

NUMERACY GAINS AT WAIKATO INSTITUTE OF TECHNOLOGY (WINTEC) FOR 2018

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SUMMARY

This report tracks numeracy gains achieved by targeted 2018 students at Waikato Institute of Technology. In collating data, we applied the multi-year testing requirement referred to by the Tertiary Education Commission (TEC, 2012, 2017a, b) as the sequence concept. To be able to compare initial and progress assessment scores, we were required to set up a multivariate layout manually. We report on learners' step-based progress to exemption levels for numeracy. Of the targeted numeracy cohort (N=591), 44.2% of learners (n=261) progressed to exemption-level scores (step 5 or higher). We used cross-tabulations to report on numeracy progress by ethnicity and Centre of Study at the institute. To establish whether learners showed statistically significant gain in numeracy, we used a matched-pairs t-test to compare initial and progress scale scores for the full cohort, followed by repeated measures analysis of variance (ANOVA) to investigate gains for within-subjects differences for two fixed factors, ethnicities and Centre of Study. To explore between-group and between-Centre differences, we performed a two-way ANOVA on Initial and Progress Scale scores for the two fixed factors. To complete the picture, we replicated TEC's (2012) algorithm for calculating gain to illustrate that these results under-reported learners' numeracy progress.

The findings showed that within-subjects gains were statistically significant, while between-subjects gains for ethnicity categories were not statistically significant. For the TEC's (2012) algorithm, we found that approximately 22.7% (n=134) of learners (n=591) who had achieved step 5 (or higher) on numeracy were classified as not having achieved statistically significant gain. We continue to view the TEC's algorithm as under-reporting success, noting the disparate impact of the algorithm in calculating progress.

We concluded that current embedded numeracy instruction practices, though successful, could still be improved. We recommend that findings on numeracy progress be considered within a joined-up system of organisational practice that takes literacy and numeracy (LN) progress data, classroom observation analyses and module completions into account. The challenge will be to develop innovations for numeracy development that align with changing approaches and practices in vocational pedagogy. A whole-of-organisation approach would require that the LN team pursue close ties with other support teams such as Student Learning Services, Te Kete Kōnae and the Wintec learning coaches.

INTRODUCTION

This report deals with the numeracy progress of students enrolled at the institute in 2018. One of the challenges of the tracking process related to the data set, specifically the implications of the sequence concept (TEC, 2012, 2017a,b)¹ which allows for relevant Literacy and Numeracy Assessment Tool (LNAT) scores from previous years to be taken into account.

For purposes of this report, we repeated the approach adopted for the report on 2017 LN performance (Greyling, 2018). Our analysis involved cross-tabulations of initial and progress numeracy assessment scores, including a full cohort analysis, as well as tables for two fixed factors, ethnicity and Centre of Study. To establish whether learners showed statistically significant gain in numeracy and numeracy, we used paired ttests to compare the full cohort's initial and progress assessment scale scores, followed by repeated measures analysis of variance (ANOVA) to compare within-subjects gains for the two fixed factors, ethnicity and Centre of Study. To uncover between-group and between-Centre

¹ . The sequence concept is specified in a Tertiary Education Commission (TEC) guideline document (TEC, 2017). We could not find an easy way of operationalising the sequence concept. We used a three-year period prior to the year under scrutiny as our period of relevant data (2015 to 2017) to identify baseline scores. Data from these years were selected for students enrolled in 2018, with the first score taken as initial score and the next highest score for the period 2015-2018 as the progress score. We acknowledge the LNat administrator at Wintec, Charlene Kirikiri, who performed various multi-year data-matching steps, using Tableau Software, to identify the relevant data, based on the 2018 Single Data Return file and LNat website data. Her data-management skills allowed us to develop a multivariate data layout for repeated measures analysis with more ease than before.

differences, we performed a two-way ANOVA on Initial and Progress Scale scores for the two fixed factors. To complete the picture, we replicated TEC's (2012) algorithm for calculating gain to illustrate that these results under-reported learners' numeracy progress.

We compared the findings to show that step-based gains offered a more positive picture of numeracy gains than the current TEC LNAT algorithm. For 2018 data, 44.2% (n=261) of the targeted cohort (N=591) achieved exemption-level scores. We replicated the findings for the 2017 data, showing improved LN performance for the 2018 cohort irrespective of how gains were calculated. The LN gains also exceeded the TEC target of 25% of the targeted group having to have achieved statistically significant gain: 28.9% (n=171) of targeted learners (N=591) achieved such gain².

Conclusions and recommendations are included. We concluded that the LNAT algorithm under-reported statistically significant numeracy gains, and that TEC-approved exemption levels offered a more positive threshold for calculating category-shift numeracy gains. We recommend a whole-of-organisation strategy, aimed at improvement and innovation, which integrates LNAT data analysis, classroom observation data, and module completions.

MAIN AIMS

The main aims of the report are to

- record numeracy progress for students enrolled at the institute in 2018.
- show the numeracy progress achieved by the targeted 2018 cohort at Wintec following two approaches: step-based categorical step gains and TEC LNAT algorithm-based gains.
- outline LN gains calculated by ethnicity and by Centre.
- record evidence of compliance with TEC funding requirements.
- present conclusions.
- recommend strategies for maintaining and improving current levels of numeracy performance.

DATA-TRACKING METHODS

The methods applied in preparing this report were quantitative, namely:

In the sections that follow, we report numeracy gains for the 2018 cohort. The findings are reported in figures, tables and line charts. The following fixed factors were used to guide our analysis: ethnicity and Centre of Study. Our primary interest was in establishing whether learners had achieved statistically significant numeracy skills development.

Statistically significant gains were interpreted from multiple perspectives, namely:

- Cross-tabulations, tables and line charts were used to show category shifts from lower steps to exemption level steps by the end of the course.

² It should be noted that the 28.9% of gains include learners showing statistically significant gain at levels below the step 5 threshold level, while the cross-tabulation finding (44.2%) excludes these gains. We do not report on the number of learners who scored at levels lower than they were at initial assessment – this would be a limitation of this study as the number of learners who regressed would also be a useful statistic. A rough account of misclassifications is reported in Table 15 where our step-based approach under-reported 44 students who showed statistically significant gain, and the TEC's LNAT algorithm misclassified 134 students who progressed to step 5 or higher.

- For the full cohort, a t-test result allowed us to judge whether statistically significant gains had been achieved within a pre/post-test design.
- For numeracy progress, we performed repeated measures analysis of variance (ANOVA) to explore statistically significant within-subjects numeracy gains, as well as exploring the effect of two fixed factors, ethnicity and Centre of Study.
- For comparisons of between-subjects differences when initial and progress numeracy assessments were administered, we computed a two-way ANOVA which included two fixed factors, ethnicity and Centre of Study.
- A comparison of results for cross-tabulations, the pre/post-test procedures and the TEC's algorithm for assessing numeracy gains was included.

FINDINGS FOR NUMERACY

The findings are presented as follows:

Tables include the raw count of students for the various levels or steps, as well as percentages per step by group. In the line charts that were used, percentages were used to avoid misrepresentation. We recommend that the reader check both raw counts and percentages to develop a balanced perspective on the reported gains.

Bar charts report actual numbers per group. These numbers can be cross-validated against the information in the accompanying tables.

Comparative line charts report the percentages for each step for the levels of both ethnicity and Centre of Study – these percentages can be cross-validated against the appropriate tables and bar charts.

Paired t-test results are reported for numeracy data.

Repeated measures analyses of variance (ANOVAs) results are included to show within-subjects differences. We also included ethnicity and Centre of Study as fixed factors.

Two-way ANOVA results for the four levels of ethnicity and the six levels of Centre of Study are reported to explore between-group and between-Centre differences at initial and progress assessment.

Note: Detailed cross-tabulations are not reported – these are available on request. Our presentation is selective, showing the totals from cross-tabulated findings. In all cases, we report on how learners who scored below the exemption level of Step 4 at initial assessment fared in progress assessments.

FINDINGS FOR NUMERACY STEPS BY ETHNICITY

Following the layout referred to directly above, we disaggregated the findings of numeracy.

Wintec had 1829 students who were required to be assessed. Of these, 591 students sat the progress assessment and had both baseline (initial) and progress assessment results for numeracy. In the tables and figures that follow, we present totals. All data analysis files are lodged with the Centre for Education and Foundation Pathways, and both the data sets and the SPSS analytical results are available.

In Tables 2 to 5 and Figures 2 to 5, we report totals for four ethnicity categories, with 1 = Māori; 2 = Pasifika; 3 = Pākeha; and 4 = Other ethnicities. The latter included Asian, African and other European ethnicities.

Full cohort's numeracy performance

For the numeracy group (N=591), the distribution of step scores shows that approximately 44.2% showed gains where they scored at step 5 or higher.

Table 1: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (Full cohort, N=591)

		Step 1 Progress	Step 2 Progress	Step 3 Progress	Step 4 Progress	Step 5 Progress	Step 6 Progress	Total
Total (n=591)	Count	6	30	91	203	214	47	591
	% within Initial Step	1.0%	5.2%	15.4%	34.3%	36.2%	8.0%	100.0%

What these numbers mean is that when progress assessments were administered to the targeted sub-group (n=591)

- 55.8% (n=36) scored at step 4 or lower; and
- 44.2% (n=261) obtained scores at step 5 or higher.

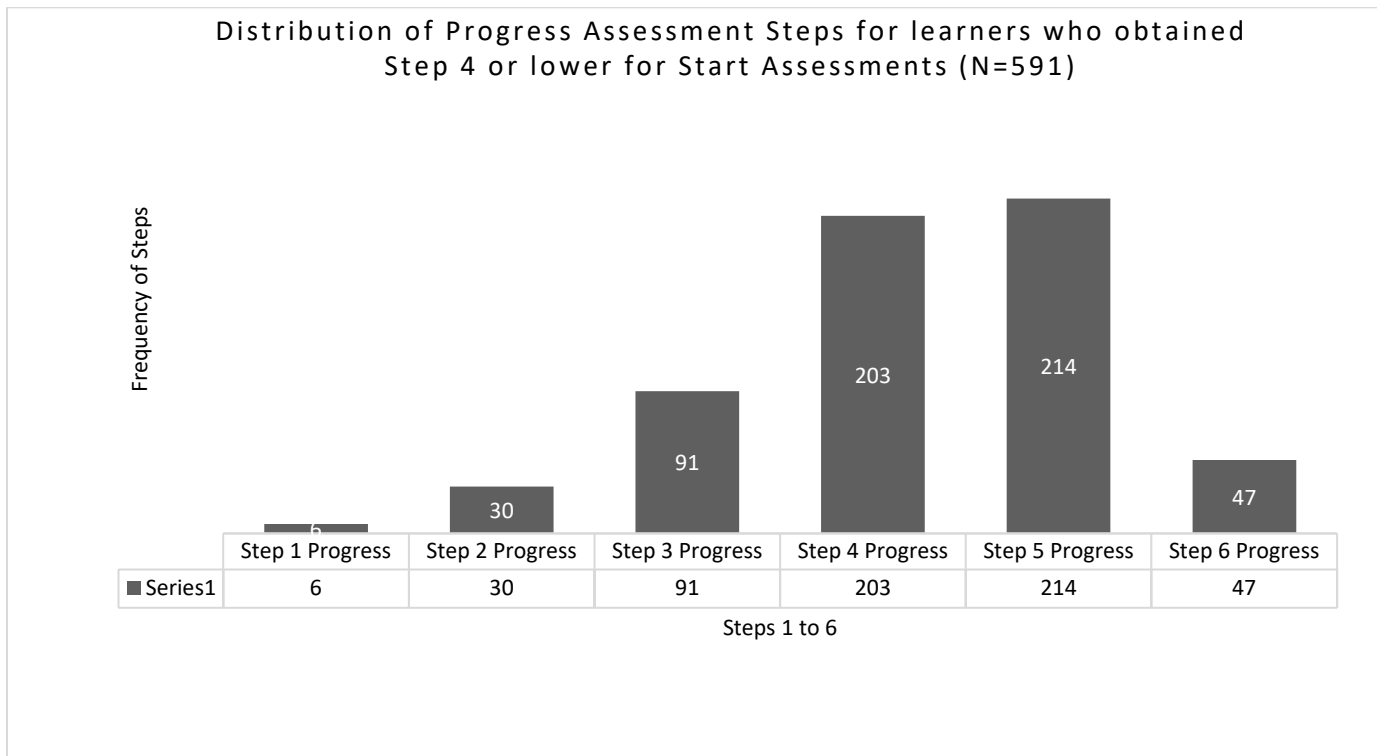


Figure 1: Distribution of Progress Assessment Steps for learners who obtained Step 4 or lower for Start Assessments (Full cohort, N=591)

Māori learners' numeracy performance

In Table 2, we report totals for Māori students (n=243), 43.6% of whom scored at step 5 or higher.

Table 2: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (Māori) (n=243)

		Step 1 Progress	Step 2 Progress	Step 3 Progress	Step 4 Progress	Step 5 Progress	Step 6 Progress	Total
Total (n=243)	Count	4	8	35	90	87	19	243
	% within Initial Step	1.6%	3.3%	14.4%	37.0%	35.8%	7.8%	100.0%

When the progress assessments were administered, we found that of the targeted group of 243 Māori learners

- 56.4% (n=137) scored step 4 or lower, and
- 43.6% (n=106) progressed to step 5 or higher.

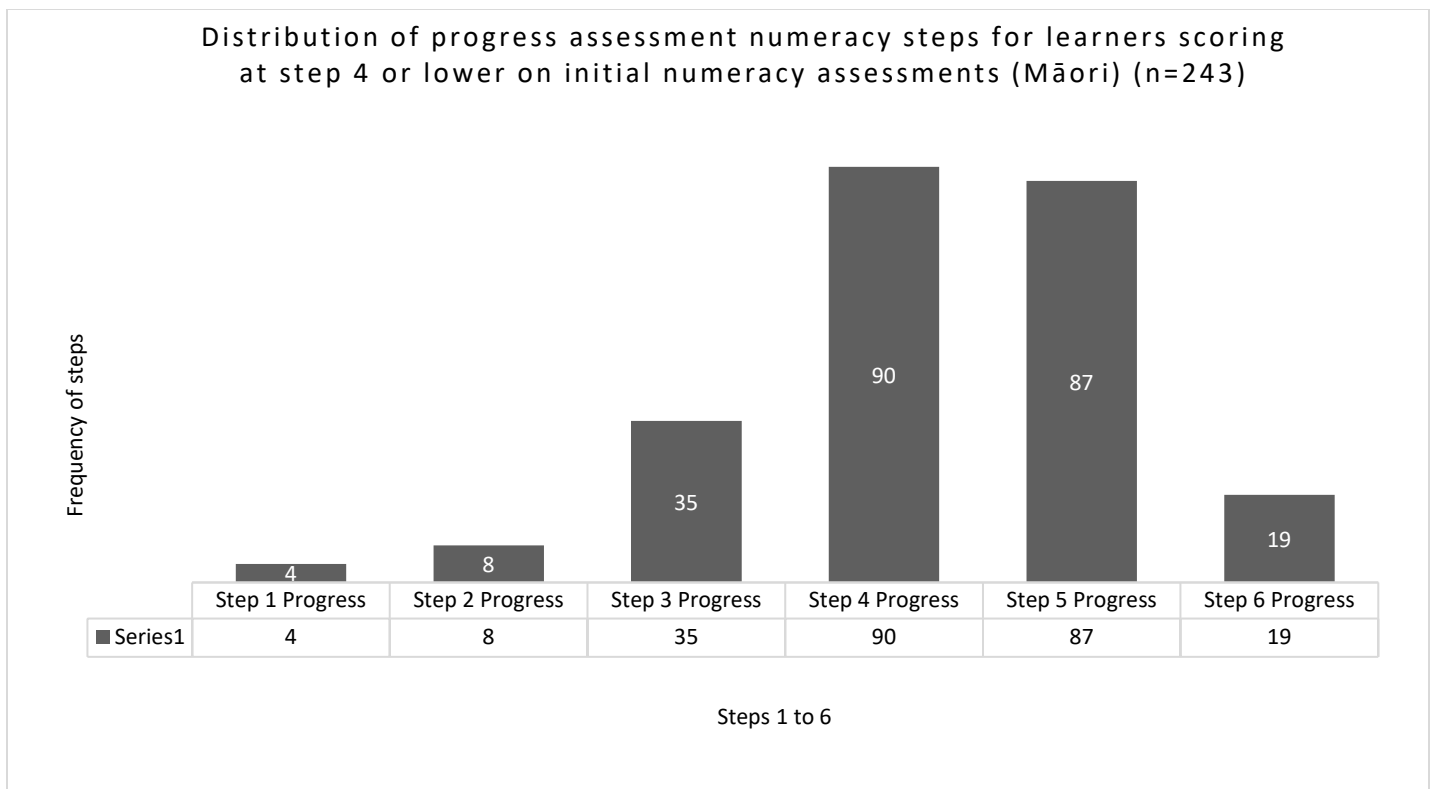


Figure 2: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (Māori) (n=243)

Pasifika learners' numeracy performance

Pasifika learners' performance on numeracy was somewhat lower than the other ethnicities' – it should be noted that their numeracy performance met the 35% Wintec target.

Table 3: Distribution of progress assessment numeracy steps for learners scoring at step 3 or lower on initial numeracy assessments (Pasifika)(n=62)

		Step 1 Progress	Step 2 Progress	Step 3 Progress	Step 4 Progress	Step 5 Progress	Step 6 Progress	Total
Total (n=62)	Count	2	5	11	22	17	5	62
	% within Initial Step	3.2%	8.1%	17.7%	35.5%	27.4%	8.1%	100.0%

When the progress assessments were administered, we found that of the targeted group of 62 Pasifika learners

- 64.5% (n=40) scored at step 4 or lower; and
- 35.5% (n=22) progressed to step 5 or higher.

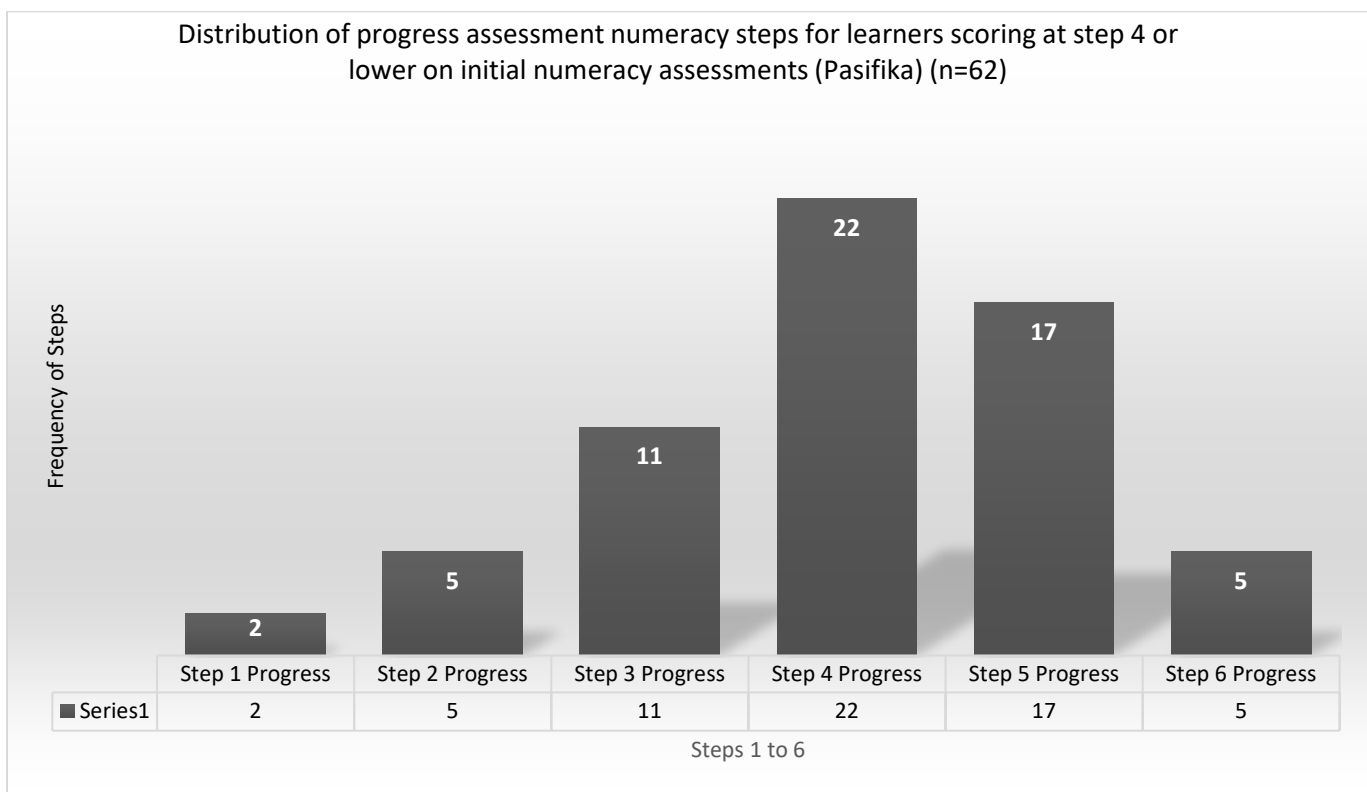


Figure 3: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (Pasifika) (n=62)

Pākeha/New Zealand European learners' numeracy performance

For New Zealand European/Pākeha we found a high proportion of students (46.2%) recorded numeracy gains compared to Pasifika. However, when scale scores were compared, it transpired that no significant differences obtained in relation to other ethnicities.

Table 4: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (New Zealand European/Pākeha) (n=225)

		Step 1 Progress	Step 2 Progress	Step 3 Progress	Step 4 Progress	Step 5 Progress	Step 6 Progress	Total
Total (n=225)	Count		16	36	69	88	16	225
	% within Initial Step		7.1%	16.0%	30.7%	39.1%	7.1%	100.0%

When the progress assessments were administered, we found that of the targeted group of 225 Pākeha/New Zealand European learners

- 53.8% (n=121) scored at step 4 or lower; and
- 46.2% (n=104) progressed to exemption-level scores at step 5 or higher.

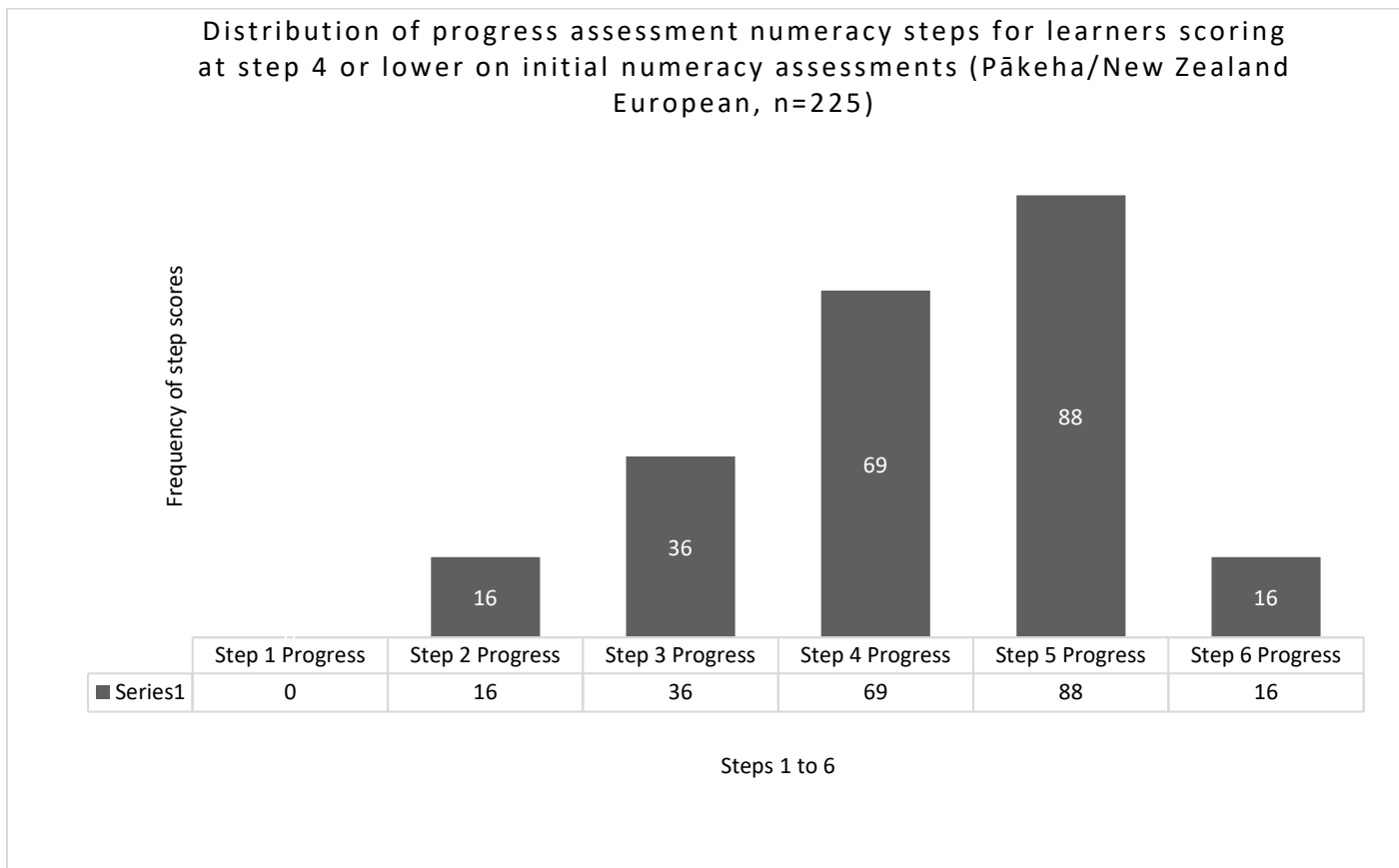


Figure 4: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (Pākeha/New Zealand European, n=225)

Other ethnicities

All learners outside Māori, Pasifika and New Zealand European/Pākeha were categorized as *other ethnicities*. We could see no reason to differentiate among the 61 students in this category. However, if this sub-group increased in number further distinctions would be considered. Table 5 reports these category-based gains for students in this group

Table 5: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (Other ethnicities) (n=61)

		Step 1 Progress	Step 2 Progress	Step 3 Progress	Step 4 Progress	Step 5 Progress	Step 6 Progress	Total
Total (n=61)	Count	0	1	9	22	22	7	61
	% within Initial Step	0.0%	1.6%	14.8%	36.1%	36.1%	11.5%	100.0%

When the progress assessments were administered, we found that of the targeted group of 61 students from other ethnicities

- 52.4% (n=32) scored at step 4 or lower; and
- 47.6% (n=29) progressed to step 5 or higher.

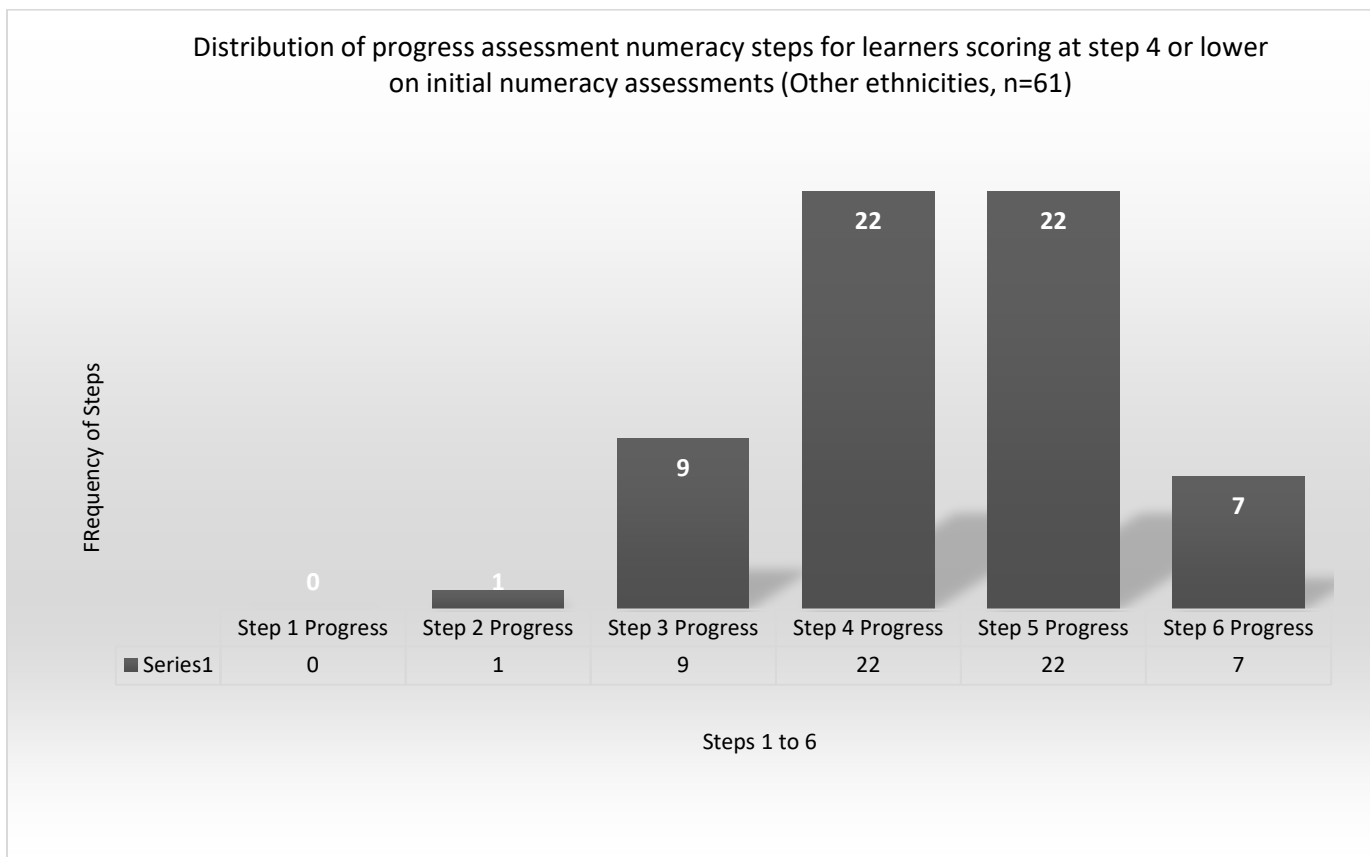


Figure 5: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (Other ethnicities, n=61)

Comparative line chart of proportions of learners at various progress steps

To show how the four ethnicities compare with each other's and the full cohort's performance, we added the following line graph which shows how close the patterns of numeracy progress were for them.

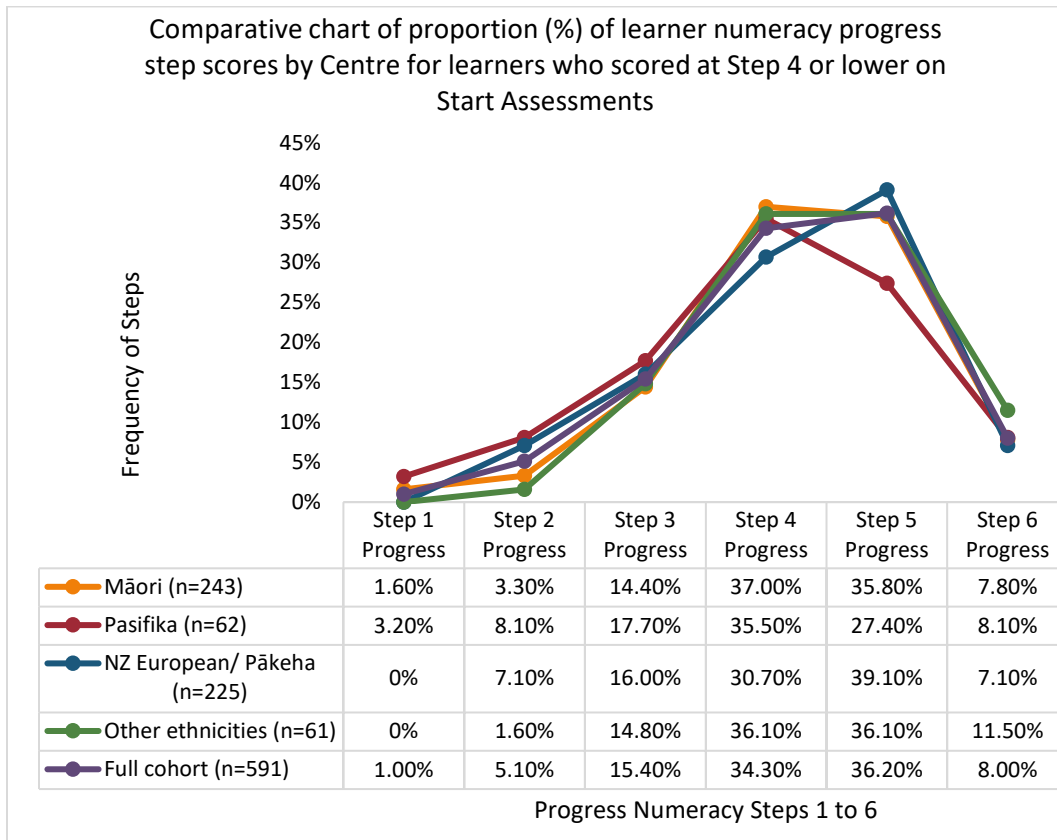


Figure 6: Comparative chart of proportion (%) of learner numeracy progress step scores by Centre for learners who scored at Step 4 or lower on Start Assessments

An eyeball assessment of the distributions in Figure 6 suggested that between-group differences would be marginal, while within-subjects group differences would most likely be significant. We report on these differences in later sections.

FINDINGS FOR NUMERACY STEPS BY CENTRE OF STUDY

The full cohort's numeracy performance has already been summarised in Table 1 and Figure 2 in an earlier section, as well as Figure 6 directly above. Find below the distributions of step scores for the six Centres of Study whose students were involved (Tables 6 to 11 and Figures 7 to 12). We repeat the caution that small numbers, when converted to percentages, may mislead the reader.

Centre for Beauty Therapy, Hairdressing and Hospitality (CBTHH) results:

Numeracy progress for CBTHH students is summarised below. Of these students, 33.3% of these students progressed to step 5 of the numeracy progressions.

Table 6: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (Centre for Beauty Therapy, Hairdressing and Hospitality) (n=24)

Centre		Step 1 Progress	Step 2 Progress	Step 3 Progress	Step 4 Progress	Step 5 Progress	Step 6 Progress	Total
CBTHH	Count	0	2	4	10	8	0	24
	% within Initial Step	0%	8.30%	16.70%	41.70%	33.30%	0%	100.00%

When the progress assessments were administered, we found that of the targeted group of 24 students from CBTHH

- 66.7% (n=16) scored at step 4 or lower; and
- 33.3% (n=8) progressed to step 5 or higher.

It is worth noting that small sample sizes impact on the proportions (expressed as % in this case). As stated elsewhere, this is the reason that tables contain both counts and percentages. Figures capture the real-world counts represented by the percentages:

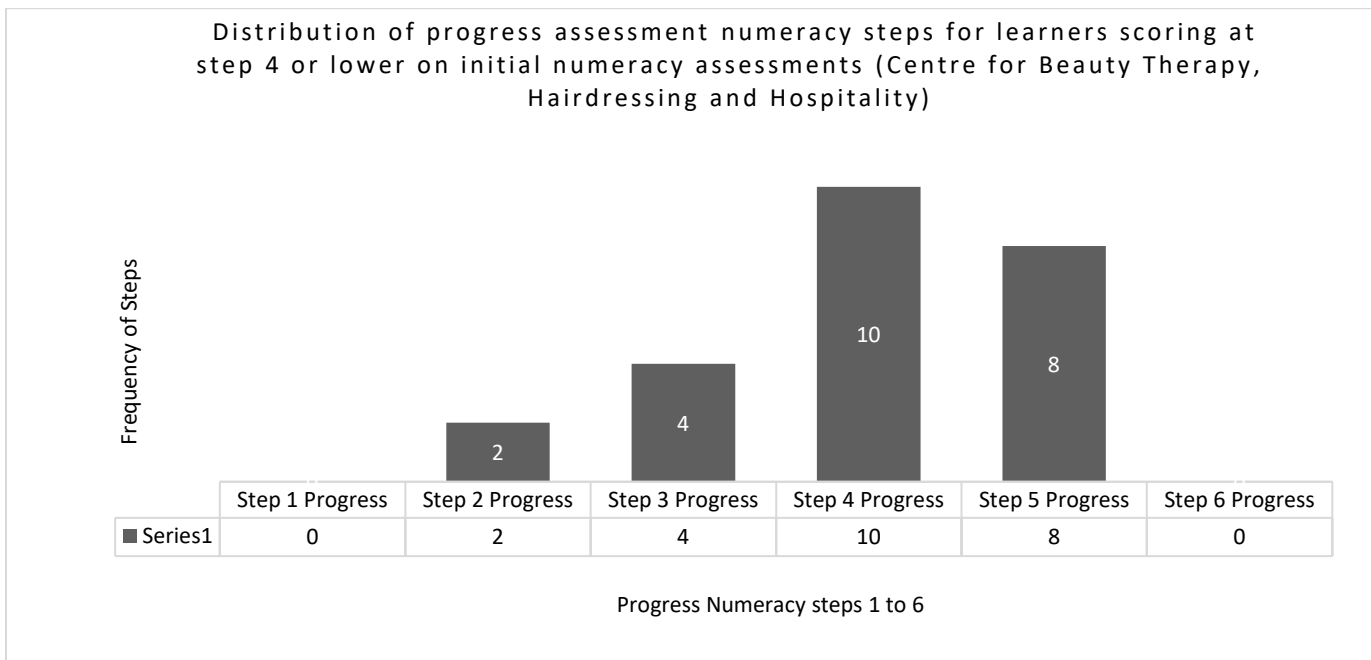


Figure 7: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (Centre for Beauty Therapy, Hairdressing and Hospitality)

Centre for Business and Enterprise (CBE) results

Results for CBE show that 38.1% of targeted learners progressed to exemption level scores.

Table 7: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (Centre for Business and Enterprise)

Centre		Step 1 Progress	Step 2 Progress	Step 3 Progress	Step 4 Progress	Step 5 Progress	Step 6 Progress	Total
CBE	Count	0	3	4	19	13	3	42
	% within Initial Step	0%	7.10%	9.50%	45.20%	31.00%	7.10%	100.00%

When the progress assessments were administered, we found that of the targeted group of 42 students from CBE

- 61.9% (n=26) scored at step 4 or lower; and
- 38.1% (n=16) progressed to step 5 or higher.

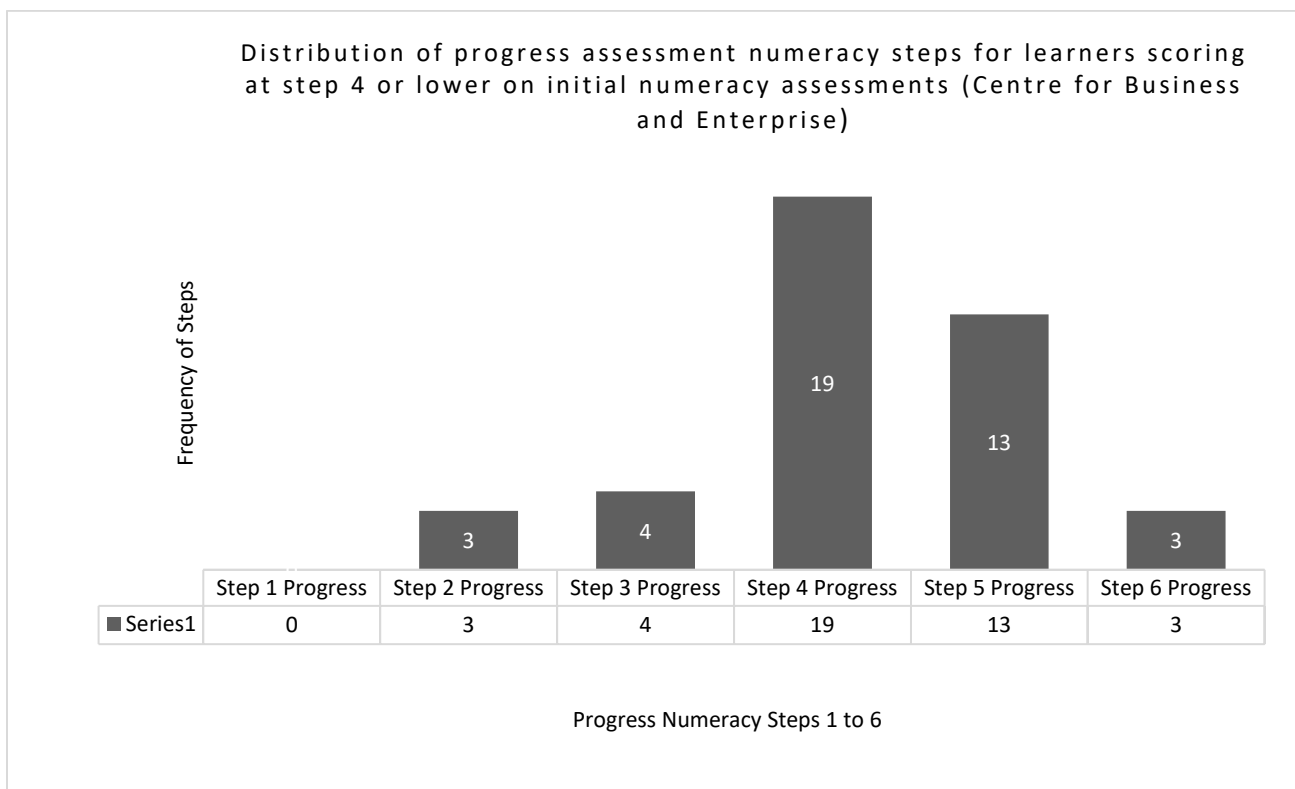


Figure 8: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (Centre for Business and Enterprise)

Centre for Education and Foundation Pathways (CEFP) results

CEFP results show significant category shifts to steps 5 and 6. However, we noted that misclassifications by the LNAT algorithm were highest for CEFP (See Table 17).

Table 8: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (Centre for Education and Foundation Pathways)

Centre		Step 1 Progress	Step 2 Progress	Step 3 Progress	Step 4 Progress	Step 5 Progress	Step 6 Progress	Total
CEFP	Count	3	7	29	52	44	9	144
	% within Initial Step	2.10%	4.90%	20.10%	36.10%	30.60%	6.30%	100.00%

When the progress assessments were administered, we found that of the targeted group of 144 students from CBE

- 63.2% (n=91) scored at step 4 or lower; and
- 36.8% (n=53) progressed to step 5 or higher.

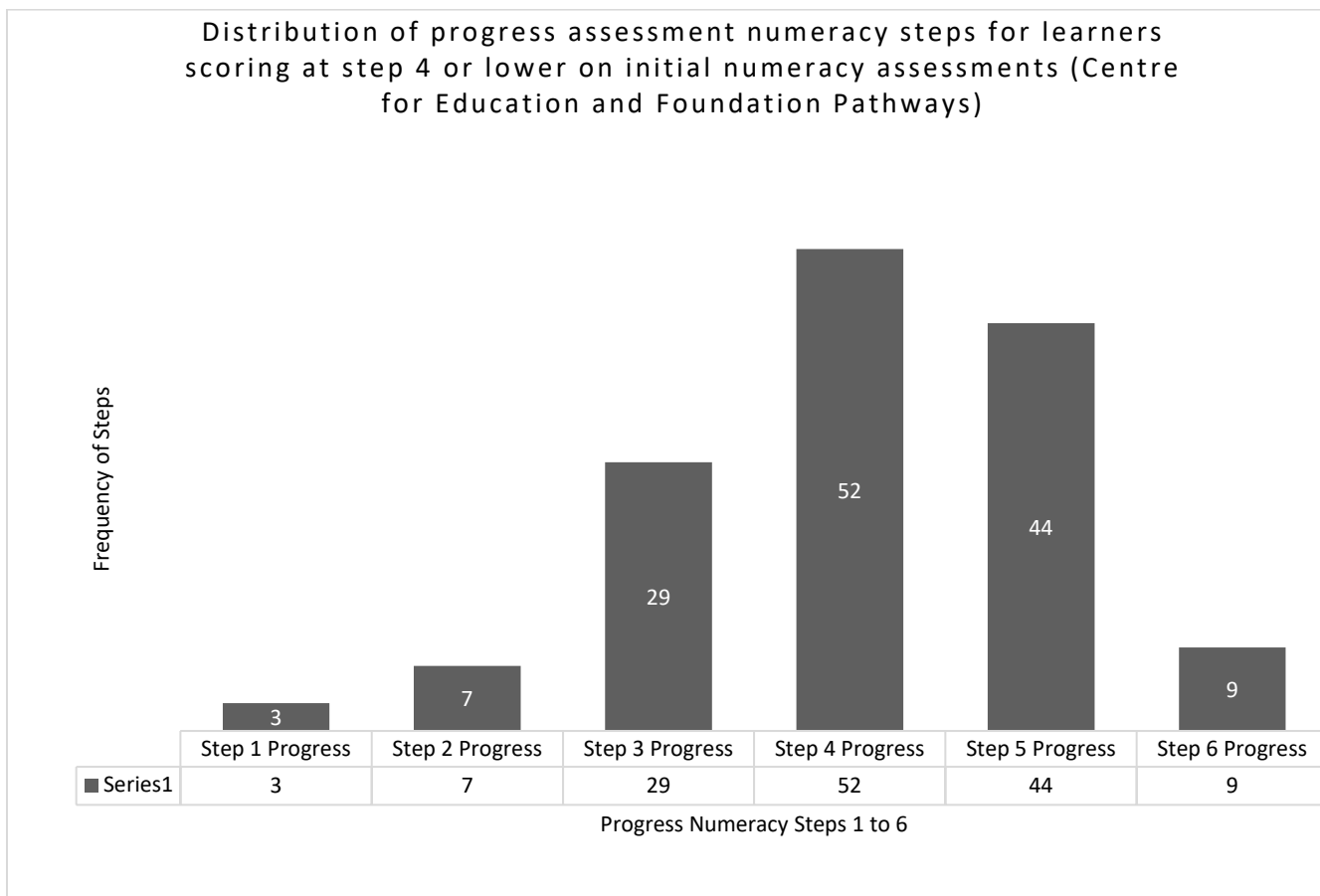


Figure 9: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (Centre for Education and Foundation Pathways)

Centre for Trades (Trades) results

Centre for Trades results refer to 278 of 591 students (full cohort). This number represents 47% of the full cohort; thus, if 48.6% of learners who scored step 4 or lower on the initial assessment progressed to step 5 or higher, we note these as significant gains.

Table 9: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (Centre for Trades)

Centre		Step 1 Progress	Step 2 Progress	Step 3 Progress	Step 4 Progress	Step 5 Progress	Step 6 Progress	Total
Trades	Count	3	15	42	83	112	23	278
	% within Initial Step	1.10%	5.40%	15.10%	29.90%	40.30%	8.30%	100.00%

When the progress assessments were administered, we found that of the targeted group of 278 students from Trades

- 51.4% (n=143) scored at step 4 or lower; and
- 48.6% (n=135) progressed to step 5 or higher.

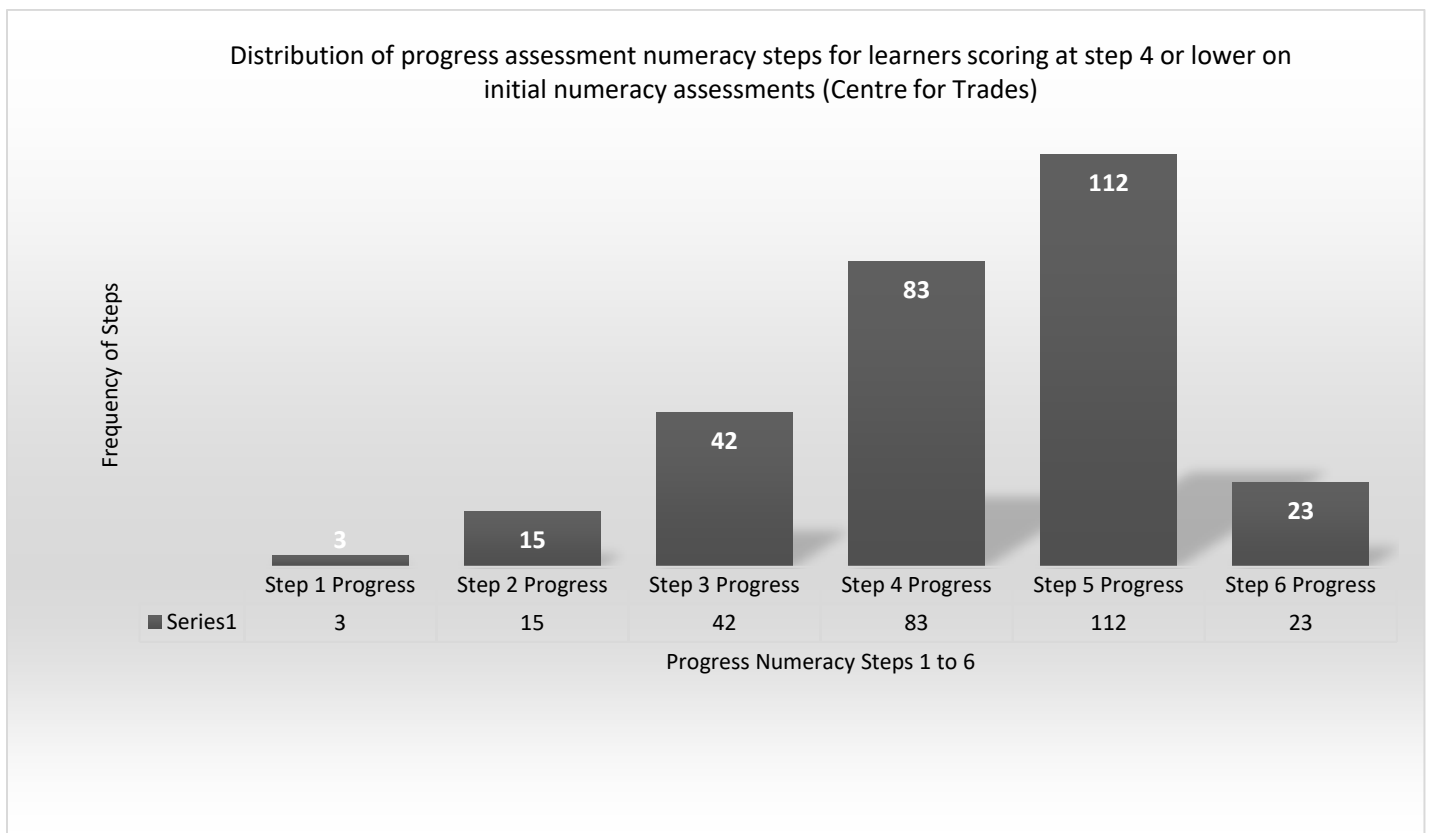


Figure 10: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (Centre for Trades)

Centre for Science and Primary Industries (CSPI) results

CSPI results show that 45.1% of students progressed to Step 5 or higher on the numeracy progressions.

Table 10: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (Centre for Science and Primary Industries) (n=91)

Centre		Step 1 Progress	Step 2 Progress	Step 3 Progress	Step 4 Progress	Step 5 Progress	Step 6 Progress	Total
CSPI	Count	0	3	11	36	29	12	91
	% within Initial Step	0%	3.30%	12.10%	39.60%	31.90%	13.20%	100.00%

When the progress assessments were administered, we found that of the targeted group of 91 students from CSPI

- 54.9% (n=50) scored at step 4 or lower; and
- 45.1% (n=41) progressed to step 5 or higher.

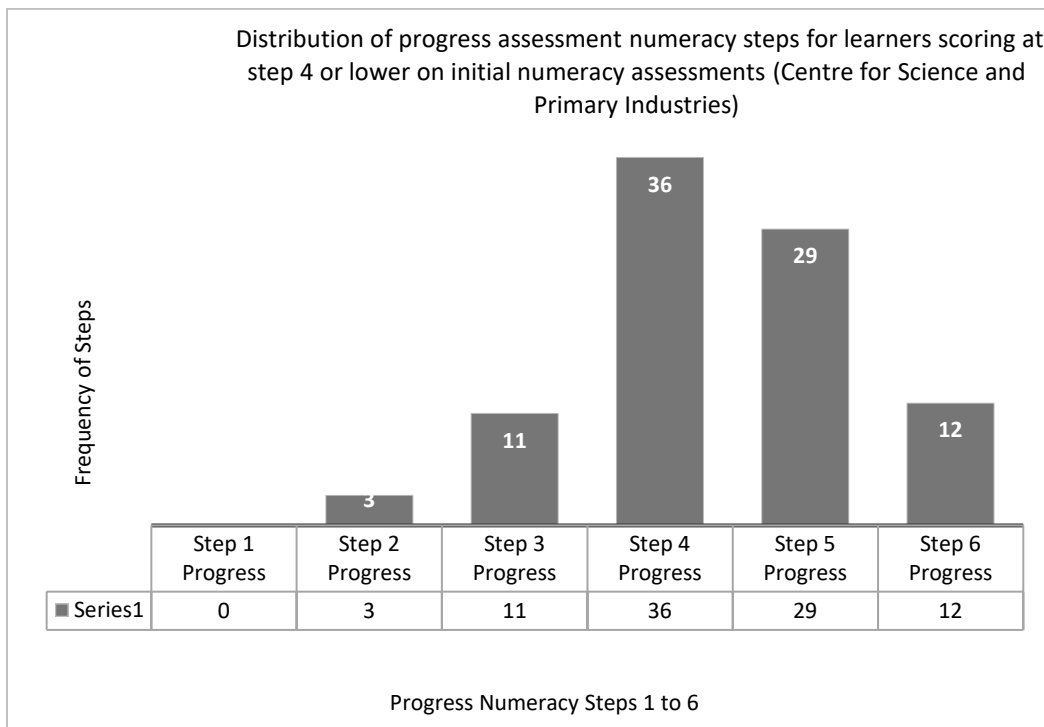


Figure 11: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (Centre for Science and Primary Industries)

Centre for Sports Science and High Performance (CSSHP)

These results show progress at a level above the Wintec target of 35%. In this case, percentages based on small sample sizes could be viewed as misleading.

Table 11: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (Centre for Sports Science and High Performance)

Centre		Step 1 Progress	Step 2 Progress	Step 3 Progress	Step 4 Progress	Step 5 Progress	Step 6 Progress	Total
	Count	0	0	1	3	8		12
CSSHP	% within Initial Step	0%	0%	8.30%	25.00%	66.70%	0%	100.00%

When the progress assessments were administered, we found that of the targeted group of 91 students from CSPI

- 33.30% (n=4) scored at step 4 or lower; and
- 66.70% (n=8) progressed to step 5 or higher.

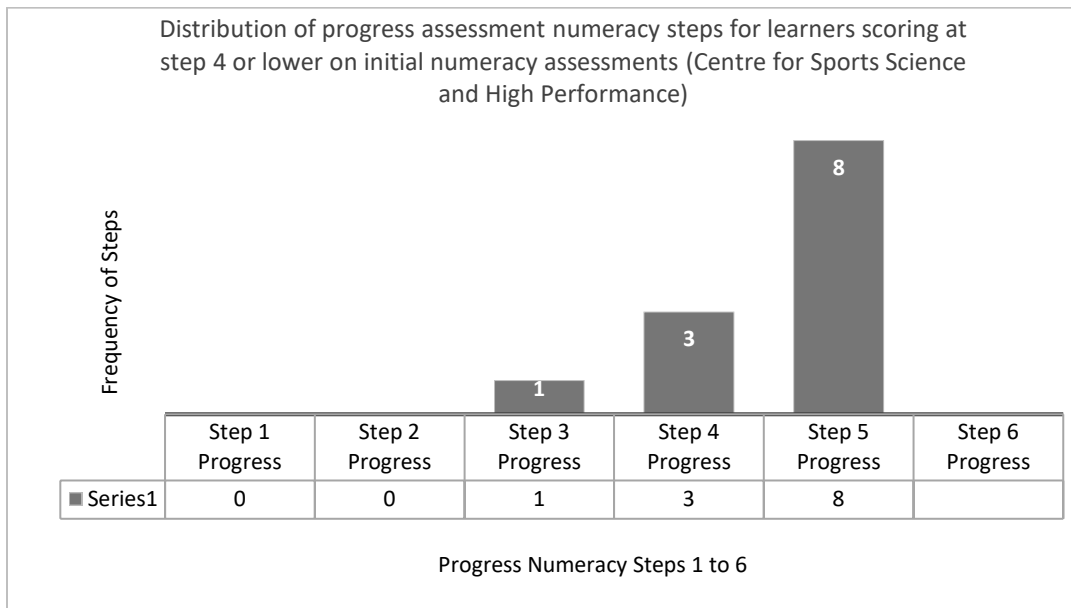


Figure 12: Distribution of progress assessment numeracy steps for learners scoring at step 4 or lower on initial numeracy assessments (Centre for Sports Science and High Performance)

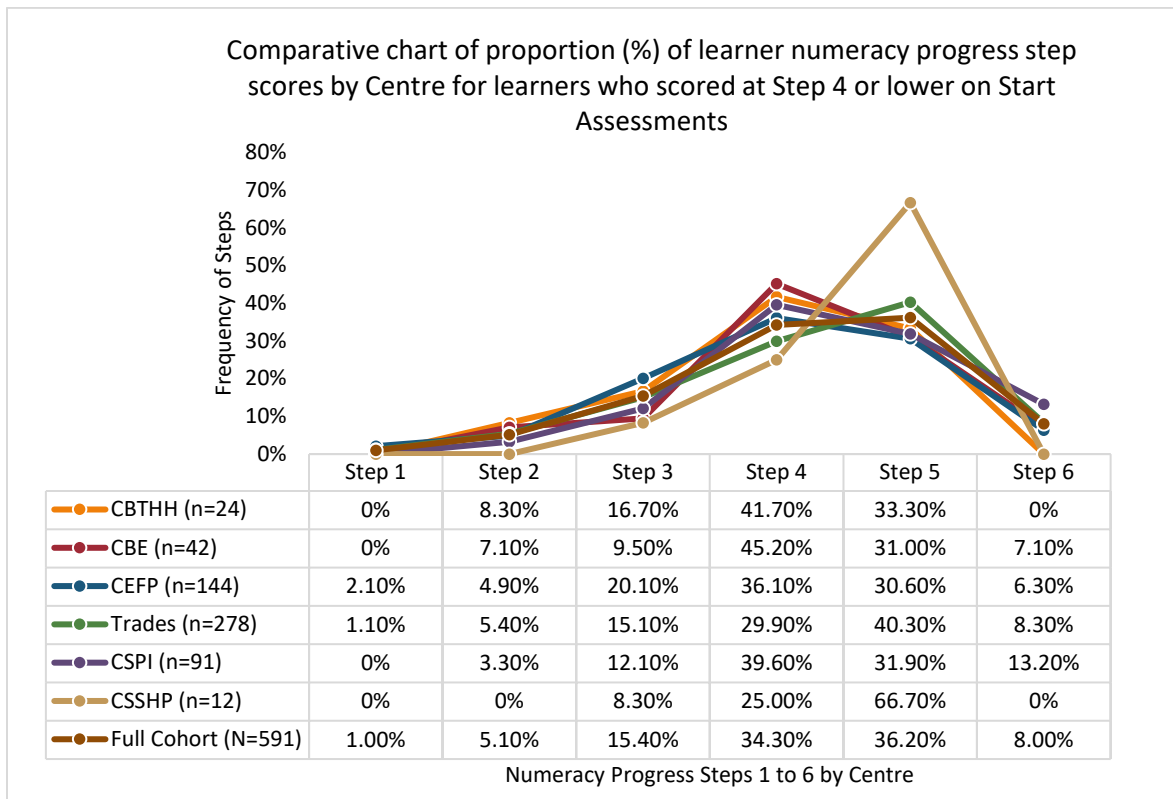
Comparative line chart for the six levels of Centre of Study and full cohort scores


Figure 13: Line Chart of Numeracy Progress by Centre of Study and full cohort

Figure 13 exhibits distributions for Centres of Study similar to those for the ethnicities (Figure 6). As we noted elsewhere, when sample sizes were small as for CBTHH (n=24) and CSSHP (n=12), some distortions could occur. The distribution of step data also meant that some cells in the cross-tabulation were empty. We nonetheless included Centre of Study as a fixed factor in the two-way ANOVA to determine the extent to which it could explain the variance in initial and progress scores. We also investigated the interaction between the two fixed factors and their effect.

FINDINGS FOR T-TEST AND ANALYSIS OF VARIANCE (ANOVA)

In this section we report the paired t-test and ANOVA results.

T-test results for the full cohort

One of our measures of numeracy progress was to perform a matched pairs t-test of the scale scores for initial and progress assessments. We tested the null hypothesis that there was no significant difference between the two sets of scores for the full cohort.

Table 12: Paired samples t-test for differences between progress and initial scale scores for numeracy

		Paired Differences				t	df	Sig. (2-tailed)	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower				Upper
Pair 1	Progress - Initial numeracy	60.501	73.164	3.010	54.590	66.412	20.103	590	0.000

These results implied that we rejected the null hypothesis, and that a statistically significant difference in means was found when the paired scale scores for initial and progress assessments were compared (t value=20.1, df=590, mean difference=60.5, p value<0.001). The mean difference indicated that learner progress assessment scores improved by 60.5 (out of a 1000) which signalled a statistically significant difference in performance. However, we argue later in the report that the low effect size is cautionary: there remained room for improving learner performance.

Two-way ANOVA results comparing performance by Ethnicity and Centre of Study

The approach adopted here was to perform a two-way ANOVA to establish the extent to which the four levels of ethnicity and the six levels of Centre of Study were similar or different. We reasoned that if the groups were relatively similar at the start, we would be able to compare their initial and progress scores in a repeated measures analysis. We could then argue that the four groups proceeded from a relatively similar baseline, and any differences in variance found between initial and progress assessments could be compared.

The two-way ANOVA results appear below.

Table 13: Tests of Between-Subjects Effects for Ethnicity and Centre of Study

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	Progress	223178.251 ^a	22	10144.466	1.680	0.027	0.061
	Initial	72631.778 ^b	22	3301.444	1.017	0.441	0.038
Intercept	Progress	43847936.730	1	43847936.730	7261.3	0.000	0.927
	Initial	36144214.403	1	36144214.403	11132.4	0.000	0.951
Ethnicity	Progress	24650.092	3	8216.697	1.4	0.254	0.007
	Initial	2965.602	3	988.534	0.3	0.822	0.002
Centre of Study	Progress	30625.331	5	6125.066	1.0	0.408	0.009
	Initial	31620.954	5	6324.191	2.0	0.085	0.017
Ethnicity * Centre of Study	Progress	140247.194	14	10017.657	1.7	0.060	0.039
	Initial	26873.723	14	1919.552	0.6	0.873	0.014
Error	Progress	3429934.991	568	6038.618			
	Initial	1844162.648	568	3246.765			
Total	Progress	206901465.000	591				
	Initial	165391285.000	591				
Corrected Total	Progress	3653113.242	590				
	Initial	1916794.426	590				

a. R Squared = .061 (Adjusted R Squared = .025)

b. R Squared = .038 (Adjusted R Squared = .001)

For ethnicity, Centre of Study and the interaction between these two factors on the dependent variables (Progress and Initial scale scores), the F ratios were low (F values=1.4, 0.3; 1.0, 2.0; and 1.7, 0.6), significance levels exceeded the 0.05 probability value (p=0.254, 0.822; 0.408, 0.085; 0.060, 0.873), and low effect sizes (partial eta² values = 0.007, 0.002; 0.009, 0.017; 0.039, 0.014) obtained.

Our conclusion was therefore that there were no significant between-group differences for the main effects, ethnicity and Centre of Study, and the interaction effect of these two factors when initial and progress scores on numeracy were examined. In Figure 14, we notice that the means for the two instances of assessments (initial and progress) were very

close to the same value (varying by approximately 1.6% for initial assessments, and approximately 3% for progress assessments).

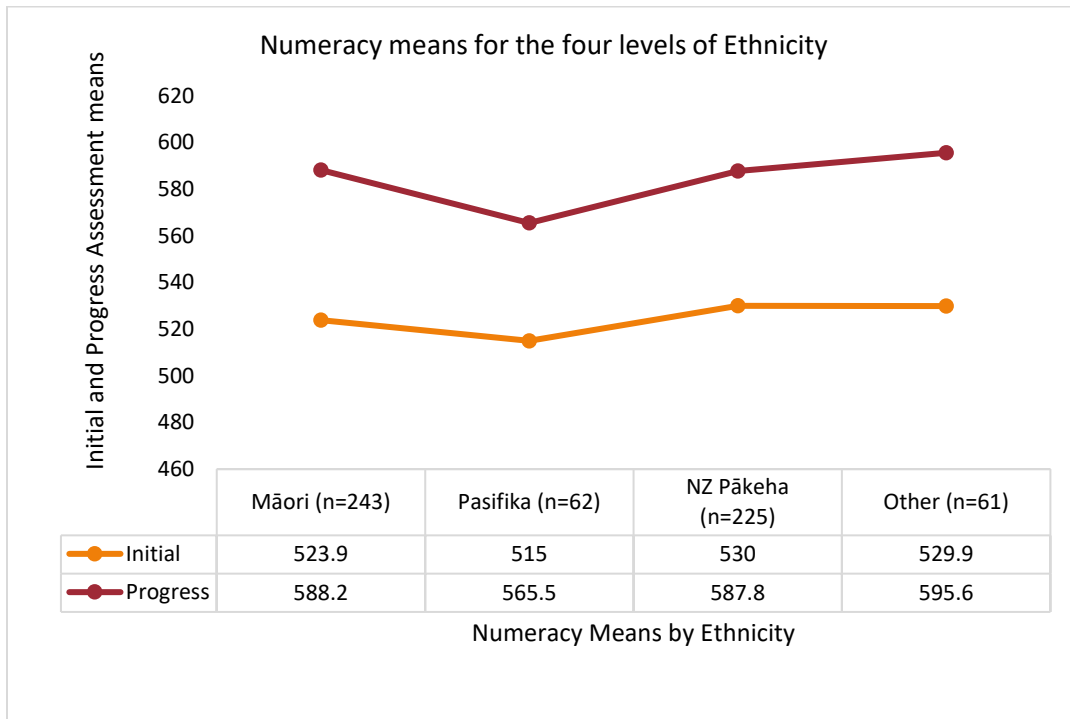
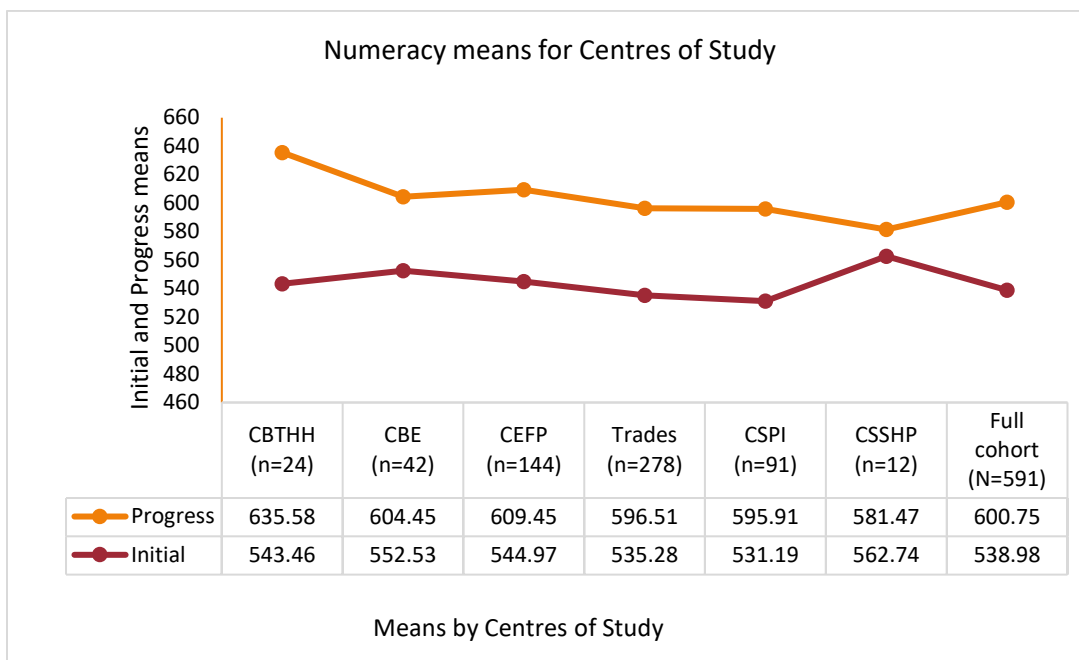


Figure 14: Numeracy means for the four levels of Ethnicity and Centre of Study

Figure 14 confirmed the findings of the two-way ANOVA that between-subjects differences were negligible, while within-subjects differences seemed to be different. A similar pattern could be observed for Centre of Study directly below (Figure 15):



Results for a repeated measures ANOVA

The only remaining aspect of interest would be a repeated measures ANOVA to examine whether the statistically significant within-subjects difference, reported for the paired t-test, obtained for the fixed factors of ethnicity and Centre of Study, as well as their interaction. Table 14 outlines the findings:

Table 14: Tests of Within-Subjects Effects for repeated measures ANOVA

Measure:

Source		Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Numeracy Progress	Sphericity Assumed	185910.7	1	185910.7	71.430	0.000	0.112
	Greenhouse-Geisser	185910.7	1	185910.7	71.430	0.000	0.112
	Huynh-Feldt	185910.7	1	185910.7	71.430	0.000	0.112
	Lower-bound	185910.7	1	185910.7	71.430	0.000	0.112
Numeracy Progress * Ethnicity	Sphericity Assumed	8454.6	3	2818.2	1.083	0.356	0.006
	Greenhouse-Geisser	8454.6	3	2818.2	1.083	0.356	0.006
	Huynh-Feldt	8454.6	3	2818.2	1.083	0.356	0.006
	Lower-bound	8454.6	3	2818.2	1.083	0.356	0.006
Numeracy Progress * Centre of Study	Sphericity Assumed	4319.0	5	863.8	0.332	0.894	0.003
	Greenhouse-Geisser	4319.0	5	863.8	0.332	0.894	0.003
	Huynh-Feldt	4319.0	5	863.8	0.332	0.894	0.003
	Lower-bound	4319.0	5	863.8	0.332	0.894	0.003
Numeracy Progress * Ethnicity * Centre of Study	Sphericity Assumed	62543.8	14	4467.4	1.716	0.049	0.041
	Greenhouse-Geisser	62543.8	14	4467.4	1.716	0.049	0.041
	Huynh-Feldt	62543.8	14	4467.4	1.716	0.049	0.041
	Lower-bound	62543.8	14	4467.4	1.716	0.049	0.041
Error (Numeracy Progress)	Sphericity Assumed	1478326.3	568	2602.7			
	Greenhouse-Geisser	1478326.3	568	2602.7			
	Huynh-Feldt	1478326.3	568	2602.7			
	Lower-bound	1478326.3	568	2602.7			

These results revealed that when the initial and progress scores for numeracy were compared, there were statistically significant differences (F value=71.43, $df=1$, $p<0.05$, $\text{partial } \eta^2=0.112$). The moderate to small effect size implied that the numeracy development strategies in use in targeted Wintec programmes explained 11.2% of the variance when initial and progress assessment scores were compared. There was no statistically significant difference between initial and progress numeracy assessments when the effect of the fixed factors, ethnicity and Centre of study, were considered. The probability values exceeded 0.05 (Numeracy Progress and Ethnicity, $p=0.356$; Numeracy Progress and Centre of Study, $p=0.894$) which indicates a non-significant relationship.

The three-way interaction of Numeracy Progress, Ethnicity and Centre of Study also yielded a statistically significant effect (F value=1.716, $df=14$, $p<0.05$, $\text{partial } \eta^2=0.041$). However, the low $\text{partial } \eta^2$ value implied that 4.1% of the variance between initial and progress scores was explained by this interaction. Pairwise comparisons did not yield a significant result. Hence, we viewed this effect as negligible and of no practical significance.

THE TERTIARY EDUCATION COMMISSION'S LNAT ALGORITHM FOR CALCULATING GAIN

In this section, we report the findings for the TEC's LNAT algorithm to calculate gain. Once we had prepared a multivariate layout of the data, we replicated the algorithm in a series of functions in an Excel file. We outline the equation below:

The TEC's algorithm for calculating learner progress is the following:

Calculating Gain Score:

- Calculate Gain Score where **Gain Score** = Progress Scale Score - Initial Scale Score.

Calculating Gain Score Error

- Square the standard error values for initial and progress scores.
- Add the squared values for Total Standard Error values calculated in the step directly above.
- Calculate the Square Root of the total obtained in step 3 – the so-obtained value is known as **Gain Score error**.

Calculating statistically significant gain

- Multiply the Gain score error calculated in the section above by the constant, 1.645.
- Statistically significant gain is defined as follows: Gain Score Error x 1.645 < Gain Score.

Mathematical notation

Gain score = Progress Scale Score – Initial Scale Score

Gain Score Error = $\sqrt{a^2 + b^2}$ where a^2 = standard error for initial assessment, and b^2 = standard error for progress scale assessment. Statistically significant gain is where Gain > Gain Score Error x 1.645, where the so-obtained value is [+].

First, we calculated the misclassification in terms of our category-based analysis. We reasoned that once we had applied the TEC's algorithm, learner scores judged to be statistically significant would be labelled as category 1 (significant) or category 0 (not significant). This allowed us to cross-tabulate Statistically Significant Gain and Progress Numeracy Step. The cross-tabulation would provide the following information:

- The learner count related to TEC's statistically significant gain.
- The misclassification of learners who obtained steps of 4 or higher.

Table 15 below shows that in terms of the TEC's algorithm, 227 out of 666 students (34.1%) achieved statistically significant gain. If we consider the TEC's ruling that once learners achieve step 5 or higher, they should no longer be assessed, we could identify the misclassifications that occurred as a result of the TEC's algorithm. A misclassification of 134 learners (22.7% of the total) occurred – these learners were deemed not to have achieved statistically significant gain.

Table 15: Cross-tabulation of Significant gain and Progress Step achieved

		Numeracy Progress Step						Total	
		1	2	3	4	5	6		
Significant Gain	0	Count	6	28	83	169	131	3	420
		% within Sig Gain	1.4%	6.7%	19.8%	40.2%	31.2%	0.7%	100.0%
		% within Step Prog	100.0%	93.3%	91.2%	83.3%	61.2%	6.4%	71.1%
		% of Total	1.0%	4.7%	14.0%	28.6%	22.2%	0.5%	71.1%
1		Count	0	2	8	34	83	44	171
		% within Sig Gain	0.0%	1.2%	4.7%	19.9%	48.5%	25.7%	100.0%
		% within Step Prog	0.0%	6.7%	8.8%	16.7%	38.8%	93.6%	28.9%
		% of Total	0.0%	0.3%	1.4%	5.8%	14.0%	7.4%	28.9%
Total		Count	6	30	91	203	214	47	591
		% within Sig Gain	1.0%	5.1%	15.4%	34.3%	36.2%	8.0%	100.0%
		% within Step Prog	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	1.0%	5.1%	15.4%	34.3%	36.2%	8.0%	100.0%

1 = significant gain and 0 = non-significant gain

Table 16 reports results for the four ethnic groupings: step-based progress to exemption levels (column 1), gain analysis based on the LNAT algorithm (column 2) and the misclassifications of the latter algorithm (column 3). The misclassifications making up 22.7% of the targeted group has to be noted.

Table 16: Comparing step-based progress and the TEC algorithm for the four levels of ethnicity

Ethnicity	Step-based analysis: Progress to Step 5 and higher	TEC-algorithm-based analysis	Incorrect classification, yet obtained step 4 or higher (% of full cohort or each ethnicity total)
Full cohort (N=591)	44.2% (n=261)	28.9% (n=171)	22.7% (n=134)
Māori (N=243)	44.9% (n=109)	33.7% (n=82)	21.0% (n=51)
Pasifika (N=62)	50% (n=31)	37.1% (n=23)	21% (n=13)
New Zealand European/ Pākehā (N=225)	36.4% (n=82)	16.4% (n=37)	24.9% (n=56)
Other (N=61)	64% (n=39)	47.5% (n=29)	23% (n=14)

Table 17 replicates the structure of Table 16 for student performance in the various Centres of Study:

Table 17: Comparing step-based progress and the TEC algorithm for the six levels of Centre of Study

Centre of Study	Step-based analysis: Progress to Step 4 and higher achieved	TEC-algorithm-based analysis for statistically significant gain	Incorrect classification, yet obtained step 4 or higher (% of full cohort or each ethnicity total)
Full cohort (N=591)	44.2% (n=261)	28.9% (n=171)	22.7% (n=134)
Centre for Beauty Therapy, Hairdressing and Hospitality (N=24)	33.3% (n=8)	29.2% (n=7)	16.7% (n=4)
Centre for Business and Enterprise (N=42)	38.1% (n=16)	31% (n=13)	19.1% (n=8)
Centre for Education and Foundation Pathways (N=144)	36.8% (n=53)	20.8% (n=30)	18.1% (n=26)
Centre for Trades (N=278)	48.6% (n=171)	33.8% (n=94)	24.1% (n=67)
Centre for Science and Primary Industries (N=91)	45.1% (41)	28.6% (n=26)	24.2% (n=22)
Centre for Sports Science and High Performance (N=12)	66.7% (n=8)	8.3% (n=1)	58.3% (n=7)

In Table 17, we note the same pattern is manifested here as for ethnicities, with the step-based account of progress consistently more positive than the TEC's algorithm-based analysis.

DISCUSSION

In general, this report is intended to meet the requirements of the Wintec LN Policy (2018, Revised) which is aimed at ensuring that TEC funding requirements are met and organisational performance tracked. The purpose was not only to track numeracy progress, but also to generate findings that could potentially be useful within and outside the institute.

Standard statistical comparisons using a t-test and Analysis of Variance (One-way and Repeated measures): Table 12 reports t-test results which indicate that statistically significant progress in numeracy was achieved for targeted 2018 learners. In Table 14, the repeated measures analysis confirmed the result, showing that within-subjects numeracy progress was statistically significant. In Table 13, we reported that between-group and between-Centre effects were not significant at either initial or progress assessment. The low F ratios and moderate to small partial η^2 value prompted us to interpret the result as having no practical significance. We concluded that there were no statistically significant between-group differences (for either ethnicity of Centre of Study) at either initial or progress assessment.

For the repeated measures ANOVA, we added the two fixed factors to see whether they contributed to within-subjects differences. Table 14 shows that neither factor fixed factor was significant; however, the interaction between the two fixed factors yielded a significant result (F ratio=1.72; df=14, $p < 0.05$, partial $\eta^2 = 0.041$). However, the pairwise comparison did not confirm this result. We deemed the low partial η^2 value of 4.1% to signal that this result was of no practical significance. In addition, the low significance values for the two fixed factors ($p > 0.05$) indicate that on their own they did not contribute to the model of analysis. However, the repeated measure, *Numeracy Progress*, was statistically significant (F value=71.43; df=1; $p < 0.001$; partial $\eta^2 = 0.112$). It is worth noting that the effect size implies that Wintec numeracy development strategies in targeted programmes explained 11.2% of the variance when initial and progress scores were compared. This represents a moderate to small effect (Field, 2014) – we concluded that learners' literacy skills could still be improved.

Cross-tabulations and Progress: We set out to show that if we took TEC's step-based exemptions guideline as a measure of progress, we could generate an account of numeracy progress that was far more positive than the results yielded by the TEC's LNAT algorithm. Our reasoning has consistently been that if learners who achieved step 5 were deemed to be adequately equipped to cope with the numeracy demands of their courses, and did not have to be assessed again, then this step could be a threshold level signaling that they achieved the required level of statistically significant gain. Tables 1 to 11 and Figures 1 to 12 illustrate visually learners' numeracy progress. Figures 6 and 13 capture the distribution of numeracy progress steps for learners (disaggregated by ethnicity and Centre of Study) who scored at step 4 or lower on initial assessments and how many of them progressed to step 5 or higher.

TEC LNAT algorithm: Tables 15, 16 and 17 compare progress reported as either steps or by applying the TEC LNAT algorithm. The results indicate that the latter algorithm misclassifies a significant number of learners who scored a numeracy step of 5 or higher. We continue to see this as a misrepresentation of learners' numeracy progress. We speculate that increased standard error values at the higher end of the distribution lead to the disparate impact of the LNAT algorithm on results. What we can justifiably say is that the LNAT algorithm showed that 134 learners (out of 591) who obtained step 5 (n=131) or step 6 (n=3) were classified as not having achieved statistically significant gain. In our view, this makes the algorithm contestable.

CONCLUSIONS

Our conclusions were the following:

- **Numeracy progress met the TEC target:** The 2018 cohort achieved statistically significant gain irrespective of the measure used. The TEC LNAT algorithm showed that for within subjects differences 28.9% of targeted learners achieved statistically significant gain. This is 3.9% above the target set in the 2015 refresh policy for LN (TEC, 2015).
- **A significant number of learners were misclassified by the TEC LNAT algorithm:** Of the 591 students targeted for progress assessment, 134 obtained scores at step 5 or above, yet were classified as not having achieved statistically significant gain. The disparate impact of the LNAT algorithm should not be under-estimated, and once the algorithm is used as a performance measure by TEC, we will be justified in contesting its validity.
- **The TEC's algorithm vs step-based analyses as an anomaly:** As we showed for 2017 and earlier findings (Greyling, 2015, 2018), the TEC's LNAT algorithm has a disparate impact, under-reporting numeracy progress in the sector. Another option would be to advocate for both the algorithm and step-based analyses to be used. That would capture the positives from both approaches.
- **Between-group differences for the fixed factors, ethnicity and Centre of Study, were negligible:** The two-way ANOVA exploring the effect of the two fixed factors, ethnicity and Centre of Study, showed that these groups' scores were not significantly different, neither at initial nor progress assessment.
- **Numeracy progress and the partial eta² value – a cautionary note:** Although a step-based approach yields a far more positive account of numeracy progress than the LNAT algorithm, we need to be aware of other statistical ways of describing learner progress. For example, the partial eta² value (See Table 14) generated by the repeated measures ANOVA reminds us that tutors' numeracy strategy instruction account for 11.2% of the variance in scores when learners' initial and progress assessment performance were compared. The repeated measures ANOVA also showed that neither ethnicity nor Centre of Study impacted on numeracy performance.

- **Literacy development remains an important factor in vocational education in New Zealand:** A visit to the Ako Aotearoa website (<https://ako.ac.nz/professional-learning/alnacc/>) confirms how important literacy and numeracy are in vocational education in New Zealand (Ako, 2019). LN strategies and techniques should be refreshed to remain aligned with the changing modes of teaching and learning in vocational pedagogy, as well as the demands of the workplace.

RECOMMENDATIONS

Our recommendations are as follows:

- **Continue to track Wintec compliance and performance:** The findings in this report provide an account of progress for the cohort of 2018 learners who were required to be assessed on numeracy because they scored at step 4 or lower at the start of their programme. This report and its Excel data provide a basis for confirming or contesting TEC or other claims about Wintec learners' numeracy performance. The report therefore meets Wintec 2018 LN Policy requirements and TEC funding targets (TEC, 2015a, b, c, d and e; 2018).
- **Pursue innovative numeracy skills development aligned with new approaches in vocational education and industry demands:** As modes of vocational education change to align with changing literacy demands of industry, tutors have to adapt to a changing repertoire of numeracy (and other literacy) skills associated with these developments. One of the focal points for the Wintec LN-embedding team is to support tutors to align their literacy strategies with changing vocational and educational demands. Although we noted statistically significant differences for the repeated measures t-test and ANOVA, the low effect size suggested that learners' numeracy skills could still be improved. The LN-embedding team and the targeted tutors (at levels 1 to level 3) should be focused on refreshing literacy strategies, innovating and improving tutor competencies to develop learner skills for the world of work.
- **Communicate these findings to LN stakeholders:** These findings should be communicated to Centres of Study whose students have been assessed. These results can be used for setting organisational targets. For example, in 2017 a target was set for the 2018 cohort: 35% of the students who were targeted for re-assessment were required to progress to exemption levels. Wintec exceeded the target by 9.2% (44.2% - 35%). In the 2015 TEC Refresh policy, the TEC set a target of 25% of students having to show statistically significant gain. Wintec student performance at 28.9% exceeds the policy requirement by 3.9%.
- **Use these findings within a whole-organisation approach to improve and innovate:** The LN-embedding team should pursue
 - in-depth case studies of good practice in the literacy domain;
 - improvement projects that link these findings to classroom observation findings and module completion data.
 - strategies for mobilising the New Zealand resources available for use, specifically Ako Aotearoa support and Pathways Awarua.
 - evidence-based practices that lead to LN resources being embedded in tutor practices.
 - an approach that joins up reading and numeracy assessment data, classroom observation analyses (Greyling, 2019, 2017, 2016), best-practice case studies such as those reported in Greyling, Belcher and McKnight (2013), Greyling and Lingard (2015) and Greyling and Waitai (2016), and meta-level reflective analyses (Greyling, 2016).
 - joined-up approaches that draw on the expertise of other support teams such as Student Learning Services, Te Kete Kōnae and the Wintec coaching team.

- **Continue to develop LN as a valued field of research:** The Tertiary Education Strategy (2015-2019) specifies that the sector is required to make research-informed decisions to bolster their practices. This statement, coupled with the TES statement, reminds us that LN is an important research field. In that sense, we note that numeracy performance remains a small, yet important component of a much bigger research picture. These findings should be viewed in the context of a multitude of other variables that contribute to learner success. Cross-validation and triangulation are key research processes in making informed pedagogical and management decisions (Flick, 2004).

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