A Longitudinal Study of Student Performance on Items Rich in Graphics

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This investigation examined the performance of students (9–12 year olds) over a three-year period as they solved graphics-based mathematics items which are commonly found in standardised tests. There were statistically significant improvements in the performance of students (across each of the six language types) in each year of the study. Mean scores for boys were higher than girls on most measures with statistically significant differences in Axis (number line), Map and Retinal-list categories.

Interpreting and decoding spatial information (such as the interpretation of graphs, maps, and diagrams) is necessary in educational contexts and essential in everyday life (Åberg-Bengtsson, 1999). In recent years there is renewed debate regarding the approaches that teachers and curriculum developers should take to ensure the development of a numerate populace who can cope effectively with the practical mathematical demands students experience in both school and out-of-school settings (e.g., Australian Association of Mathematics Teachers, 1997). These practical demands include the capacity to collect, handle and interpret data within graphical contexts. Moreover, there has been an increased awareness in the fact that some of the graphics students are required to (increasingly) interpret are not explicitly taught in school contexts (Lowrie & Diezmann, 2005).

Although the focus on representation (and spatial processing) in teaching, learning, and understanding mathematics is widely acknowledged (e.g., Cucuo & Curcio, 2001) the research on the use and understanding of images and graphics is quite limited (Postigo & Pozo, 2004) despite the calls for this essential and increasingly important literacy (Zevenbergen, 2005). Postigo and Pozo (2004) argued that previous research conducted in this field is quite heterogeneous since the study of maps, diagrams and numerical graphs have their own syntax and conventions. It is also the case that student performances across different types of graphics (e.g., number lines and maps) are not overly strong (Lowrie & Diezmann, 2005) and that correlations between items within the same graphic are at best moderate (Lowrie & Diezmann, 2007).

Gender and Performance on Graphics Items

A broad body of literature has examined the differences between students on spatial tasks with gender differences in performance a central concern. Although gender differences are widely acknowledged (Linn & Petersen, 1985) the extent of these differences, the age when these differences occur (and/or diminish) and reasons for these differences have raised considerable debate. Some studies have concluded that differences in the performance of boys and girls across spatial tasks have become less apparent in the past 50 years (across a range of variables) since children's experiences have become less discrete—in the sense that traditional stereotypical roles are less obvious. Lowrie and Kay (2001), for example, argued that 12 year olds were likely to have been exposed to similar spatial experiences—irrespective of their gender. Other researchers (e.g., Spelke, 2005) have argued that the gap between the performance of boys and girls has diminished in the past ten years.

It is certainly the case, however, that few studies have examined gender differences over time. Moreover, researchers have tended to broadly analyse large data sets rather than being more focused and strategic about examining differences between males and females on mathematics tasks. Fennema and Leder (1993) have suggested that rather than examining large data sets of mathematics performance, studies should be purposeful and focused. The present investigation expands upon the research literature by examining students' performance in a specific field of mathematics education—the decoding of spatial tasks that contain information presented in graphics.

Research Design and Methods

The purpose of this investigation was to:

1. Examine the decoding performance of students' solving graphics items over time; and
2. Determine whether there were gender differences in their performance.

The Participants and Procedure

The participants ($n = 327$: Female = 148, Male = 169) were randomly selected from nine primary schools across different states in rural and metropolitan areas of Australia. These included six non-government and three government schools. The participants were investigated in the last three years of their primary education (age range 9-12 years). They completed the 36 item GLIM Test (see Diezmann & Lowrie, this symposium) in approximately 50 minutes within intact classes on an annual basis. The participants were not involved in any treatment program throughout the study—they continued with the mandatory curriculum of their respective state.

Results and Discussion

1. Performance Differences on Graphics Languages over Time.

The first analysis measured participants' knowledge of graphical languages over a three-year period (Grades 4 to 6). An Analysis of Variance (ANOVA) (year with graphical languages) revealed a statistically significant difference between the performance of students across year [$F(2,1047) = 91.76$, $p<.001$]. Subsequent post hoc analysis revealed statistically significant differences in the performance of students between Grade 4 and Grade 5 [$t(1,351) = 3.28$, $p<.001$] and Grade 5 and Grade 6 [$t(1,324) = 2.07$, $p<.001$].

An ANOVA was then used to determine performance differences of students within each graphical language. There was a statistically significant difference between student performance within language across year [$F(2,1048) = 16.05$, $p<.001$]. Subsequent post-hoc analyses revealed statistically significant differences between students' performance on each of the six graphical languages (see Table 1). Thus, the performance of participants across all six categories of graphs was significantly higher in Grade 6 than in Grade 5 and Grade 4. The results support the findings of other studies showing that the graphic performance of adolescents (Postigo & Pozo, 2004) and mapping skills of primary-aged children (Liben & Downs, 1993) improved over time.

Table 1

Means, Standard Deviations and F Values for Questions 1 and 2

	Grade 4		Grade 5		Grade 6		Year F Ratio	Gender F Ratio
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Df(2,1048)**	**Df(1,1048)**
Axis	4.15	3.37	4.61	3.87	4.95	4.42	42.52***	71.31***
	(1.17)	*(1.33)*	*(1.24)*	*(1.43)*	*(1.13)*	*(1.20)*		
Opposed-position	3.26	3.35	4.05	3.79	4.21	4.10	41.75***	.97
	(1.40)	*(1.27)*	*(1.32)*	*(1.19)*	*(1.26)*	*(1.24)*		
Retinal-list	3.16	2.96	3.86	3.61	4.15	3.98	51.60***	5.2*
	(1.36)	*(1.35)*	*(1.24)*	*(1.40)*	*(1.26)*	*(1.41)*		
Map	4.34	4.10	5.08	4.64	5.25	4.98	60.55***	18.56***
	(1.24)	*(1.31)*	*(.93)*	*(1.09)*	*(.93)*	*(1.06)*		
Connection	3.19	3.23	3.66	3.66	4.20	3.84	35.22***	1.2
	(1.39)	*(1.20)*	*(1.35)*	*(1.16)*	*(1.27)*	*(1.26)*		
Miscellaneous	4.16	4.17	4.61	4.50	5.09	4.95	38.34***	.77
	(1.42)	*(1.48)*	*(1.29)*	*(1.27)*	*(.94)*	*(1.18)*		

Note: * p < .05; *** p < .001

2. Gender Differences in Student Performance

The second aim of the investigation was to determine whether there were gender differences in the performance of students over time. The mean scores for the male students were higher than that of the female students in all six languages in Grade 4, Grade 5 and Grade 6 (see Table 1). An ANOVA (gender with graphical languages) revealed statistically significant differences between boys and girls [$F(6, 1020) = 15.23$, $d = .08$, $p<.001$] Post-hoc analysis revealed statistically significant differences between boys and girls and *axis*, *retinal* and *map* categories (see Table 1).

Although recent research by Liben and Downs (1993) found no gender differences when Grade 5 children were required to complete a series of axis questions, the Axis language findings are consistent with the results of Lowrie and Diezmann (2005, 2007) and Hannula (2003).

Kitchin (1996) postulated that gender differences in the interpretation and decoding of maps may be a result of females having less access to situations that develop spatial skills or that measuring tasks favour male problem-solving strategies. Boardman (1990) highlighted the fact that gender difference in mapping ability may increase over time and that by adolescence boys demonstrate more highly developed map skills than girls. In the present study, performances differences between boys and girls remained relatively constant over the three-year period. It could be argued that the girls in our study were much more likely to be exposed to maps than students in the earlier studies—especially given the increased attention of maps in the school curriculum (and arguably even more influential, the exposure all students have to maps in everyday life). Despite this, gender differences remain.

Conclusions

There were significant improvements in the students' performances across all graphics categories over the three-year period. The students were not involved in any treatment program during this time and simply continued with the regular mathematics curriculum. I would speculate that the participants' general literacy and quantitative literacy would have improved over this timeframe—and as a result—this increase in mathematics capacity provided an additional knowledge base to call upon when solving the problems. The most marked improvements were across the *connection* language—with similar questions more than likely encountered through science curricula. Consistently, the students found the *retinal-list* tasks most difficult to solve. These items required the students to transform, reflect, rotate and translate objects.

The boys outperformed the girls in each of the six graphical languages. Furthermore, there were statistically significant differences between the performances of boys and girls across the *axis, retinal* and *map* languages.

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