Abstract: This study explored primary students’ knowledge of maps through a sample of mathematics test items. One cohort completed these items annually for three years in a mass testing situation. Another cohort was interviewed once on the same map items. Mass testing results revealed that students’ performance generally improved over time. However, significant gender differences in favour of boys were noted annually on each item. Interview results highlighted key difficulties experienced by both girls and boys including interpreting vocabulary incorrectly, attending to the incorrect foci on maps, and overlooking critical information. Our results indicate a need for a focus on extracting and reading information from maps, and analysing and interpreting this information. Girls’ achievement should be closely monitored.
ASSESSING PRIMARY STUDENTS’ KNOWLEDGE OF MAPS

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INTRODUCTION

In contemporary times, the demand and necessity to become proficient with maps has burgeoned as representations become more complex (e.g., Google Earth) and the desire to traverse unfamiliar environments increases. Hence, the acquisition of complex and dynamic mapping knowledge is required in school mathematics (e.g., Lowrie & Logan, 2007). The purpose of this paper is to investigate students’ ability to interpret maps and to identify issues that influence this knowledge.

BACKGROUND

Maps and Information Graphics

Maps are one of the six basic types of information graphics that variously represent quantitative, ordinal and nominal information through a range of perceptual elements (Mackinlay, 1999). The other five graphical languages are: Axis Languages (e.g., number line), Opposed Position Languages (e.g., bar chart), Retinal List Languages (e.g., saturation on population graphs), Connection Languages (e.g., network), and
Miscellaneous Languages (e.g., pie chart). In maps, information is encoded through the spatial location of marks, which are made from a range of perceptual elements such as position, length, angle, slope, area, volume, density, colour saturation, colour hue, texture, connection, containment, and shape (Cleveland & McGill, 1984). Although maps provide an authentic context for learning and assessing mathematical knowledge, students do not always find their interpretation straightforward. Wiegand (2006), for example, maintained that there are three levels of sophistication involved in map interpretation. The initial stage involves extracting information from a map and generally reading names and attributes. Analysis involves ordering and sequencing information. Finally, interpretation requires higher levels of problem solving and decision making involving the application of information.

Spatial Tasks, Map Interpretation, and Gender

Interpreting maps is a spatial task. The literature indicates that on spatial tasks males outperform females (e.g., Bosco, Longoni, & Vecchi, 2004) and on map tasks that males and females adopt different strategies. Saucier et al. (2002) suggested that males employed Euclidean-based strategies to describe directions (e.g., north or west) and distance whereas females tended to use landmark-based approaches (e.g., left or right) to make sense of information. They also found that males outperformed females on tasks that were Euclidean in nature but there were no gender differences on tasks that were represented in a landmark-based form. Reasons for apparent performance differences between males and females on spatial tasks are often associated with confidence and attitudes toward mathematics, classroom interactions, psychological factors, the everyday (out-of-school) experiences of students and even the manner in which tasks are represented. However, most gender differences are attributed to general experiences rather than neurological makeup (Halpern, 2000).

To examine possible differences between the performance of males and females in mathematics, Fennema and Leder (1993)
have called on studies to be more focused and strategic. They suggest that rather than taking a broad view of mathematics performance, more studies should be framed at a micro level rather than across large populations. In this investigation we focus on students’ mathematics performance on map items that have Euclidean and landmark features.

DESIGN AND METHODS
This study is part of a longitudinal investigation of primary students’ ability to interpret information graphics. Three research questions are explored:

1. Are there differences between students’ performance on Map items over time?
2. Is there a difference between boys’ and girls’ performance on Map items over time?
3. What difficulties do students’ experience on Map items?

The Instrument and Items

The Graphical Languages in Mathematics [GLIM] Test is a 36-item multiple choice test that was developed to assess students’ ability to interpret items from the six graphical languages including maps. Test items vary in complexity, require substantial levels of graphical interpretation, and conform to reliability and validity measures (Diezmann & Lowrie, 2007). The GLIM items were selected from state, national and international tests (e.g., QSA, 2002a) that have been administered to 10- to 13-year-olds. This paper reports on students’ performance on three of six GLIM map items which include Euclidean or landmark features (See Appendix).
The GLIM map items were administered to different cohorts in mass testing and interview situations. The mass testing cohort completed the GLIM test annually for three consecutive years. The selected map items were scored as 1 or 0 for correct/incorrect responses. The interview cohort was presented with 12 graphical language items annually from the GLIM test including two map items. Students were interviewed on one of the three selected map items each year: Item B (Grade 4), Item A (Grade 5), and Item C (Grade 6). In the interviews, students selected a multiple choice answer and were asked to justify their responses. Interviewers encouraged students to explain their thinking but did not provide scaffolding. Students’ responses on each item were analysed for difficulties.

The Participants

A total of 476 students from two Australian states participated in this study. The participants comprised two cohorts. Cohort A and B participated in the mass testing and interview components of the study respectively. Cohort A comprised 378 students (M=204; F=174) from eight primary schools (6 New South Wales, 2 Queensland). Cohort B comprised 98 (M=44; F=54) students from five different primary schools (3 New South Wales, 2 Queensland). The students were in Grade 4 or equivalent when they commenced in the 3-year study. (Grade 4 in New South Wales is equivalent to Grade 5 in Queensland. New South Wales grade levels are used throughout this paper for convenience.) Students’ socio-economic status was varied and less than 5% of students had English as a second language.

RESULTS AND DISCUSSION

Part A: Grade and Gender Differences in Map Performance

Questions 1 and 2 relating to grade and gender differences were investigated through an analysis of Cohort A’s responses to three map items (See Appendix) that were presented annually in a mass testing situation when students were in Grades 4 to 6. Students’ performance on these items was analysed using a multivariate analysis of variance (MANOVA). The dependent variables were Grade (Q. 1) and Gender (Q. 2). The MANOVA indicated statistically significant differences between the two dependent variables across the items with Grade \( [F(6, 2092)=11.28, p \leq .001] \) and Gender \( [F(3, 1045)=9.91, p \leq .001] \). Table 1 presents the means (and standard deviations) for grade and gender over the 3-year period.

<table>
<thead>
<tr>
<th></th>
<th>Grade 4</th>
<th>Grade 5</th>
<th>Grade 6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Item</td>
<td>.78</td>
<td>.79</td>
<td>.76</td>
</tr>
</tbody>
</table>

Table 1: Means (and standard deviations) for grade and gender over the 3-year period.
A (.42) (.41) (.43) (.30) (.20) (.29) (.28) (.23) (.31)  
Item  .79  .81  .77  .87  .92  .81  .91  .92  .89
B (.41) (.39) (.42) (.34) (.28) (.39) (.29) (.27) (.31)
Item  .63  .70  .55  .73  .80  .65  .75  .80  .70
C (.48) (.46) (.50) (.44) (.40) (.48) (.43) (.40) (.46)

Table 1: Means (and Standard Deviations) of Student Scores by Grade and Gender

Are there differences between students’ performance on Map items over time?  
ANOVAs revealed statistically significant differences between the performances of students on each of the three map items Item A [F(2, 1053)=24.7, p ≤ .001]; Item B [F(2, 1053)=9.3, p ≤ .001]; and Item C [F(2, 1053)=7.9, p ≤ .001]. Post hoc analysis showed that mean scores, in all but one case, increased across each of the three years of the study for all three items (See Table 1). It is noteworthy that there were statistically significant differences between the performance of the students between Grade 4 and Grade 5 (across all three items) but differences were not significant between Grades 5 and 6 (on any items). This may be due, in part, to the fact that the improvements in scores from Grade 4 to Grade 5 were substantial (with increases from 10%-20%) — and thus ceiling effects are evident, especially for Items A and B.

Is there a difference between boys’ and girls’ performance on Map items over time?  
There were statistically significant differences between the performance of boys and girls across all three items: Item A [F(1, 1053)=4.89, p ≤ .03]; Item B [F(1, 1053)=7.6, p ≤ .001]; and Item C [F(1, 1053)=23.5, p ≤ .001]. For each item, across each year of the study, the mean scores for the boys were higher than that of the girls. These results indicated that the boys’ capacity to interpret these map items was approximately twelve months ahead of that of the girls (with Grade 6 girls’ means between 3%-14% below Grade 5 boys’ means). Generally, girls’ mean scores improved at a constant rate across the three years of the study while the boys’ mean scores plateaued from Grade 5—although this may be due to very high scores achieved by the boys in Grade 5 (particularly on Items A and B with means of .96 and .92 respectively).
Our finding that gender differences in favour of boys were evident on map items in the middle to upper primary years is consistent with our previous findings on structured number-line items (Diezmann & Lowrie, 2007). This trend of gender differences on spatial tasks is not confined to the later years in primary school but seems to be apparent from the early years of school (Levine, Huttenlocher, Taylor, & Langrock, 1999). This study and Levine et al.’s study suggests that girls need to be provided with early and ongoing support to develop their map knowledge to a similar level to boys in the primary years.

**Part B: Students’ Difficulties with Maps Items**

The final question was explored through an analysis of unsuccessful students’ responses from Cohort B on the same three map items as in Part A (See Appendix).  

*What difficulties do students’ experience on Map items?*

Students were unsuccessful on these items in the interviews for various reasons including guessing responses, misunderstanding the question, interpreting vocabulary incorrectly, attending to the incorrect foci, and overlooking critical information. The first two reasons for a lack of success are generic errors and are not discussed here. Examples of the latter three reasons are presented to provide some insight into students’ thinking on map items. Due to performance differences in favour of boys identified in Part A this paper, examples of each of these errors were sought from Cohort B girls’ responses. Although a full gender comparison of responses is beyond the scope of this paper, differences were consistent across cohorts.

*Interpreting Vocabulary Incorrectly:* Some students were misled by their interpretation of a key spatial term in the text. For example on Item A (See Appendix), Noni incorrectly interpreted “through” as relating to being “included in” or being “outside of the bike track” in *What part of the Park won’t she ride through* (emphasis added)?

Noni: Because at first I went through all of them and B4, A4 and B5, like, is included in the bike track and I stuck with A5 and B5 and I just pick (sic) A5 because I thought it’s more outside of the bike track (emphasis added).

*Attending to Incorrect Foci:* Although students’ counting was generally accurate, they sometimes counted an incorrect item or action. In addition, they did not use the map as a referent in their counting. For example on Item B (See Appendix)—*How many times did he (Ben) cross the track?*—Bree focussed on the movements between landmarks on the map rather than the number of times the track was crossed. Thus, she selected the incorrect response of ‘three’ rather than the correct response of ‘two’. Her response indicated no reference to the landmarks in relation to the track.
Bree: I reckon it was three because he went from the gate to the tap (one) and then he went to the tap (two) and then to the shed (three) (emphasis added).

**Overlooking Critical Information:** Some students only paid attention to part of the information given in their responses. For example, on Item C (See Appendix) some students focused on the numerical and directional information in isolation rather than in combination in a set of instructions. On this item, students were required to identify the “second road on the left” rather than simply the second road and the left and right turns independently.

Ellen: Post Rd (her incorrect answer). Started at the pool, then took right turn (Wattle Road) then left turn and it’s Post Rd.

Analysis of students’ difficulties on the three map items suggests two points of interest. First, students’ difficulties relate to each of Wiegand’s (2006) levels of sophistication in map interpretation. *Extracting information* from a map requires knowledge of vocabulary (e.g., Item A - “through”). *Analyzing information* requires knowledge of how to interpret complex information (e.g., Item C - “second on the left”). *Interpreting information* requires knowledge of what can and should be counted (e.g., Item B). Second, girls’ difficulties on Items B and C suggest that Saucier et al.’s (2002) proposal that gender differences can be explained by girls’ use of landmark-based approaches (e.g., left or right) and boys’ use of Euclidean-based strategies (e.g., north or west) is not supported. Both genders (Cohort B) experienced difficulties with these items. Boys also outperformed girls on these items (Table 1).

**CONCLUSION**

Our study revealed that some students are making errors on relatively simple map items. Difficulties with mathematical know-how (of maps) indicate a need for a focus on mathematical practices (Ball, 2004). This focus should address each level of sophistication in understanding map information (Wiegand, 2006): extracting and reading, analysing, interpreting. Learning opportunities related to these levels need to be provided and achievement monitored throughout the primary years especially for girls. Our identification of gender differences in the middle to upper primary years suggests that research is needed in the early primary years to identify and ameliorate early differences and in high school to establish the impact of these differences.
References


### Appendix: Map Items

<table>
<thead>
<tr>
<th>Item A (QSA, 2001, p. 16)</th>
<th>Item B (QSA, 2002a, p. 11)</th>
<th>Item C (QSA, 2002b, p. 7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deb rides her bike along the bike track. What part of the park won’t she ride through?</td>
<td>Ben went from the gate to the tap, then to the shed, then to the rubbish bins. How many times did he cross the track?</td>
<td>Bill leaves the pool. He drives north and takes the first road on the right, then the second road on the left. Which road is he in?</td>
</tr>
</tbody>
</table>

![Map of Picnic Park](image1)

![Map of Playground](image2)

![Map of City](image3)