44 8)

The movement across quartiles from the extremes is a little less but there is still a lot of movement Only 74 of the 172 students (43 0%) in reference schools remained within the original quartile while 35 (20 3%) moved across two or more quartiles In trial schools the figures were 151 of the 384 students (39 3%) stable in the original quartile with 66 (17 2%) moving across two or three quartiles

Discussion and Conclusion

This data were collected 15 years later than the study reported by Young-Loveridge During that time there have been changes in the education system and changes in teachers' approaches to mathematics teaching and learning and the term numeracy has taken greater prominence in education It is interesting to look at the trial school data separately to the reference school data since the teachers in the trial schools were part of the research team and took part in extensive professional development during the first three years of the project It was expected that this would have an impact on the teaching and learning within the trial school classrooms and the evidence is that it did The children's mathematical understanding in the trial schools during those years developed at a faster rate than it did in the reference schools In spite of these differences though, there were different rates of learning within classes, whether trial schools or reference schools, and the measures of stability are lower in both groups of schools than could be expected from previous research Whatever the reasons it seems clear that mathematical behaviour on entry to school is only a small part of what affects students' learning at this level The fact that there are many children (about a third) who began in the lower part of the class in terms of their mathematical understanding and moved into the upper part of the class within 5 years suggests that we need to be very careful not to label children on the basis of demonstrated achievement Children do learn at different rates The lack of stability also raises a question about when intervention is most appropriate

It would also be interesting to see whether participation in pre-school programs had a long term effect on students' learning Many of the studies mentioned above were about early intervention programs at the pre-school level and the impact of these on children's response to schooling Unfortunately details about the pre-school experiences of children in the ENRP, if any, are not available This is an area though that needs further study

For me one thing that stands out is that these findings are evidence that teachers can and do make a difference to children's learning Students who arrived at school with little knowledge in number domains made considerable gains often moving ahead of students who had greater knowledge These results challenge the belief that children who arrive at school in the lower group are condemned to remain in it Many, in ordinary classroom situations, can and do learn number concepts effectively

Acknowledgements The main team of researchers involved in the ENRP included D M Clarke (director), J Cheeseman, B Clarke, A Gervasoni, D Gronn, M Horne, A McDonough, P Montgomery, A Roche, G Rowley, and P Sullivan All of this team have been involved in the first three years of the research presented here This research was funded by the Victorian Department of Employment, Education and Training, the Catholic Education Office (Melbourne), and the Association of Independent Schools Victoria

References

Bennet, N , Desforges, C , Cockburn, A , & Wilkinson, B (1984) *Quality of pupil learning experiences* Hillsdale: Erlbaum

Clarke, D M , Cheeseman, J , Gervasoni, A , Gronn, D , Horne, M , McDonough, A , Montgomery, P , Roche, A , Sullivan P , Clarke, B , & Rowley, G (2002) *Early Numeracy Research Project Final Report* Melbourne: DEET

Commonwealth of Australia (2001a) *Handbook: Quality improvement assurance scheme* (Second Edition) National Childcare Accreditation Council www ncac gov au/Publications/QIASHandbook pdf

Commonwealth of Australia (2001b) *Sourcebook: Quality improvement assurance scheme* (First Edition) National Childcare Accreditation Council www ncac gov au/Publications/QIASSourcebook pdf

Fuson, K C (1992) Research on learning and teaching addition and subtraction of whole numbers In G Leinhardt, R Putnam & R A Hattrup (Eds), *Analysis of arithmetic for mathematics teaching* Hillsdale, New Jersey: Lawrence Erlbaum

Fuson, K C , Richards, J , & Briars, D J (1982) The acquisition and elaboration of the number word sequences In C Brainerd (Ed), *Progress of in cognitive development research* In *Children's logical and mathematical cognition* (Vol 1, pp 33-92) New York: Springer-Verlag

Gelman, R,, & Gallistel, C R (1986) *The child's understanding of number* Cambridge, Ma: Harvard University Press

Griffin, S , Case, R , & Siegler, R S (1994) Rightstart: Providing the central conceptual prerequisites for first formal learning of arithmetic to students at risk for school failure In K, McGilly (Ed) *Classroom lessons: Integrating cognitive theory and classroom practice* (pp 25-49) Cambridge, Ma: MIT Press/Bradford Books

Horne, M , & Rowley G (2001) Measuring growth in early numeracy: Creation of interval scales to monitor development In M van den Heuvel-Panhuizen (Ed), *Proceedings of the 25th conference of the International Group for the Psychology of Mathematics Education* (Vol 3, pp 161-168) Utrecht: PME

Kilpatrick, J, Swafford, J , & Findell, B (2001) *Adding it up* (Report of the Mathematics Learning Study Committee, NACS) Washington: National Academy Press

McNaughton, G (1999) *The Tasmanian review of early childhood* Directorate of Education, Tasmania http://www doe tased edu au/ooe/publications/Curriculum_Issues/1

Montague–Smith, A (1997) Mathematics in nursery education (reprinted 2000) London: David Fulton

Peisner-Feinberg,, E , Burchind, M , Clifford, R , Culkin, M , Howes, C , Kagan, S , & Yazejian (2001) The relation of preschool childcare quality to children's cognitive and social development trajectories through second grade *Child Development, 72*(3), 1534-1553

Reynolds, A , Temple, J , Robertson, D , & Mann, E (2001) Long term effects of an early childhood intervention on educational achievement and juvenile arrest Journal of the American Medical Association, *285*(18)

Rowley, G , Clarke, B A , Clarke, D M , Gervasoni, A , Horne, M , & McDonough, A (2002, April) *Using interviews to document growth in numeracy over three years* Paper presented to the Annual Conference of the American Educational Research Association, New Orleans, USA

Young-Loveridge, J (1991) *The development of children's number concepts from ages five to nine* (Volume 1) Hamilton, New Zealand: University of Waikato