GENDER DIFFERENCES IN THE EARLY YEARS IN ADDITION AND SUBTRACTION

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Recent large scale international studies have indicated that while a gender differential in mathematics performance still exists at secondary school level there are few differences in the primary school years. However there is some indication that differences exist in the use of mental strategies rather than in correctness of responses. In this paper some findings from a large scale longitudinal study of children in grades 0-3 are presented. The results appear to confirm that in Grades 2 and 3 a gender difference exists in the strategies children use to answer addition and subtraction problems.

BACKGROUND

In the last few decades of the last century there was considerable interest in gender differences in achievement, participation and attitude. The emphasis has changed though to recognise the more complex interactions between gender and socio-cultural variables (Leder, Forgasz & Vale, 2000). However in the last few years the amount of research in this area has diminished. Perhaps this is partly due to the complexity of the issue and a belief that the differences have diminished. There have been some changes. In mathematics in the last year of secondary school in Victoria, the girls' results are now not significantly different to those of the boys. In some mathematics subjects on average girls are moving ahead, though this hides the fact that the proportion of girls choosing the more difficult mathematics is low (Leder et al., 2000). The girls are also still under represented in the top group. The nature of the assessment can affect performance with the girls doing better on the more extended written problem solving tasks and the boys still having the edge in the examinations (Leder, Brew & Rowley, 1999). Attitudes towards mathematics as a male domain have also changed. For example "students now consider boys more likely than girls to give up when they find a problem too challenging, to find mathematics difficult and to need additional help" (Leder, 2001, p. 50).

The Third International Mathematics and Science Study (TIMSS) provided an opportunity to look at gender differences at both primary school and high school level. Overall there were differences in performance still clearly favouring the boys in the upper secondary school but at middle primary school (age 9) in most countries there were no significant gender differences in performance (Mullis, Martin, Fierros, Goldberg & Stemler, 2000). In Australia and New Zealand there were no statistically significant differences found for gender at either middle primary school (age 9) or junior secondary school (age 13) (Lokan, Ford & Greenwood, 1996, 1997). In the PISA study of 15 year olds in all but 3 of the 33 countries the boys outperformed the girls in mathematical literacy but the difference was not significant in 14 of those countries including Australia (Lokan, Greenwood & Cresswell, 2001). Performance differences thus show more with the older children. On the large scale testing performance measures the effect of gender is low for the younger children.

While advances have been made, it is clear that there is still not gender equity. At middle primary school, while there appears to be little difference in performance, a closer look shows differences in mental strategies which may contribute to the performance and participation data for older children. Most measures of performance use pen and paper approaches, the measure of success is the correctness of the answer and, if method is given a role, efficient use of standard algorithms is rewarded. There have been some studies that have shown there is a tendency for different methods and approaches to be used, while overall performance is the same (Carr & Jessup, 1997; Fennema, Carpenter, Jacobs, Franke & Levi, 1998; Gallagher & DeLisi, 1994). The studies of young children are of particular interest as this is where there are generally no performance differences showing. In a longitudinal study of 44 boys and 38 girls as they progressed from grades 1 to 3 Fennema et al. (1998) interviewed the children twice a year with some number based tasks. The interview approach allowed for approaches and mental strategies to be investigated as well as performance. They found that the boys used significantly more derived facts and invented algorithms while the girls used significantly more counting strategies and modelling, though there was no difference in correctness of responses (Fennema et al., 1998). These differences indicate another look is needed at gender differences in attainment in mathematics.

THE STUDY

The findings reported in this paper are based on data gathered as part of the Early Numeracy Research Project (ENRP, Clarke, 2001), a large scale project with teachers and children in grades 0 – 2 (ages 5 – 8). One of the aims of the project was to evaluate the effect of professional development and the key design elements of school improvement (Hill & Crévola, 1999) on student numeracy outcomes (in this context numeracy and mathematics could be considered equivalent). To monitor the effects the students were assessed for their mathematical understanding twice a year.

Sample, instruments and methods

All students in grades 0 – 2 in 35 *trial* schools, representative of schools in Victoria, Australia, participated in the three year long study from 1999 to 2001. A sample of students from a set of 35 *reference* schools, matched in terms of geographical location, socio-economic status, language background, school size and indigenous population, was used as a control group. While over 11000 students participated altogether the data reported here is based on the 1237 children (F=565, M=672) who began in grade 0 in March 1999 and were still with the project in grade 2, November 2001. Of these 942 (F=423, M=519) were in trial schools and the remaining 295 were from the reference schools. The project finished at the end of 2001 but data were collected in November 2002 from a smaller random sample of 630 (F=305, M=325) of the children who had been with the project all the way through. Of these 438 (F=208, M=230) were in trial schools and 192 were from reference schools.

A task based interview assessment was used in March (the beginning) and November (the end) of each school year to assess the children in the project. This interview assessed a number of domains of mathematics from the curriculum areas of number, measurement and space but this paper is looking specifically at the domain of Addition and Subtraction Strategies. The development of the interview assessment and the related framework of growth points has been described elsewhere (Clarke, Sullivan, Cheeseman, & Clarke, 2000). As can be seen the Growth Points for the domain of Addition and Subtraction Strategies, shown in Figure 1, are based on the mental strategies the children use rather than the just correctness of the answers. For example students answering questions such as 27 + 10 and 6 + 4 by counting on, while they may obtain 37 and 10, may be operating at growth point 2 or 3 rather than growth point 4.

GP 1. Count all (two collections)

Counts all to find the total of two collections.

GP 2. Count on

Counts on from one number to find the total of two collections.

GP 3. Count back/count down to/count up from

Given a subtraction situation, chooses appropriately from strategies including count back, count down to and count up from.

GP 4. Basic strategies (doubles, commutativity, adding 10, tens facts, other known facts)

Given an addition or subtraction problem, strategies such as doubles, commutativity, adding 10, tens facts, and other known facts are evident.

GP 5. Derived strategies (near doubles, adding 9, build to next ten, fact families, intuitive strategies)

Given an addition or subtraction problem, strategies such as near doubles, adding 9, build to next ten, fact families and intuitive strategies are evident.

GP 6. Extending and applying addition and subtraction using basic, derived and intuitive strategies

Given a range of tasks (including multi-digit numbers), can solve them mentally, using the appropriate strategies and a clear understanding of key concepts.

Figure 1. ENRP Growth Points for the domain of Addition and Subtraction Strategies.

The framework and interview deliberately included Growth Points and corresponding questions which would be normally considered beyond the curriculum at the grade 0-2 level. For example the tasks for Growth Point 6 included tasks like estimating whether 134 + 689 and 1246 – 358 were larger or smaller than 1000 with the explanation being sought, and the mental calculation of three digit addition and subtraction.

Analyses, results and discussion

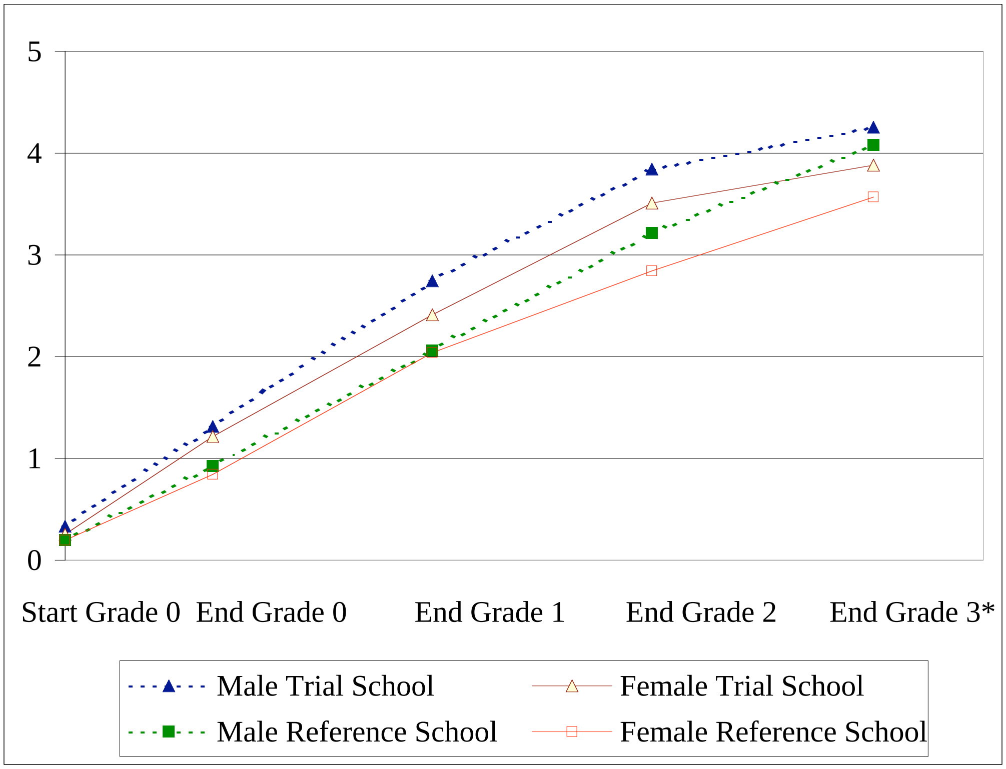
Initially the students were assigned growth points for each interview period, based on the interview data, by trained personnel who had shown high reliability (Rowley & Horne, 2000). It is acknowledged that the growth points do not form an interval scale so an interval scale from 0 to 6 which mirrored the growth points fairly closely was created to enable statistical comparisons of the data (Horne & Rowley, 2001).

Figure 2 shows the mean of the growth points scale for girls and boys at each testing period in the trial and reference schools over the three years of the project and the subsequent year. As can be seen, while the growth for the trial school children exceeded that of the reference school children, the gender difference is clearly there in both and reference schools.

* Reduced sample size

Figure 2. Growth on the Addition and Subtraction Strategies Scale for trial and reference schools by gender

In the trial schools during 2002 the students were no longer being taught by teachers who had participated in the extensive professional development provided as part of the project. The impact of this shows in the reduced growth during 2002. It can also be seen that the gender gap is increasing.



Analysis of Covariance was done to investigate the growing gender difference. Table 1 shows the ANCOVA results for November 2001 (end of Grade 2) and November 2002 (end of grade 3). Because there were some differences on entry in March 1999 (start of grade 1) the growth points for addition and subtraction on entry to the project were used as the covariate in the analysis. The independent variables investigated were Gender and a variable Data, which represented participation in the project as a trial or reference school.

Both gender and participation in the project independently had a significant impact on attainment but there was no significant interaction between participation and gender meaning that, on this domain at least, the gender differential was the same in both trial and reference schools. The interval scale was used to enable statistical investigation to highlight aspects that needed further study and gender is clearly one of these.

	End Grade 2		End Grade 3	
	N = 1237		*N* = 630	
	F	Sig.	**F**	Sig.

Covariate: Start Grade 0	68.1	0.000	47.2	0.000
GENDER	19.8	0.000	25.9	0.000
DATA	65.3	0.000	7.4	0.007
GENDER * DATA	0.2	0.689	0.8	0.385

Table 1. ANCOVA for Addition and Subtraction Strategies comparing boys and girls in both trial and reference schools with the start of Grade 0 as the covariate.

While the means in the growth graph above show part of the picture, the spread of the children across the growth points enables the nature of the differences to be investigated. Table 2 shows the percentages of boys and girls in the trial and reference schools who had demonstrated attainment of each growth point at the interview time.

	Boys					Girls				
	Mar 1999 Start Gr 0	Nov 1999 End Gr 0	Nov 2000 End Gr 1	Nov 2001 End Gr 2	Nov 2002* End Gr 3	Mar 1999 Start Gr 0	Nov 1999 End Gr 0	Nov 2000 End Gr 1	Nov 2001 End Gr 2	Nov 2002* End Gr 3
Trial Schools										
GP 0	70.7	13.8	1.2	0.4		67.1	11.0	2.2	0.2	
GP 1	19.3	43.1	17.0	1.3	2.2	26.0	48.8	19.9	4.0	1.4
GP 2	8.7	32.9	35.9	22.2	6.1	6.4	35.4	44.7	27.2	17.8
GP 3	1.2	8.6	15.6	12.1	10.9	0.5	4.5	15.8	15.4	11.5
GP 4	0.2	1.2	20.5	25.0	27.8			14.4	26.7	33.7
GP 5		0.2	9.3	35.6	41.7		0.2	3.1	26.2	34.6
GP 6		0.2	0.6	3.3	11.3				0.2	1.0
Reference Schools										
GP 0	77.8	23.2	6.6	2.0		77.5	16.9	5.2	1.4	
GP 1	17.0	47.2	25.4	9.2	2.1	17.6	58.8	24.3	12.0	4.1
GP 2	5.2	27.5	45.9	30.1	16.8	3.5	21.3	51.3	41.5	20.6
GP 3		2.1	10.7	14.4	8.4	1.4	1.5	11.3	16.2	19.6
GP 4			8.2	22.2	22.1		1.5	7.0	16.9	37.1
GP 5			3.3	20.3	44.2			0.9	11.3	15.5
GP 6				2.0	6.3				0.7	3.1

* reduced sample size

Table 2. Percentage distribution of boys and girls across the addition and subtraction growth points through grades 0-2.

While it is clear that more trial school children have reached the upper growth points than reference school children it is also clear that in both trial and reference schools more boys than girls have attained the upper growth points. Since GPs 1-3 are concerned with different counting strategies and GPs 5 and 6 with derived strategies the data for the trial schools is amalgamated in table 3 based on the strategy used.

	Boys					Girls				
	Mar 1999	Nov 1999	Nov 2000	Nov 2001	Nov 2002*	Mar 1999	Nov 1999	Nov 2000	Nov 2001	Nov 2002*
No successful strategy	70.7	13.8	1.2	0.4		67.1	11.0	2.2	0.2	
Counting Strategies	29.1	84.6	68.4	35.7	19.2	32.9	88.8	80.3	46.7	30.7
Basic Strategies	0.2	1.2	20.5	25.0	27.8			14.4	26.7	33.7
Derived Strategies		0.4	9.9	38.9	53.0		0.2	3.1	26.4	35.6

Table 3. Percentage distribution across strategy types for boys and girls in trial schools.

Notice that more girls in grade 0 moved to using counting strategies but then more boys moved to basic and derived strategies. By the end of grade 3, 53% of the boys are effectively using derived strategies but for the girls this percentage is less than 36%. In the reference schools this difference was more marked with nearly 50% of the boys but less than 19% of the girls using derived strategies. Likewise 30% of the girls but only 19% of the boys in the trial schools are still using counting strategies by the end of grade 3 while in reference schools these percentages are 44% for the girls and 27% for the boys.

It is of some concern that gender differences in strategies are showing so early in schooling. The percentage of girls using counting strategies for addition and subtraction is higher than that for boys in grades 2 and 3 while a greater percentage of the boys than the girls have moved past counting on to derived strategies. It is also noticeable that the percentage of boys moving on to more complex problems applying addition and subtraction strategies is higher.

CONCLUDING COMMENTS

These results show that there are differences in the strategies used by girls and boys in tackling addition and subtraction problems as early as grades 2 and 3 and support the findings of the study by Fennema et al. (1998). What is not so clear is why these differences exist.

There were differences between the trial and reference schools in the project, though these differences reduced in the year following the project completion. One possible explanation is the expectations the teachers had of the children. The teachers of grades 0-2 in the trial schools, in response to questionnaire items, claimed that a major change in their teaching was that they had changed their expectations of what it was possible for young children to do in mathematics, and that they used the framework of growth points to extend all children rather than the curriculum document for the particular grade (Clarke, 2000). The teachers of Grade 3, however, had not participated in the project and hence, like the teachers in the reference schools, used the curriculum document. There may be a similar effect for the gender difference. The impact of teacher expectations limiting children, and school curriculum where algorithms for addition and subtraction are often taught in Grade 3 combined with the girls wishing to please may contribute to the differences in strategies, but this is speculation. This raises the question of whether and why expectations and teaching might differ for girls and boys. Another possibility may be that the girls rely more on the methods with which they have most confidence and avoid the risk taking of trying their own approaches. Again this raises questions rather than answering them. Is risk taking greater among boys than among girls at this age? Is there a difference in the perceptions of boys and girls about what the teachers require and about the type of responses required in mathematics? Do these patterns of different strategies rather than different performance continue in higher grades?

Apart from speculating on the reasons for the differences there is also a concern about the impact of this difference for the future mathematical learning and participation of students in mathematics and this raises further questions. Does the lack of derived strategies and the reliance on counting hinder further development or is this just demonstrating different pathways? Further study that uses techniques to tap strategies rather than just performance is needed at all levels.

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References:

Carr, M., & Jessup, D. L. (1997). Gender differences in first grade mathematics strategy use: Social and metacognitive influences. *Journal of Educational Psychology*, *98*(2), 318-328.

Clarke, D. M. (2000). The early numeracy research project: Some insights from an exciting first year. In Department of Education, Employment and Training. (Eds.), *High expectations: Outstanding achievement* (Proceedings of the Early Years of Schooling P-4 conference, CD-ROM). Melbourne: DEET.

Clarke, D. M. (2001). Understanding, assessing and developing young children's mathematical thinking: Research as powerful tool for professional growth. In J. Bobis, B. Perry, & M. Mitchelmore (Eds.), *Numeracy and beyond*: *Proceedings of the 24th Annual Conference of the Mathematics Education Research Group of Australasia* (Vol. 1, pp. 9-26). Sydney: MERGA.

Clarke, D. M., Sullivan, P., Cheeseman, J., & Clarke, B. A. (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 Education Research Group of Australasia, pp. 180-187). Fremantle, Western Australia: MERGA.

Fennema, E., Carpenter, T. P., Jacobs, V. R., Franke, M. L., & Levi, L. W. (1998). A longitudinal study of gender differences in young children's mathematical thinking. *Educational Researcher*, *27*(5), 6-11.

Gallagher, A. M., & DeLisi, R. (1994). Gender differences in scholastic aptitude tests – Mathematical problem solving among high ability students. *Journal of Educational Psychology*, *86,* 204-211.

Hill, P. W., & Crévola, C. A. (1999). The role of standards in educational reform for the 21st century. In D. D. Marsh (Ed.), *Preparing our schools for the 21st century* (Association of Supervision and Curriculum Development Yearbook, pp. 117-142). Alexandria, VA: ASCD.

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. 3-161 – 3-167). Utrecht, The Netherlands: Freudenthal Institute.

Leder, G. C. (2001). Pathways in mathematics towards equity: a 25 year journey. In M. van den Heuvel-Panhuizen (Ed.) *Proceedings of the 25th conference of the International Group for the Psychology of Mathematics Education. Vol. 1* (pp. 1-41 – 1-54). Utrecht, The Netherlands: Freudenthal Institute. [July 12-17].

Leder, G. C., Brew, C. & Rowley, G. (1999). Gender differences in mathematics achievement – Here today and gone tomorrow. In G. Kaiser, E. Luna, & I. Huntley (Eds.), *International comparisons in mathematics education* (pp. 213-224). London: Falmer Press.

Lokan, J. Ford, P. & Greenwood, L. (1996). *Maths & Science on the line: Australian junior secondary school students' performance in the Third International Mathematics and Science Study*. Melbourne: Australian Council for Educational Research.

Lokan, J. Ford, P. & Greenwood, L. (1997). *Maths & Science on the line: Australian middle primary school students' performance in the Third International Mathematics and Science Study*. Melbourne: Australian Council for Educational Research.

Lokan, J., Greenwood, L., & Cresswell, J. (2001). *15-up and counting, reading, writing reasoning: How Literate are Australia's students? The PISA 2000 survey of students' reading, mathematical and scientific literacy skills.* Melbourne: ACER

Mullis, I. V. S., Martin, M. O., Fierros, E. G., Goldberg, A. L., & Stemler, S. E. (2000). *Gender differences in achievement, IEA's Third International Mathematics and Science Study*. Boston: International Study Centre, Boston College.

Rowley, G., & Horne, M. (2000, December). *Validation of an interview schedule for identifying growth points in early numeracy.* Paper presented at the Australian Association of Research in Education conference, Sydney.