Distribution of high achieving students on NAPLAN across schools: Implications for policy and teacher training

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Concern is often raised about the performance of Australia's 'best' mathematics students on international studies, relative to past students and other countries. An important consideration in developing strategies to ensure our most proficient mathematics students experience learning growth is an understanding of the distribution and concentration of high achieving students across schools, with subsequent implications for policy and teacher training. In this paper, student performance on the Numeracy test from the NAPLAN assessment is explored by grouping and comparing students at different levels of performance.

The study of mathematics has long been regarded as a gateway subject opening up a wide range of opportunities for high school students who seek to undertake further study at university. In addition, proficiency in numeracy ensures students have the capability to function effectively in modern society. Mathematics is playing an increasingly important part in the Australian economy due to big data being generated and distributed by government, business and industry; the transition towards a greater proportion of the economy being service-based which requires mathematical expertise, and increased quantification due to digital technologies (Australian Academy of Sciences, 2016).

At the same time as Australia has an increasing need for mathematical and statistical expertise, international studies have found worrying trends in the performance of Australian students in international studies. Thomson, De Bortoli and Buckley (2013) report that only four percent of Australian students achieved at highest proficiency (*Level 6*) in mathematical literacy on the 2012 Programme for International Student Assessment [PISA] international testing of 15-year-olds. Whilst this compares favourably with the Organisation for Economic Co-operation and Development [OECD] average of three percent, only a small proportion of these Australian Level 6 students placed in the top 20 percent of students from around the world. In addition, it was found that the performance of Australian students has worsened over time (Thomson et al., 2013).

Thomson, Hillman, Wernert, Schmid, Buckley and Munene's (2012) analysis of the 2011 data from the four-yearly large scale international assessment of Year 4 and Year 8 students, Trends in International Mathematics and Science Study [TIMSS], found improvements in the Year 4 mathematics scores since 1995, whilst the Year 8 performance was not significantly different over time. Whilst the proportion of Australian Year 4 (10%) and Year 8 (9%) students performing at the *Advanced* international benchmark compares favourably with the international median (3-4%), it is significantly less than a country such as Singapore with 40 percent of Year 4 students and almost 50 percent of Year 8 students achieving at the highest level. The relative performance of Australian students on these international tests could reflect a decline in the capability of our education system to develop top students in mathematical literacy, or it could be that Australia's performance

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has remained static whilst other countries have surged ahead in lifting the performance of their students on what the TIMSS and PISA tests measure.

These two international studies utilised large samples of Australian students, with 6,146 Year 4 students across 280 primary schools and 7,556 Year 8 students across 275 schools participating in TIMSS 2011, and 14,481 15-year-old students across 775 schools participating in PISA 2012. The National Assessment Program - Literacy and Numeracy [NAPLAN] provides an even larger source of data on Australian students, with approximately 250,000 students in each year level. NAPLAN is particularly useful because all students Australia-wide undertake the same assessment instrument, and it has a high participation rate. In addition, in contrast to PISA and TIMSS, the students are assessed at Years 3, 5, 7, and 9 which provides the opportunity to look at the longitudinal trends in learning growth of individual students or groups of students.

Previous analyses of NAPLAN data have looked at achievement gaps between different demographics such as school sector (Miller & Voon, 2012), gender (Wilson & Barkatsas, 2014), indigenous status (Forgasz, Leder, & Halliday, 2013; Leder & Forgasz 2014), and Language Background other than English (Wilson & Barkatsas, 2014). These studies have predominately used the mean of the entire Year Level cohort to summarise or model the data for a particular demographic (Wilson & Barkatsas, 2014). This paper, instead, focuses on grouping and analysing students by their level of performance above the mean for the Year Level cohort. Mathematically high achieving students are defined as those achieving at or above the mean plus two standard deviations (i.e. $\mu+2\sigma$).

Before we can work out *what* to do for high achieving students, it is important to understand more about these students and where they learn. This paper investigates the mathematical performance of Australian primary and secondary school students using the National Assessment Program – Literacy and Numeracy (NAPLAN) data for 2013. The key research questions are:

- What is the distribution of total scores in the various NAPLAN numeracy assessments?
- How are mathematically high achieving students distributed across schools?
- How are mathematically high achieving students clustered by school?

The approach to addressing these questions is detailed in the next section, followed by a discussion of the results obtained, implications for policy and teacher education, and potential avenues for further investigation.

Methodology

An application was made to the Australian Curriculum, Assessment and Reporting Authority [ACARA] for access to NAPLAN Student Level Data for students in Years 3, 5, 7 and 9 in 2013 with matched student data for these students from 2011. The data file contained student demographics, test participation, and test results for the numeracy, reading, spelling and writing tests. The focus of this paper is based on the data obtained from the numeracy assessment for 2013.

Students and schools were identified by randomised identification numbers. Demographic variables for each student included the Test Administration Authority (e.g. state), geolocation (e.g. metropolitan, provincial or remote), sector (e.g. government or non-government), age of student at the time of the test, sex, indigenous status, Language Background Other Than English (LBOTE) status, and parents' educational and occupational backgrounds.

In Years 3 and 5, there is one non-calculator numeracy test comprising 35 and 40 test items respectively for the two year levels. In Years 7 and 9 there are two numeracy tests, one calculator and one non-calculator test, each containing 32 test items. Year 7 and 9 students may have participated in either or both of the calculator and non-calculator tests providing test results for either 32 or 64 test items. For all numeracy assessments, a student's raw score on each test is converted to a NAPLAN Scale Score ranging from 0 to 1,000 according to the NAPLAN score equivalence tables which are published on the internet (http://www.nap.edu.au/results-and-reports/how-to-interpret/score-equivalence-tables.html).

The Excel and SPSS software packages were used to analyse the numeracy data for each Year level to produce descriptive statistics at varying performance levels above the mean.

Results and Discussion

The NAPLAN numeracy tests are constructed so that common items between tests allow vertical equating between different year levels and horizontal equating across time. The test results are then extrapolated onto a 1,000-point scale. The process of test calibration is explained more fully in the NAPLAN Technical Report (ACARA, 2014). The 1,000-point scale is broken up into 10 bands, with each band from Bands 2 to 9 spanning 52 points. For each NAPLAN test year, six bands are reported to parents: the band designated the National Minimum Standard [NMS] for that year level, one band below the NMS, and four bands above the NMS. The scale score upper and lower limits for each test year level are outlined in Table 1 below. In contrast, the data file provided by ACARA specifies the scaled score for all (de-identified) students, allowing the full range of student performance to be analysed, including those who performed outside the six reported bands of achievement.

Table 1
Range of Scaled Scores for National Minimum Standard by year level

	Year 3 *Band 2*	Year 5 *Band 4*	Year 7 *Band 5*	Year 9 *Band 6*
Lower scaled score	> 270	> 374	> 426	> 478
Upper scaled score	≤ 322	≤ 426	≤ 478	≤ 530

Distribution of students' numeracy performance

All students in Years 3, 5, 7, and 9 in Australia are intended to sit the NAPLAN assessments; 93% of Years 3, 5, and 7 students and 90% of Year 9 students were present for some or all of the tests in 2013. The number of students who were present and obtained numeracy test results comprise the sample examined, which is listed in Table 2 below.

Table 2
Basic statistics for 2013 numeracy scaled score results by year level

	Year 3	Year 5	Year 7	Year 9
Number of students tested	246,265	241,965	244,303	236,693
Minimum score attained	61	132	193	219
Maximum score attained	741	837	900	976
Mean (μ)	398	488	544	587
Median	396	484	536	580
Mode	396	484	509	556
Standard deviation (σ)	72	78	75	85

Comparing the 2013 numeracy performance data in Table 2 with the NMS range in Table 1 highlights that all measures of central tendency – the mean (μ), median and mode – are above the NMS for the respective year level indicating that a large proportion of students are 'doing well' in numeracy. However, the range between lowest and highest scaled scores is large for each test year. The indexed frequency curves, in Figure 1 below, illustrate the overlapping distribution of Year 3, 5, 7, and 9 students' scaled scores. For Years 7 and 9, a small number of students did not sit both the calculator and non-calculator test and their results have been excluded from Figure 1.

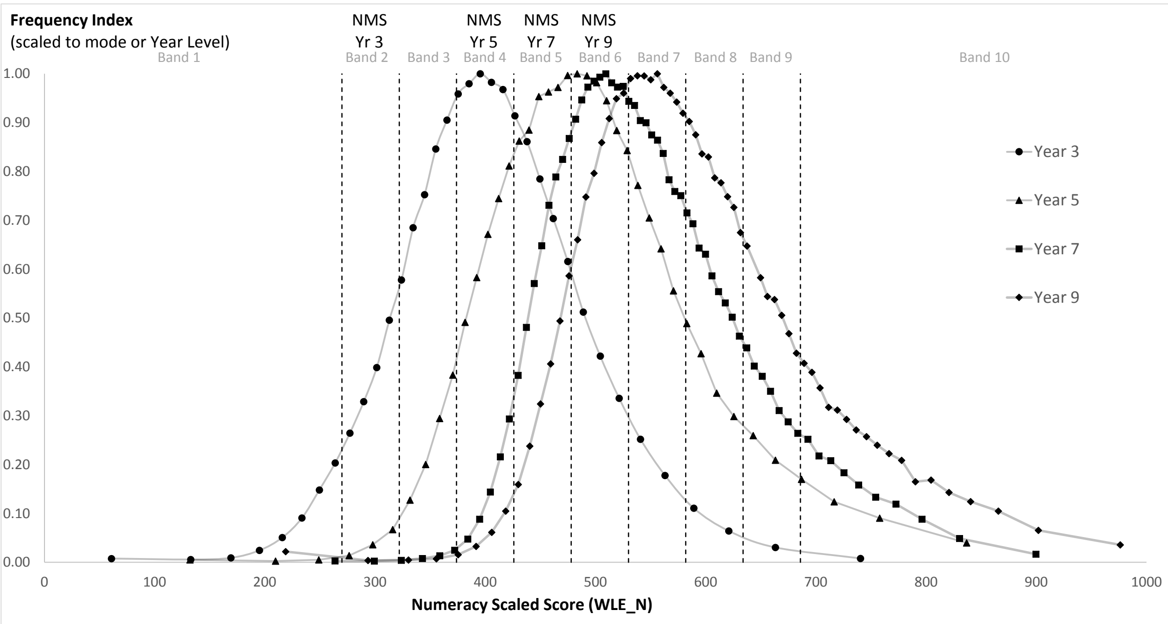

Figure 1. Distribution of students' numeracy scaled score results by year level for NAPLAN 2013

Of particular note in Figure 1 is that there are students in Years 3, 5, and 7 achieving well above the NMS scaled score range expected for Year 9 students. These high achieving students are performing at or higher than the mean plus two standard deviations relative to their year-level peers. Given the concerns discussed earlier in the literature review, it is reasonable to ask what we are doing for these exceptional mathematics students and whether we are adequately addressing their ongoing mathematical development.

Patterns of distribution and concentration of students by school

Schools play a pivotal role in educating students in numeracy and mathematics. Having identified students who are achieving in excess of two or more standard deviations above the mean for their year level cohort, let's consider the distribution and concentration of achieving and high achieving students across schools which is detailed in Table 3 below.

Table 3
Distribution and concentration of achieving and high achieving students by school

		Students at or above performance level…				
	Total	μ	$\mu+\sigma$	$\mu+2\sigma$	$\mu+3\sigma$	$\mu+4\sigma$
Year 3						
Number of students	246,265	130,681	37,800	5,845	1,533	119
Percentage of students		53.07%	15.35%	2.37%	0.62%	0.05%
Max. in one school		149	82	28	13	4
Number of schools	7,355	6,827	5,470	2,424	964	107
Percentage of schools		93%	74%	33%	13%	1%
Year 9						
Number of students	236,693	105,940	35,904	8,928	1,484	258
Percentage of students		44.76%	15.17%	3.77%	0.63%	0.11%
Max. in one school		385	285	205	79	24
Number of schools	2,619	2,389	2,123	1,312	429	116
Percentage of schools		91%	81%	50%	16%	4%

Of the 246,265 Year 3 students who undertook the numeracy assessment in 2013, 5,845 performed at or above the mean plus two standard deviations ($\mu+2\sigma$), 1,533 students performed at or above the mean plus 3 standard deviations ($\mu+3\sigma$), and 119 students performed at least four standard deviations above the mean ($\mu+4\sigma$). Whilst 33 percent of schools had Year 3 students performing at or above $\mu+2\sigma$, 28 of these students were clustered in one school. Similarly, 13 percent of schools had students performing at or above $\mu+3\sigma$ and 13 of these students were clustered in one school. With 107 Year 3 students performing at or above at or above $\mu+4\sigma$, only one percent of schools had such exceptional students but 4 of these students were clustered in one school. The school with four students performing in excess of $\mu+4\sigma$ was a co-educational government school in metropolitan New South Wales. A further nine schools across five states had two students performing at this level, of which five were government schools, eight were co-educational and one a boys' school, and all but one were in metropolitan areas. Seven of the ten schools had Year 3 cohorts larger than 100 students. The remaining 97 students performing at or above at or above $\mu+4\sigma$ were distributed individually across 97 schools.

A similar examination of the Year 9 data presented in Table 3 reveals that a larger percentage of the Year 9 cohort are performing at the highest level ($\mu+4\sigma$) with 0.11 percent of Year 9 students compared to 0.05 percent of Year 3 students. Fifty percent of schools have students performing at or above $\mu+2\sigma$, but 205 of these Year 9 students are clustered in one school. Sixteen percent of schools have students performing at or above $\mu+3\sigma$, but 79 of these students are clustered in one school. Four percent of schools have students performing at or above $\mu+4\sigma$, but 24 of these students are clustered in one school which was a co-educational government school in New South Wales. A further two schools had 14 such students, and another school had 11 students performing at or above $\mu+4\sigma$.

Clearly, high achieving students are distributed across a range of schools but are not evenly distributed across schools. Clusters of high performing students within a school could be explained by one or more of the following factors:

- Schools with a strong mathematics program
- Schools taking students ahead of the curriculum and thus advantaging them
- Students going ahead of curriculum, e.g., outside school programs such as Kumon
- Select-entry schools
- Schools with good reputations which attract high achieving students
- Schools which attract students from families who value mathematics
- Schools with students from advantaged socio-economic backgrounds

The larger clusters of high achieving students evidenced in Year 9, in contrast to Year 3, could be a result of select-entry schools which operate mainly for secondary or upper secondary schooling.

An understanding of the distribution and concentration of high achieving students across Australian schools is important for developing strategies to strengthen the mathematical skills of Australia's young people. Two key areas for strategy are educational policy and teacher training, and these will be discussed below.

Implications for Policy

Concerns have been raised in Australia and the USA that focusing on minimum competency and reducing the achievement gaps between different demographic groups, influenced by government policy and funding, may be having a detrimental effect on students at the top end of the scale (Griffin, Care, Francis, Hutchinson, & Pavlevic, 2012; Plucker, Burroughs, & Song, 2010). Minimum competency and excellence as goals are not mutually exclusive, and an explicit focus on both may change the levers which are influencing people's behaviour. Plucker, Hardesty, and Burroughs (2013) propose that:

> When any new education policies are created, policymakers should ask themselves two questions: How will the proposed policy impact our highest achieving students? How will the proposed policy help more students achieve at the highest levels? As simple as this sounds, these questions are rarely asked. (p. 24)

Implications for Teacher Training and Professional Development

Other concerns have been raised about teachers' readiness to teach students who are already performing at high levels in mathematics. Griffin et al. (2012) found that:

> Teachers were less able to offer intervention strategies at the top end of the proficiency scale, but they were able to offer numerous intervention strategies at the bottom end of the scale…there may be a national and systemic problem of a lack of teaching strategies or resources to encourage higher ability students to progress at a rate commensurate with their ability. (p. 85)

The recently released 2025 vision for mathematical sciences in Australia (Australian Academy of Sciences, 2016) claims that there is an acute shortage of properly qualified specialist secondary mathematics teachers due to an existing undersupply and attrition. Three recommendations are offered: (1) providing professional development in mathematics education for existing 'out-of-field' teachers, (2) setting national standards for mathematics teaching qualifications, and (3) ensuring career paths for primary and secondary mathematics teachers which reward excellent teaching.

I suggest a key element of these recommendations should be that 'excellent teachers' are those who have the skills, resources, and motivation to provide for the diversity of students in their mathematics classroom. If all high achieving students had been clustered in a small number of schools, then the obvious strategy would be to train a group of mathematics teachers specialising in the teaching of high achieving students. Given the distribution of high achieving students across a wide range of schools, knowing what and how to deliver appropriate learning experiences to students already performing at a high level should be a core part of teaching training and ongoing professional development for *all* teachers of mathematics.

Limitations of the study and opportunities for further research

The results and discussion presented in this paper are based on the analysis of only one year of data. It may be that the results obtained are a feature of this particular cohort of students or point in time. Further analysis of the matched 2011 data will determine if the same patterns occur for this cohort of students at the time of their previous NAPLAN test. Analysis of other years of NAPLAN data could determine if these patterns are repeating or changing over time.

The performance of individual students over their successive NAPLAN assessments would provide insight into whether appropriate learning experiences are being provided to students leading to growth in numeracy and mathematical performance. A comparison of student growth in performance for students at varying standard deviations above and below the mean could shed some light on the claims that higher achieving student may be 'neglected' whilst efforts are directed to less proficient students in order to help them reach national minimum standards.

Conclusions

This paper focuses on the patterns of Years 3, 5, 7, and 9 student performance and school distribution for students achieving at increasing standard deviations above the mean performance on the 2013 NAPLAN. Whilst it is desired and expected that a proportion of Year 9 students will achieve above the National Minimum Standard (NMS) for Year 9, it was found that numerous Year 3, 5 and 7 also attained a scaled performance score above the Year 9 NMS. These high achieving students, performing at or above the mean plus two standard deviations for their respective year level, are distributed across a wide range of schools but some schools have larger clusters of high achieving students. Both the distribution and concentration of high achieving student have implications for policy and teacher training. A dual focus on minimum competency levels and excellence with supportive policies is required to ensure that high achieving students are not neglected, and teachers can benefit from training and resources in order to deliver appropriate mathematical learning experiences to these high achieving students.

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