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**Spatial Orientation and Sequencing of Letters and Numbers by Young Children:
A Rasch Measurement Analysis**

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ABSTRACT

This research follows on from research on the visual discrimination of letters in the alphabet as part of a larger study. Data on 37 items for Spatial Orientation for Letter Pairs and 42 items for Letter and Number Sequencing, where each item was scored in one of two categories (wrong scored zero and correct scored one), were Rasch analysed to create two linear scales. The student sample was N=324 pre-primary and primary students in Perth, Western Australia. Ten of the initial 37 items for Spatial Orientation for Letter Pairs were deleted due to item misfit statistics, leaving 27 items and six of the original 42 items for Letter and Number Sequencing were deleted leaving 36 items. The 27 item-scale and the 36 item-scale each had a good fit to the measurement model, were highly reliable (Person Separation Indices of 0.84 and 0.94), and were unidimensional, showing no statistically significant interaction on item difficulties along the scale. Items were ordered from easy to hard and student measures from low to high on the same scale, allowing the objective identification of alphabet pairs and letter and number sequences that students found difficult to discriminate. Students who had poor visual skills of alphabet letters and numbers in pairs or sequence could be identified objectively.

Spatial Orientation and Sequencing of Letters and Numbers by Young Children:

A Rasch Measurement Analysis

This paper reports part two of a larger study of Spatial Orientation and Sequencing of Letters and Numbers by young children; that is, it involves the position of letters and numbers in relation to each other on the page (spatial position) and in relation to their position in a group (sequencing). This research describes the measurement results in terms of the output statistics from the Rasch Unidimensional Measurement Models (RUMM2020) computer program (Andrich, Sheridan, & Luo, 2005). It includes global item and person fit to the measurement model, dimensionality, person separation indices, distribution of item-person interactions, and discrimination. Some discussion is made about the non-fitting items as well as good fitting items and the targeting of the measures. This is followed by mean Rasch measures by group and final items for the Spatial Orientation and Sequencing Scales discussion. Finally, inferences drawn from the linear Rasch measurement data analysis and the summary of the results are presented.

Literature Review

Satisfactory academic development creates an expectation that children perform adequately for the age or grade level of the child in the areas of reading, spelling, writing, mathematical computations, communicating, science, computers, sports, among other areas of academic performance (Erhardt & Duckman, 2005; Kirk, Gallagher, & Anastasiow, 2000; Loikith, 1997). Cherry, Godwin and Staples (1989) suggest that people who have difficulty remembering a letter sequence may also have difficulty reading and performing other structured academic tasks that are dependant on following a sequence of letters and numbers, such as

spelling and mathematical calculations. According to Waters, Bruck and Marcus-Abramowitz (1988) the child must be proficient in reading as well as spelling in order to become literate. The performance of poor spellers relative to good spellers improved more with recognition, suggesting that poor spellers rely more on visual information than good spellers. Waters et al. (1988) also commented that performance on dictation tasks reflected the specific memories of the spelling words rather than general knowledge of spelling patterns and that patterns of performance reflected children's sensitivity to visual rather than linguistic properties of word classes (Waters et al., 1988), hence the need for valid and reliable assessment instruments.

Levine (1991) and Schneck (1996) determined that weak visual perception and impaired processing of simultaneous visual stimuli could also cause difficulty with learning sight words and spelling and that visual sequential memory was necessary for remembering the sequence of letters in a word (Levine, 1991; Schneck, 1996). In addition, children having difficulty with the mechanics of mathematics (dyscalculia) are slow to grasp the relative size of figures, to learn tables, to remember the sequencing of digits, and to understand the meaning of mathematical signs or master fractions (Green & Chee, 1997; Loikith, 1997). Managing mathematical computations, requires that children have an understanding or grasp of basic perceptions of shape, space, symbols, copying and numeracy (Chinn, 2002; Miles, Chinn, & Peer, 2000; Schneck, 1996). Furthermore, the manipulation of numbers in mathematics also requires good visual perceptual skills such as visual discrimination, directionality, sequencing, organisation of work (spatial), correct alignment of columns for calculation (placement of number values), figure ground and memory (Chinn, 2002). A number of authors agree that to solve mathematical

problems, understand geometric relationships and use graphs, children require recognition skills, the ability to discriminate and the ability to compare objects, form and space (including inversions, rotations and distortions) (Chinn, 2002; Fisher, Murray, & Bundy, 1991; Hung, Fisher, & Cremak, 1987; Levine, 1991; Schneck, 1996).

This study aimed at developing a linear measure that would identify and work on potential difficulties in reading, spelling and mathematics in children with difficulty sequencing letters and numbers.

Initial Rasch Analysis

An initial Rasch analysis was performed on the original items for Spatial Orientation of Letter Pairs (37 items) and, separately, on the Letter and Number Sequencing (42 items) where each item was scored in one of two categories (wrong scored zero and correct scored one). For the first scale, ten of the initial 37 items of Spatial Orientation of Letter and Number Pairs were deleted due to item misfit statistics. The remaining 27 items were found to have a reasonable fit to the measurement model for the 324 persons included in this study. For the second scale, Letter and Number Sequencing, six of the initial 42 items were deleted due to item misfit statistics. The remaining 36 items displayed a good fit to the measurement model.

Final Rasch Analysis Results

The following material shows the results for the final Rasch analysis for Spatial Orientation Letter and Number Pairs (27 items), and Letter and Number Sequencing (36 items).

Summary of Fit Statistics

The RUMM2020 program estimates of standardised fit residual statistics are presented in Table 1. These item-person interaction statistics determine whether the item estimations contribute meaningfully to the measurement of one construct and whether there is a consistent person-item pattern of responses. The standardized fit residuals of these two measures have a distribution with a mean near zero and a standard deviation near one, indicating that the data fit the measurement model (Andrich, 1985). This means too that there is a good pattern of person and item responses, consistent with a Rasch measurement model.

Dimensionality

For Spatial Orientation Letter and Number Pairs, there was an item-trait interaction chi-square of 77.98 with $df=81$ and a probability of 0.57. This means that the scale is constructed with excellent agreement amongst the students about the linear progressive difficulty of the items. The item-trait interaction chi-square for Letter and Number Sequencing was 124.95 with $df=108$ and a probability of 0.13, showing acceptable agreement amongst the students about the linear progressive difficulty of the items along the scale.

Table 1

Global Item and Student Fit Residual Statistics (N=324)

	ITEMS		PERSONS	
	Location	Fit Residual	Location	Fit Residual
Spatial Orientation Letter and Number Pairs (I=27)				
Mean	0.00	-0.57	2.06	-0.15
Standard Dev.	0.52	1.17	1.33	0.76
Letter and Number Sequencing (I=36)				
Mean	0.00	-0.74	2.05	-0.39
Standard Dev.	0.86	1.24	2.27	0.90

Comment on Table 1

Standardized fit residuals have a mean near zero and a standard deviation near one when the data fit the measurement model (as is the case here). This reflects good consistency of item and student scoring patterns.

Person Separation Index

The Person Separation Index for Spatial Orientation Letter and Number Pairs is 0.84, while the Person Separation Index for Letter and Number Sequencing is 0.94. For a good measure, it is desirable that this index should be 0.9 or greater, as it is an indicator that the student measures are separated by more than their standard errors (Andrich & van Schoubroeck, 1989). Based on this index, the Spatial Orientation Letters and Number Pairs scale demonstrates good separation, and the Letter and Number Sequencing Scale demonstrates an excellent separation. Their Cronbach Alphas are 0.88 and 0.98 indicating good internal reliability too.

Individual Item Fit

Items were ordered by calibrated values to evaluate their fit to the measurement model. All the items in Spatial Orientation Letter and Number Pairs fit the measurement model with probabilities greater than $p=0.02$ (see Table 2). Standardised fit residuals should fall within the range of -2 and +2. Table 2 shows that all items for Spatial Orientation Letter and Number Pairs have acceptable residuals except for item 13 and item 34. For Letter and Number Sequencing, all the items fit the measurement model with probabilities greater than $p=0.03$ (see Table 3), but a few of the residuals are a little outside what might be considered good limits.

Targeting

The student-measure item-difficulty, or targeting, graph for Spatial Orientation of Letter and Number Pairs (see Figure 1), shows that the student measures cover a range of about -1.8 to +4.0 logits and the item difficulties cover a range of about -1.0 to +1.5 logits. From the graph it can be seen that many students (about 200) were able to answer all the items correctly, while a few students (about five) were not able to answer any of the items correctly. This suggests that the targeting of the items needs to be improved in any future use of the scale by adding in some harder items to 'cover' the students with the higher measures.

Table 2

Individual Item Fit Statistics for Spatial Orientation letter and Number Pairs

Item	Location	SE	Residual	DegFree	ChiSq	DegFree	Prob
14	-0.97	0.22	-0.58	245.56	5.55	3	0.14
3	-0.94	0.21	+0.52	245.56	2.47	3	0.48
13	-0.66	0.20	-2.27	245.56	4.81	3	0.19
4	-0.57	0.19	-0.90	245.56	1.53	3	0.68
6	-0.50	0.19	-1.55	245.56	5.72	3	0.13
12	-0.45	0.19	-1.31	245.56	3.09	3	0.38
31	-0.40	0.18	+0.08	245.56	1.04	3	0.79
22	-0.20	0.18	-1.79	245.56	5.25	3	0.15
10	-0.15	0.17	-0.47	245.56	1.46	3	0.69
1	-0.13	0.17	+1.02	245.56	4.27	3	0.23
26	-0.13	0.17	-1.63	245.56	1.92	3	0.59
19	-0.11	0.17	-1.52	245.56	1.88	3	0.60
35	-0.10	0.17	+0.05	245.56	0.26	3	0.97
11	-0.03	0.17	-0.75	245.56	3.29	3	0.35
28	0.00	0.17	-1.07	245.56	2.25	3	0.52
5	0.04	0.17	-0.13	245.56	1.84	3	0.61
21	0.12	0.16	-1.71	245.56	5.49	3	0.14
27	0.14	0.16	-0.79	245.56	1.19	3	0.76
34	0.24	0.16	-2.81	245.56	7.32	3	0.06
32	0.31	0.16	-1.38	245.56	3.05	3	0.38
15	0.43	0.16	-1.11	245.56	3.12	3	0.37
36	0.46	0.16	+0.81	245.56	0.92	3	0.82
16	0.48	0.15	+0.98	245.56	0.49	3	0.92
29	0.51	0.15	-0.09	245.56	0.59	3	0.90
33	0.58	0.15	+1.76	245.56	2.12	3	0.55
17	0.59	0.15	-0.50	245.56	2.63	3	0.45
18	1.43	0.14	+1.71	245.56	4.44	3	0.22

Notes on Table 2 and 3:

1. Location refers to the difficulty of the item on the linear scale.
2. SE means Standard Error, and refers to the degree of uncertainty in a value.
3. Residual represents the difference between the expected value of an item, calculated according to the Rasch measurement model and the actual value.
4. DegFree stands for degrees of freedom, and refers to the number of scores in a distribution that are free to change without changing the mean distribution.
5. ChSq stands for Chi-square
6. Prob relates to the probability based on the Chi-square and refers to the levels of certainty to which an item fits the measurement model.

Table 3

Individual Item Fit Statistics for Letter and Number Sequencing

Item	Location	SE	Residual	DegFree	ChiSq	DegFree	Prob
4	-1.53	0.31	-1.12	241.11	1.57	3	0.67
3	-1.51	0.31	-1.23	241.11	2.02	3	0.57
9	-1.20	0.28	-0.67	241.11	1.52	3	0.68
8	-1.12	0.28	-0.72	241.11	0.39	3	0.94
2	-1.07	0.27	-1.19	241.11	5.10	3	0.16
5	-0.85	0.26	-0.37	241.11	2.78	3	0.43
1	-0.66	0.25	0.83	241.11	4.10	3	0.25
12	-0.61	0.24	-0.56	241.11	2.27	3	0.52
7	-0.59	0.24	-1.20	241.11	2.88	3	0.41
6	-0.57	0.24	-0.49	241.11	2.29	3	0.51
40	-0.45	0.23	0.20	241.11	3.50	3	0.32
14	-0.40	0.23	-2.29	241.11	9.09	3	0.03
37	-0.35	0.23	0.84	241.11	0.83	3	0.84
27	-0.30	0.22	-2.57	241.11	7.40	3	0.06
33	-0.27	0.22	0.89	241.11	0.99	3	0.80
15	-0.12	0.21	-0.89	241.11	2.47	3	0.48
24	-0.11	0.21	-2.32	241.11	9.19	3	0.03
21	-0.09	0.21	-3.22	241.11	7.21	3	0.07
36	-0.09	0.21	0.66	241.11	2.85	3	0.41
10	-0.09	0.21	0.78	241.11	6.04	3	0.11
32	-0.04	0.21	-1.97	241.11	3.83	3	0.28
19	0.04	0.21	-2.09	241.11	4.04	3	0.26
11	0.06	0.21	0.90	241.11	2.44	3	0.49
38	0.09	0.20	-0.65	241.11	2.56	3	0.47
31	0.22	0.19	-2.06	241.11	3.86	3	0.28
23	0.31	0.19	-2.38	241.11	4.01	3	0.26
20	0.62	0.18	-1.40	241.11	2.25	3	0.52
34	0.70	0.18	0.94	241.11	3.88	3	0.27
17	0.79	0.18	-2.45	241.11	5.01	3	0.17
41	0.83	0.17	-0.61	241.11	3.93	3	0.27
16	1.23	0.16	-0.88	241.11	4.82	3	0.19
22	1.23	0.16	-0.95	241.11	3.44	3	0.33
35	1.24	0.16	2.06	241.11	2.27	3	0.52
26	1.36	0.16	-0.25	241.11	2.12	3	0.55
30	1.37	0.16	-0.12	241.11	0.97	3	0.81
28	1.97	0.15	-0.17	241.11	1.07	3	0.78

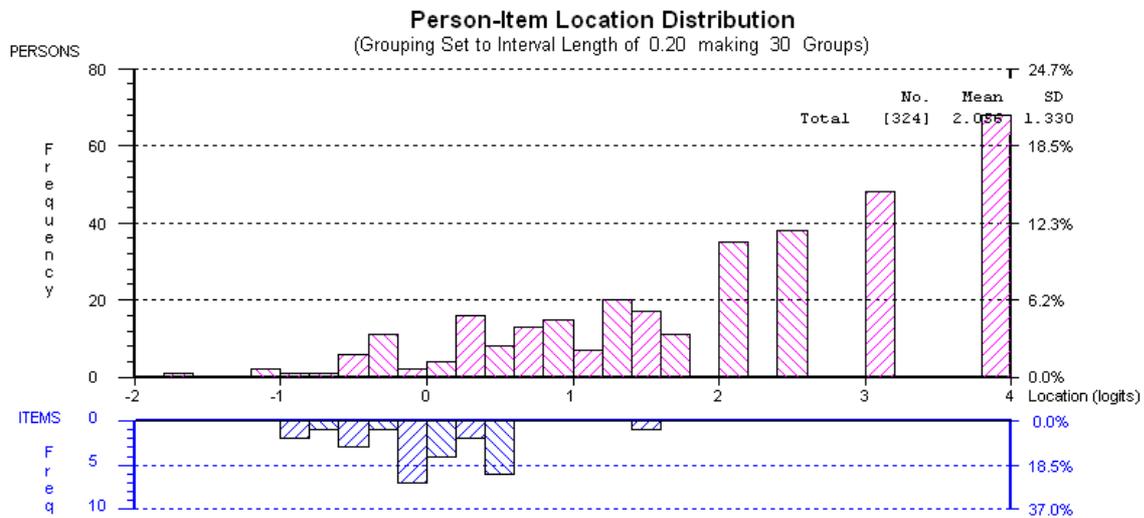


Figure 1 Targeting Graph for Spatial Orientation Letter and Number Pairs

Note: Student measures are on the upper side in logits. Item difficulties are on the lower side of the same scale in logits. Many students (about 200) answered the items correctly.

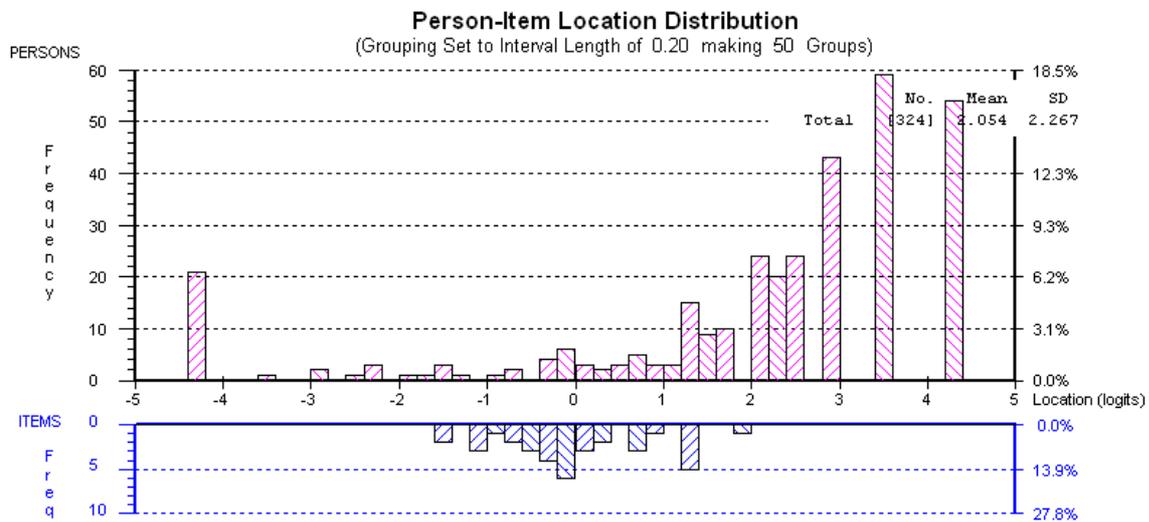


Figure 2: Targeting Graph for Letter and Number Sequencing

Note: Student measures are on the upper side in logits. Item difficulties are on the lower side of the same scale in logits. Many students (about 220) answered the items correctly.

For Letter and Number Sequencing (see Figure 2), the targeting graph shows that the student measures cover a range of about -4.4 to +4.3 logits and the item difficulties cover a range of about -1.7 to +2.0 logits. From the graph it can be seen that many students (about 220) were able to answer the items correctly, while some students (about 30) were unable to answer any items correctly. The targeting of the items needs to be improved in any future use of the scale by adding in some harder items to ‘cover’ the students with the higher measures.

Discrimination

Item Characteristic Curves examine the relationship between the expected response and the observed score for each item. These curves display how well the item discriminates between different groups of mean student measures (locations). An example of one item characteristic curve for each construct is presented. Figure 3 shows the Item Characteristic Curve for Item 31 Spatial Orientation of Letter and Number Pairs. This curve shows that the item discriminates well for students with different measures. The Item Characteristic Curves for all the other items were checked and found to be satisfactory (but are not reported here to avoid unnecessary repetition).

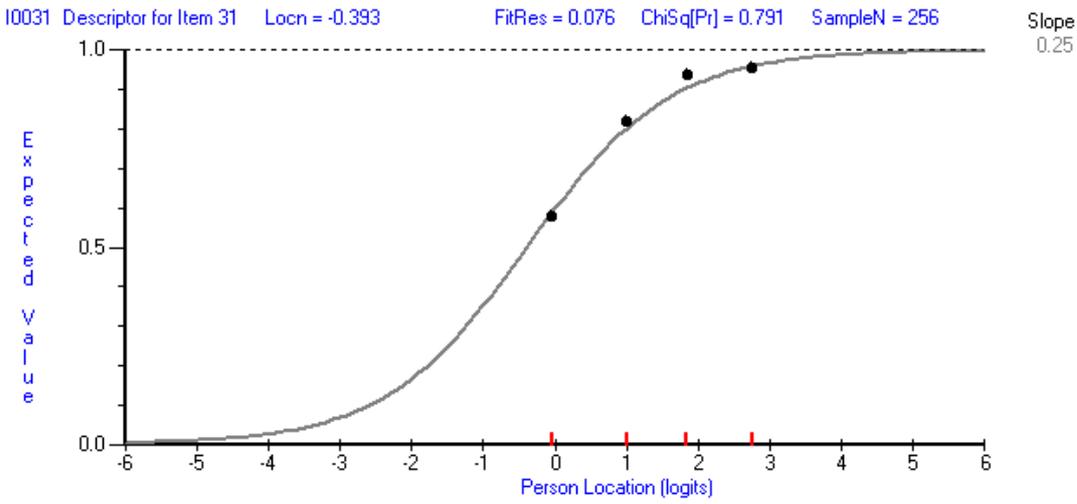


Figure 3: Item Characteristic Curve: Item 31 – Spatial Orientation of Letter and Number Pairs

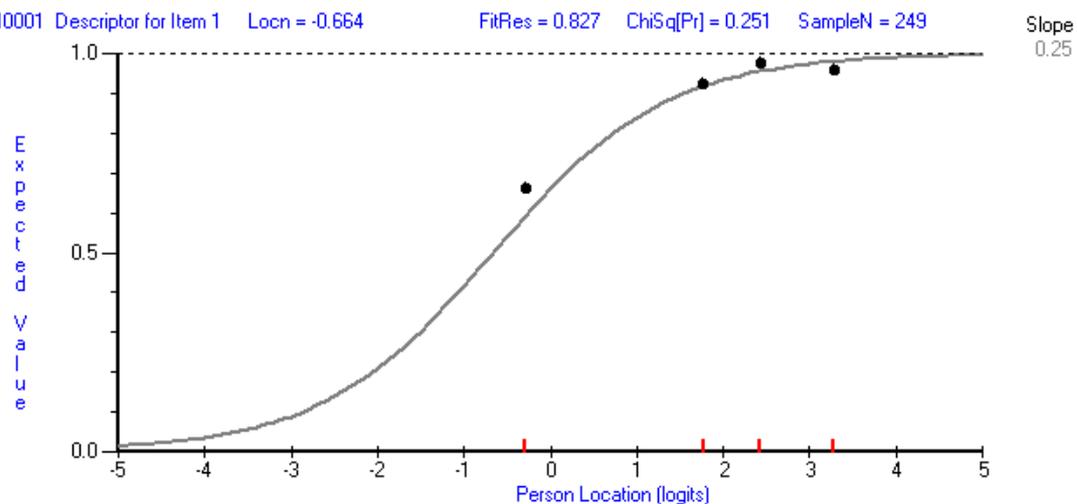


Figure 4: Item Characteristic Curve: Item 1 – Letter and Number Sequencing

Item Characteristic Curves for each item in Letter and Number Sequencing were also found to discriminate well for groups of students with different measures. Figure 4 presents an example of an Item Characteristic Curve for Item 1 in Letter and Number Sequencing. The Item Characteristic Curves for all the other items were checked and found to be satisfactory (but are not reported here to avoid repetition).

Consistency of Use of Scoring Categories

The RUMM2020 program produces graphs of the scoring categories for each item. The Scoring Category Curves show the relationship between the probability of scoring in each category (zero for wrong and one for right) on each item. Figure 5 is the Scoring Category Curve for item 1 of Spatial Orientation of Letter and Number Pairs. This figure shows that the scoring was done logically and consistently. When students have low measures on item 1, then they have a high probability of obtaining a zero score (answer incorrectly) and, when they have a high measure, they have a high probability of scoring 1 (answer correctly). The Scoring Category Curves for all the other items were checked and they were satisfactory too. Figure 6 shows the Scoring Category Curve for Item 1 of Letter and Number Sequencing. This figure confirms that the scoring was done logically and consistently for this item. The Scoring Category Curves for all the items of Letter and Number Sequencing were checked and they were also found to be satisfactory, but they are not presented here to avoid unnecessary repetition.

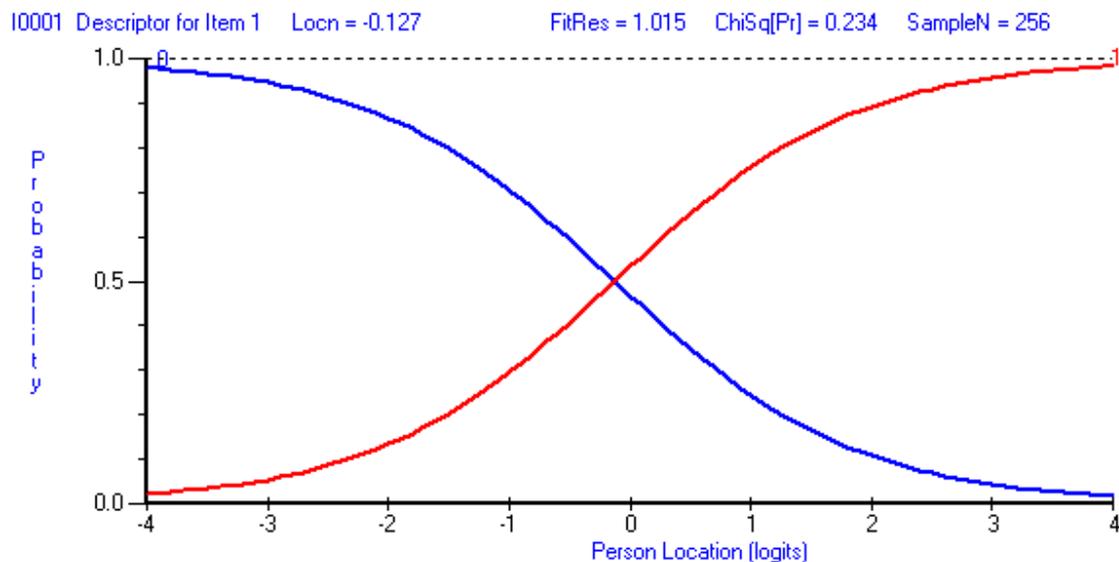


Figure 5: Scoring Category Curve: Item1 – Spatial Orientation Letter and Number Pairs

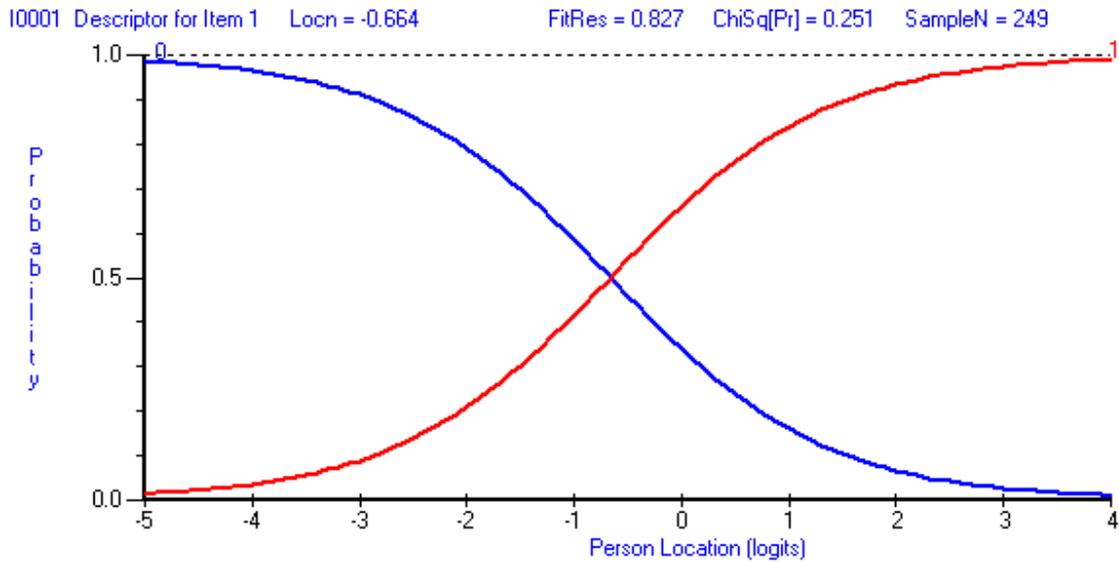


Figure 6: Scoring Category Curve: Item1 – Letter and Number Sequencing

Characteristics of the Sample (SOLNP)

The measures for Spatial Orientation of Letter and Number Pairs (SOLNP) were displayed in a graphical format separated by gender (Figure 7), type of school (Figure 8), age (Figure 9), grade (Figure 10) and whether intervention had been received (Figure 11). The mean differences were then tested for statistical significance using t-tests. Females have a higher mean measure than males for Spatial Orientation of Letter and Number Pairs which is statistically, significantly different ($t=2.96, df=322, p=0.000$). Public school students have a higher mean measure than private school students for Spatial Orientation of Letter and Number Pairs but this is not statistically, significantly different ($t=1.53, df=322, p=0.08$). As would be expected, the mean measures generally increased by age from four years of age (lowest) to nine years of age

(highest) and this was statistically, significantly different in favour of the older students ($t=9.86$, $df=66$, $p=0.000$). Again, as expected, the mean measures generally increased by grade from Pre-primary (lowest) to Year 3 (highest) and this was statistically, significantly different ($t=11.6$, $df=127$, $p=0.000$). While the mean measures for no intervention were higher than for intervention, this was not statistically, significantly different ($t=1.93$, $df=322$, $p=0.025$).

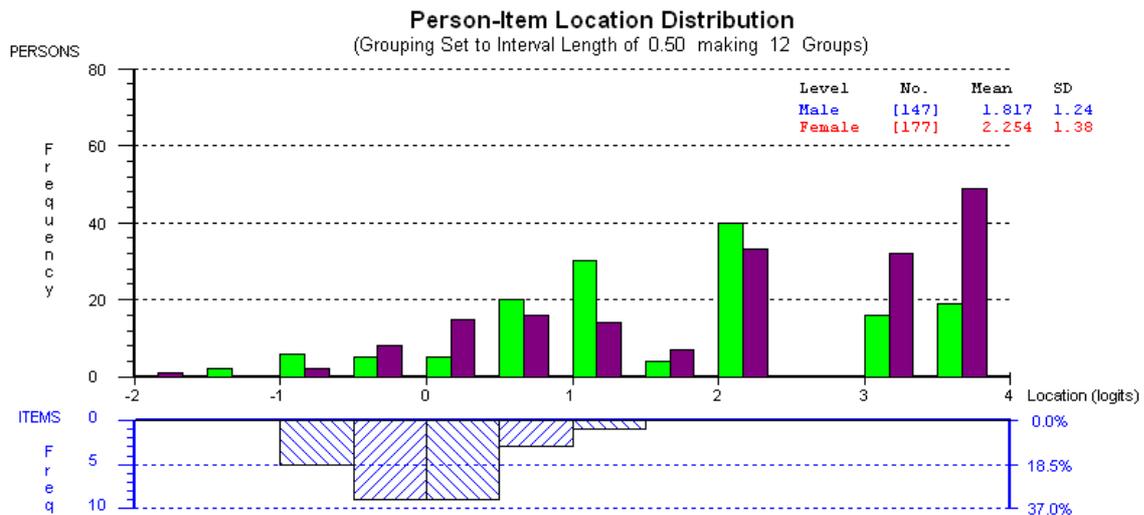


Figure 7: Target Graph by Gender for Spatial Orientation of Letter and Number Pairs
 Note: There is a colour error in the RUMM program. Purple represents the females (not red) and green represents the males (not blue).

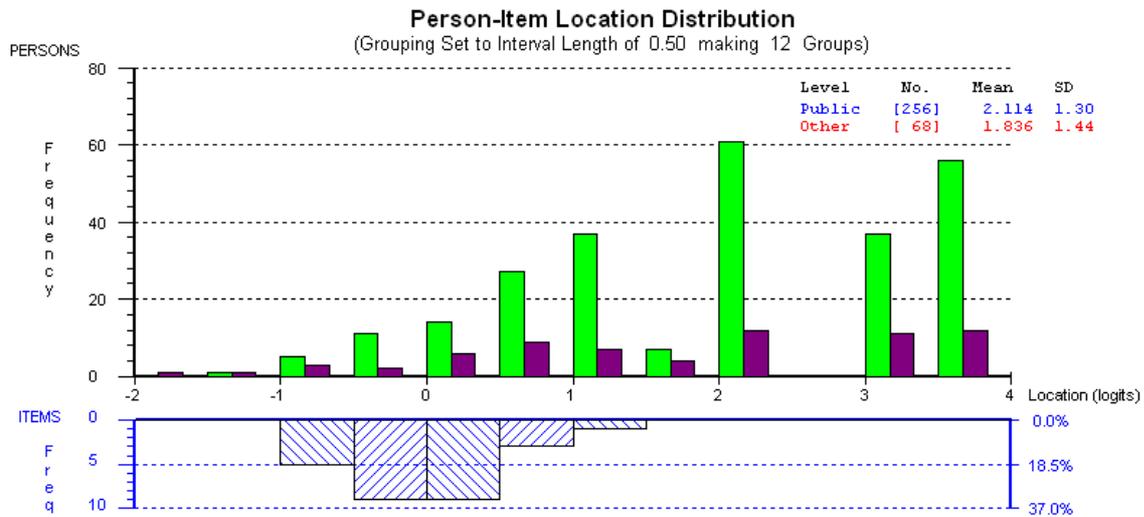


Figure 8: Target Graph by Type of School for Spatial Orientation of Letter and Number Pairs
 Note: There is a colour error in the RUMM program. Purple represents other schools (not red) and green represents the public schools (not blue).

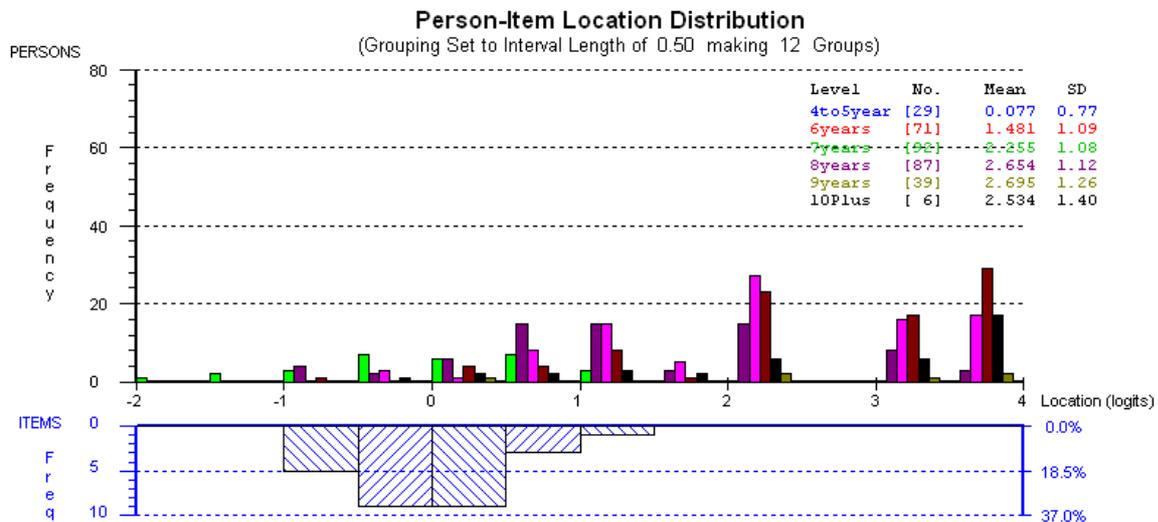


Figure 9: Target Graph by Age for Spatial Orientation of Letter and Number Pairs
 Note: There is a colour error in the RUMM program. Four and five year olds are represented by green (not blue), six year olds are represented by Purple (not red), seven year olds are represented by pink (not green), eight year olds are represented by maroon (not purple), nine year olds are represented by black (not brown-green) and ten years and above are represented by brown-green (not black).

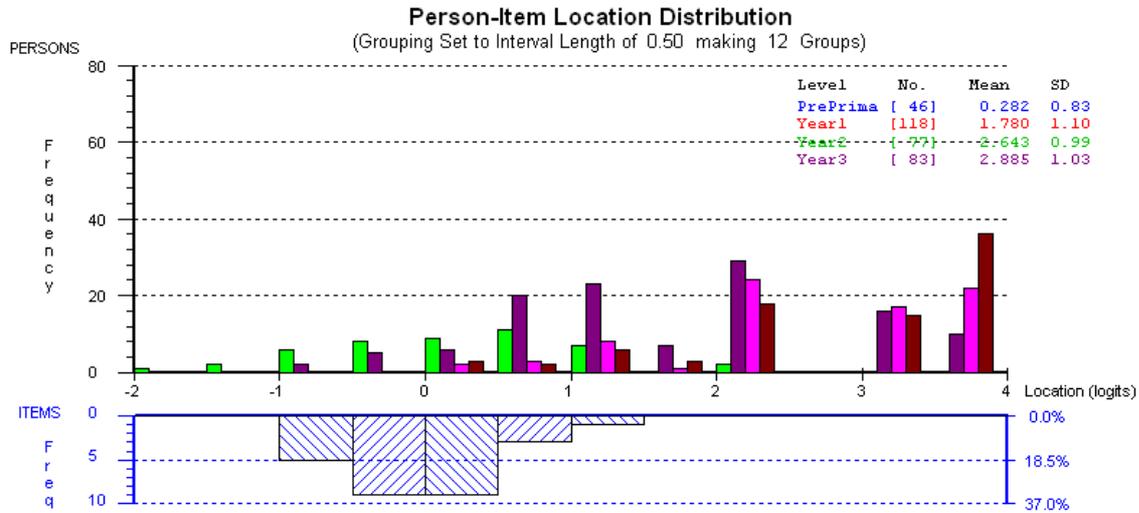


Figure 10: Target Graph by School Year for Spatial Orientation of Letter and Number Pairs
 Note: There is a colour error in the RUMM program. Pre-primary is represented by green (not blue), Year 1 is represented by purple (not red), Year 2 is represented by pink (not green), and Year 3 is represented by maroon (not purple).

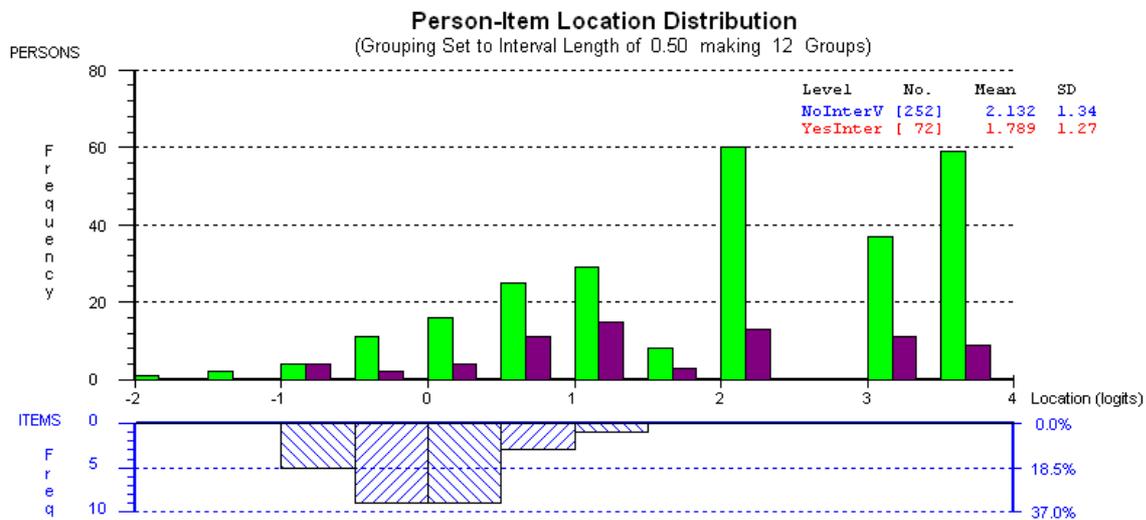


Figure 11: Target Graph by Intervention for Spatial Orientation of Letter and Number Pairs
 Note: There is a colour error in the RUMM program. Green represents no intervention and purple intervention.

The graphical data for Letter and Number Sequencing was checked in the RUMM computer program but is not produced here to avoid unnecessary repetition but the graphs are similar to those produced for Spatial Orientation of Letter and Number Pairs. Females have a higher mean measure than males for Letter and Number Sequencing but this is not statistically, significantly different ($t=1.18$, $df=322$, $p=0.18$). Public school students have a higher mean measure than private school students for Letter and Number Sequencing and this is not statistically, significantly different ($t=0.84$, $df=322$, $p=0.20$). As would be expected, the mean measures generally increased by age from four years old (lowest) to ten year old or older (highest) and this was statistically, significantly different in favour of the older student ($t=7.86$, $df=66$, $p=0.000$). Again, as expected, the mean measures generally increased by grade from Pre-primary (lowest) to Year 3 (highest) and this was statistically, significantly different ($t=13.3$, $df=127$, $p=0.000$). While the mean measure for no intervention was higher than for intervention, this was not statistically significantly different ($t=0.37$, $df=322$, $p=0.38$).

Discussion

The final 27 items and their difficulties are presented, in order from easiest to hardest, in Table 4 for Spatial Orientation of Letter and Number Pairs. The students found it easy to discriminate the longer lower case letters, for example the h, k, and b. They found it moderately easy to discriminate upper case letter pairs that had an upright line on the left of the letter (e.g. K, F) and the number 7, moderately difficult to discriminate number pairs with sharper angles (e.g. 2, 4, 5) and most difficult to discriminate lower case letter pairs and number pairs that were curved in the Victorian Cursive font (e.g. 3, z, q).

In the Letter and Number Sequencing scale (see Table 5 for the 36 item difficulties ordered from easy to hard), students found it easy to discriminate number sequences, such as 273/372 and 378/387, and moderately easy to discriminate letter and number sequences when given a choice of five combinations to choose from (e.g.

ab | ab ba ad ab) or when the letters that are out of sequence are not similar in form (e.g. play/payl). Sequences that were not changed (e.g. 1543/1543, bdhtf/bdhtf) or where the change was in the middle of the sequence (e.g. was/saw, 9834/9843) were moderately difficult to discriminate, while sequences where two sequential letters consisting only of a body were swapped (e.g. soac/saoc, laugh/laugh), were the most difficult to discriminate.

Comments on the Non-Fitting Items Deleted from the Two Scales

Ten items were deleted from the Spatial Orientation of Letter and Number Pairs Scale due to poor fit to the Rasch measurement model. Usually the main reason for non-fit is poor agreement in regard to the item difficulty. For example, half of the high ability students may say an item is easy and half say that it is difficult, thus it does not fit the measurement model and is deleted. The 10 items deleted in Spatial Orientation of Letter and Number Pairs were f, j, s, g, L, R, G, Z, N, and 9. While, the students may have disagreed on these letters partly because of the font used in this assessment, it is not considered likely that this was the main source of disagreement. It is also of particular interest that most of the letter and number pairs deleted due to disagreement were the commonly confused letters, thus, students tending towards difficulty with spatial orientation would find them difficult, while students with a good concept of spatial orientation would find them easy when printed in the reversed orientation.

Table 4
Difficulties for 27 Final Items in Spatial Orientation of Letter and Number Pairs Scale

Item No	Item	Difficulty	SE	Item No	Item	Difficulty	SE
14 (easiest)	h h	-0.97	0.22	28	2 S	+0.00	0.17
3	m m	-0.94	0.21	5	t t	+0.04	0.17
13	k k	-0.65	0.20	21	B B	+0.12	0.16
4	p p	-0.57	0.19	27	9 P	+0.14	0.16
6	v b	-0.50	0.19	34	2 S	+0.24	0.16
12	n n	-0.45	0.19	32	4 +	+0.32	0.16
31	6 @	-0.39	0.18	15	y n	+0.43	0.16
22	E E	-0.20	0.18	36	2 5	+0.46	0.16
10	e s	-0.15	0.17	16	b d	+0.48	0.15
26	X K	-0.13	0.17	29	D O	+0.51	0.15
19	F F	-0.11	0.17	33	3 E	+0.58	0.15
35	7 C	-0.10	0.17	17	q P	+0.59	0.15
11	o c	-0.03	0.17	18	3 E	+1.43	0.14

Note: Items are ordered from easiest (item 14, -0.97 logits) to hardest (item 18, +1.43 logits)

Table 5
Difficulties for 36 Final Items in the Letter and Number Sequencing Scale by Order

Item No	Item	Difficulty	SE	Item No	Item	Difficulty	SE
4 (easiest)	273/372	-1.53	0.31	36	ts/5 choices	-0.09	0.21
3	378/387	-1.52	0.31	10	1543/1543	-0.04	0.21
9	495/594	-1.20	0.28	32	bdhtf/bdhtf	+0.04	0.21
8	251/251	-1.12	0.28	19	was/saw	+0.06	0.21
2	22/22	-1.07	0.27	11	9834/9843	+0.09	0.21
5	1372/1732	-0.84	0.26	38	pjb/5 choices	+0.22	0.20
1	21/12	-0.66	0.26	31	soua/soua	+0.31	0.20
12	83257/83257	-0.61	0.24	23	on/no	+0.62	0.19
7	56/65	-0.59	0.24	20	fgpt/fgpt	+0.69	0.18
6	6761/6761	-0.57	0.24	34	dp/5 choices	+0.79	0.18
40	54/five options	-0.45	0.23	17	like/liek	+0.83	0.18
14	play/payl	-0.40	0.23	41	63/5 choices	+1.23	0.17
37	nac/5 choices	-0.35	0.23	16	found/fuond	+1.23	0.16
27	hers/hers	-0.30	0.22	22	hfklf/hfhlt	+1.24	0.16
33	ab/5 choices	-0.27	0.22	35	fr/5 choices	+1.24	0.16
15	get/gef	-0.12	0.21	26	jump/jmup	+1.36	0.16
24	stop/stop	-0.11	0.21	30	soac/saoc	+1.37	0.16
21	pqbd/qpdb	-0.09	0.21	28	laugh/laugh	+1.97	0.15

Note: Items are ordered from easiest (item 4, -1.53 logits) to hardest (item 28, +1.97 logits)

In Letter and Number Sequencing, six of the original 42 items were deleted due to non-fit to the Rasch measurement model. Three of the deleted sequences consisted of comparisons of the same sequence such as do/do and but/but. One sequence was a familiar word (dog/god) and two deleted sequences consisted of number sequences where the student had a choice of five possible responses (e.g. 29 | 59 92 29 29 59). In this scale, the font should not have affected the students' interpretation of the sequences as they were comparing sequences produced in the same font.

Inferences from the Measures of the Two Linear Rasch Scales

Linear scales were created that show good fits to the measurement model for the Spatial Orientation of Letter and Number Pairs, and Letter and Number Sequences. Valid inferences can now be made about the student measures for spatial orientation from these two linear scales. The bottom 24 student measures for Spatial Orientation of Letter and Number Pairs have been taken because these students all scored 13/27 or less, meaning that they were the students who responded incorrectly to half of the lower case letter pairs, most of the upper case letter pairs as well as most of the numbers. These student measures are presented in Table 6.

Table 6
Lowest 24 Student Measures Spatial Orientation of Letter and Number Pairs

ID	Raw score	Location	SE	Residual
324	4	-1.74	0.54	0.37
5	7	-1.07	0.45	0.67
151	7	-1.07	0.45	-0.11
200	8	-0.88	0.43	1.03
164	9	-0.71	0.42	-0.19
229	10	-0.55	0.41	0.36
323	10	-0.55	0.41	-0.78
84	10	-0.55	0.41	0.25
27	10	-0.55	0.41	-0.14
156	10	-0.55	0.41	0.81
80	10	-0.55	0.41	0.41
167	11	-0.39	0.40	1.67
203	11	-0.39	0.40	0.78
79	11	-0.39	0.40	0.78
18	11	-0.39	0.40	0.57
66	12	-0.23	0.40	1.23
166	12	-0.23	0.40	1.58
119	12	-0.23	0.40	2.40
205	12	-0.23	0.40	1.60
317	12	-0.23	0.40	0.68
303	12	-0.23	0.40	-1.74
81	12	-0.23	0.40	1.33
76	13	-0.08	0.40	-1.29
103	13	-0.08	0.40	0.38

The student who scored four in Spatial Orientation of Letter and Number Pairs was only able to identify lower case letters when presented in pairs. Students who scored 10 had some difficulty discriminating upper case letter pairs as well as number pairs, whereas the students who scored 13 mainly found the number pairs where the number had a sharp angle and curved letter pairs difficult to identify. Students scoring poorly in Spatial Orientation of Letter and Number Pairs have difficulty discriminating which orientation or direction a letter or number should face and may need extra assistance to improve this skill.

The bottom 35 student measures for Letter and Number Sequences have been taken because these students scored less than 11 out of 36, meaning that they were only able to identify number sequences and unable to identify any letter sequences. These student measures are presented in Table 7. Students, who scored zero, were not able to correctly identify any items in the scale and had difficulty discriminating numbers as well as letters in sequences. The students scoring 4 correct were only able to identify number sequences of 3 numbers and had difficulty with all the letter sequences and the longer number sequences. These student measures identify students who may require assistance to improve their skill in sequencing letters and numbers as used in spelling and calculations.

Table 7

Lowest 35 Student Measures Letter and Number Sequencing

ID	Raw score	Location	SE	Residual
18	0	-4.28	1.22	
169	0	-4.28	1.22	
167	0	-4.28	1.22	
166	0	-4.28	1.22	
165	0	-4.28	1.22	
324	0	-4.28	1.22	
162	0	-4.28	1.22	
156	0	-4.28	1.22	
289	0	-4.28	1.22	
37	0	-4.28	1.22	
163	0	-4.28	1.22	
12	0	-4.28	1.22	
8	0	-4.28	1.22	
7	0	-4.28	1.22	
6	0	-4.28	1.22	
5	0	-4.28	1.22	
4	0	-4.28	1.22	
2	0	-4.28	1.22	
153	0	-4.28	1.22	
323	0	-4.28	1.22	
161	0	-4.28	1.22	
203	1	-3.48	0.86	-0.25
164	2	-2.92	0.68	-0.08
150	2	-2.92	0.68	+0.50
81	3	-2.53	0.59	-0.21
16	4	-2.24	0.53	+0.06
151	4	-2.24	0.53	+0.88
3	4	-2.24	0.53	+0.46
80	5	-1.99	0.49	+0.05
64	6	-1.77	0.46	-0.90
206	7	-1.58	0.44	+1.15
66	7	-1.58	0.44	-0.76
26	7	-1.58	0.44	+0.75
199	8	-1.40	0.42	+1.45
27	11	-0.93	0.38	-0.30

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