Does the NAPLAN match the Australian Mathematics Curriculum?

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Analysis of recently-released NAPLAN tests reveals that the tests cover year levels well below the nominal year and that some aspects of the mathematics curriculum are under-represented. A high level of untested curriculum content descriptions was found.

There is considerable public interest in how Australian schoolchildren fare in Mathematics. In addition to the normal school reports which are addressed to parents/caregivers, the National Assessment Programme: Literacy and Numeracy [NAPLAN] (Australian Curriculum Assessment and Reporting Authority [ACARA], n. d. a) produces individual student results which are communicated to parents/caregivers as the students complete Years 3, 5, 7 and 9. The release of national test results is often accompanied in the media by articles with headlines such as "Get back to basics or the slide will continue" (Donnelly, 2018).

This study looks at how well results in the NAPLAN (ACARA, n. d. a) reflect progress against mathematics in the Australian Curriculum (ACARA, n. d. b). The NAPLAN may be treated in the media as a proxy for the intended curriculum – this is perhaps the ACARA brief – but there is no independent research on how close the relationship actually is. ACARA is certainly in an interesting, and perhaps conflicted, position as both the author of the curriculum and also in charge of producing tests which are supposed to indicate how well the curriculum is being taught and learned. In 2018, the NAPLAN test papers from 2010 to 2016 were publicly released. This event provided the possibility of contemporary and independent research into how well the NAPLAN represents the mathematics curriculum.

Literature Review

The theoretical basis and motivation of this study are informed by current research on the relationship between curriculum and assessment, particularly within mathematics education (Cai & Howson, 2013). A curriculum is not simply an official syllabus document which prescribes the coverage of topics and performance expectations for the learning of mathematics. That way of understanding a curriculum at a system level is better known as the "intended" curriculum (Travers & Westbury, 1989). Besides the intended curriculum, a curriculum must also be understood and aligned at two other levels – the implemented curriculum at a classroom level and the attained curriculum at a student level.

The conceptualisation of the Australian Curriculum in many ways reflects the goals and aspirations of the nation in terms of standardising the formulation of content at the implemented curriculum level as well as recommending sound pedagogies at the level of the implemented curriculum (Atweh & Goos, 2011). However, there is a gap in terms of aligning to the attained curriculum. National testing such as the NAPLAN has the potential to assess the attainment of students as a result of the intended and implemented curriculum, particularly in mathematics education. Yet, there is little evidence to suggest a strong alignment between the intended and attained levels of curriculum, and no research has systematically investigated this relationship as manifested in the Australian Curriculum and NAPLAN test questions.

2019. In G. Hine, S. Blackley, & A. Cooke (Eds.). Mathematics Education Research: Impacting Practice *(Proceedings of the 42nd annual conference of the Mathematics Education Research Group of Australasia)* pp. 140-147. Perth: MERGA.

Currently, the NAPLAN results are widely used as a measure of mathematical attainment in Australian schools. For example, the major research project Longitudinal Study of Australian Children (MacDonald & Carmichael, 2018) takes the NAPLAN as its yardstick.

Methodology and Aims

Practical aspects of Mathematics, and also specialised aspects incorporating the value and beauty of Mathematics, should both be incorporated throughout the curriculum notes Sullivan, the key author of the current curriculum (2011, p. 5). He details the method by which the current curriculum has moved from isolating problem solving to incorporating it, along with reasoning and understanding proficiencies, throughout the mathematical content. Ability to conduct mathematical operations efficiently is styled "fluency" and also included as a proficiency.

This study focused on Year 5 as indicative of primary NAPLAN questions, and Year 9 of secondary. Questions from the 2012, 2014 and 2016 NAPLAN papers were coded. For Year 9, both the calculator and non-calculator papers were coded. The coding of each question was in terms of the most appropriate curriculum Content Description Code (CDC) it covers ("classification"); a difficulty scale ("depth"); a record of any proficiency strands to which the question relates ("proficiencies"); and an indication if the question linked to General Capabilities and Cross Curriculum Priorities.

The "classification" quantifies the extent to which the curriculum content is mirrored in the NAPLAN tests. The "depth" identifies any deficiency in the application of the "classification" coverage. The depth coding is on a scale of recall / single-operation process / complex process. The "proficiencies" coding identifies which of problem-solving, reasoning, understanding and fluency are addressed in each question.

For example, the 2015 NAPLAN Year 5 Numeracy test includes this item:

> **23** Rhys had 4 fish tanks. Each tank had 10 fish in it.
>
> He then bought one more tank.
>
> He shared all the fish equally between the 5 tanks.
>
> How many fish were then in each tank?
>
> 5 ⬭ 6 ⬭ 8 ⬭ 9 ⬭

The "classification" of this question is ACMNA076 "Develop efficient mental and written strategies and use appropriate digital technologies for multiplication and for division where there is no remainder". The "depth" of this question is complex process. The "proficiencies" coding is: problem-solving, reasoning, understanding and fluency. The Year 4 Curriculum provides definitions and exemplification of all four proficiencies.

Year level of the NAPLAN questions

Associating each question with the most appropriate CDC was time-consuming but generally uncontentious. Few questions were difficult to associate with a unique CDC. When this was the case, often it occurred because the question covered more than one strand of the curriculum, for example the 2012 Year 5 Q20 which asked how many of a given irregular shape could be cut from a square grid: both geometrical experimentation and calculation are associated. Some questions could be efficiently solved using techniques from later years, such as simultaneous equations or solving quadratics, but perhaps guess-and-improve techniques were intended, especially in the calculator-permitted tests.

NAPLAN tests are held in May each year, therefore they do not focus on content from the nominal school year (which are calendar years in Australia), but on content from preceding years. It might be expected that the Year 5 tests would mainly be associated with Year 4 content, and the Year 9 tests with Year 8 content. To the surprise of the coders, it eventuated that codes from much younger year levels often were the most appropriate, as shown in Table 1.

Table 1 School year levels of CDCs in NAPLAN tests of 2012, 2014 and 2016

Year level of CDC	< Year 2	Year 2	Year 3	Year 4	>Year 4
Year 5 2012	2	5	19	12	2
Year 5 2014	2	9	8	16	5
Year 5 2016	1	6	14	17	2
Overall %	4%	17%	34%	38%	8%

Year level of CDC	< Year 6	Year 6	Year 7	Year 8	>Year 8
Y9 2012 Non-calculator	9	7	7	5	4
Y9 2012 Calculator	12	5	10	2	3
Y9 2014 Non-calculator	12	7	9	2	2
Y9 2014 Calculator	6	4	13	7	2
Y9 2016 Non-calculator	3	4	14	7	4
Y9 2016 Calculator	3	3	16	8	2
Overall %	23%	16%	36%	16%	9%

The questions in the analysed NAPLAN tests map to curriculum year levels significantly below the year level of the students taking the tests. This is especially the case for Year 9 NAPLAN tests, where 23% of the questions are best associated with CDCs from Year 5 and earlier.

Representation of the Mathematics Strands in NAPLAN Tests

For each year level, the curriculum breaks down the mathematical content into topics within the three strands. Each topic has a CDC and some have further subtopics or "elaborations". As these elaborations were sometimes in the nature of explanations or exemplification, they were not considered in the analysis below.

Year 5 students complete a 40-question NAPLAN test. The proportion of CDCs within each strand is compared in Table 2 with the incidence of the Year 4 CDCs in the NAPLAN tests of 2012, 2014 and 2016. The number of CDCs in each strand in Years 3, 4 and 5 is also given.

Table 2 reveals that in Years 3 and 4 the curriculum applies a heavy weighting to Number & Algebra and this is matched by the incidence of Number & Algebra questions in the NAPLAN tests. Questions from the Number & Algebra strand comprised about half of the 40 questions in each test, matching well with the emphasis given in the curriculum.

Table 2 Allocation of CDCs to mathematics content strands in recent Year 5 NAPLAN tests

	Number & Algebra	Measurement & Geometry	Statistics & Probability
CDCs Y3	10	6	4
CDCs Y4	13	9	6
CDCs Y5	12	8	5
NAPLAN Year 5 2012	18	17	5
NAPLAN Year 5 2014	17	19	4
NAPLAN Year 5 2016	23	13	4
NAPLAN Y5 %	48%	41%	12%
Y4 CDCs %	46%	32%	21%

As shown in Table 3, the Statistics & Probability strand in the Year 5 curriculum has fewer CDCs than the other strands and also significantly less coverage in the NAPLAN tests. Of course, it can be argued that in Years 4 and 5 the cognitive content of Statistics & Probability is only one-fifth of that in Number & Algebra – and the strand should receive only one-fifth of the class time and one-fifth of the weighting in NAPLAN tests. However, the Year 4 curriculum does devote six CDCs to Statistics & Probability and 13 to Number & Algebra. This suggests that Statistics & Probability should receive a heavier weighting in the Year 5 NAPLAN tests.

Table 3 Allocation of CDCs to mathematics content strands in recent Year 9 NAPLAN tests

	Number & Algebra	Measurement & Geometry	Statistics & Probability
CDCs Y7	19	8	6
CDCs Y8	12	8	7
CDCs Y9	10	9	6
Y9 2012 Non-calculator	11	18	3
Y9 2012 Calculator	10	19	3
Y9 2014 Non-calculator	12	18	2
Y9 2014 Calculator	12	18	2
Y9 2016 Non-calculator	9	17	6
Y9 2016 Calculator	9	19	4
NAPLAN Y9 %	33%	57%	10%
Y8 CDCs %	44%	30%	26%

A similar analysis was conducted with the Year 9 figures, also shown in Table 3. Year 9 students attempt two NAPLAN tests, one with and one without calculators, each of 32 questions. The Year 9 NAPLAN tests consistently give far greater importance to the Measurement & Geometry strand (57%) than does the curriculum (30%), with compensating reductions in the other two strands.

General Capabilities and Cross Curriculum Priorities in the NAPLAN Tests

The General Capabilities within the Australian Curriculum are Literacy, Numeracy, Information and Communication Technology (ICT) Capability, Critical and Creative

Thinking, Personal and Social Capability, Ethical Understanding and Intercultural Understanding. The Cross Curriculum Priorities are Aboriginal and Torres Strait Histories and Cultures, Asia and Australia's Engagement with Asia and Sustainability. Very early in the process it was recognised that there was little point in coding the General Capabilities and Cross Curriculum Priorities aspects of the curriculum. Unsurprisingly, "Numeracy" was present in most of the questions and, apart from Literacy and ICT Capability, other General Capabilities and Cross Curriculum Priorities were barely represented within NAPLAN Mathematics questions. For example, of the 80 questions in the two Year 9 tests of 2014 combined, links in the broadest sense are noted in Table 4. No links were found to Personal and Social Capability, Ethical Understanding, nor Aboriginal and Torres Strait Histories and Cultures.

Table 4 Links to General Capabilities and Cross Curriculum Priorities in the 2014 Year 9 NAPLAN tests

Literacy	Numeracy	ICT Capability	Creative Thinking	All Others
31	55	17	9	6

Curriculum Proficiencies in the NAPLAN Questions

The mathematics curriculum contains four proficiency strands: Understanding (U), Fluency (F), Problem Solving (PS) and Reasoning (R). For each of these strands a code of "link" or "no link" was given for each question. Table 5 gives totals for all questions asked within the two year levels.

Table 5 Curriculum proficiencies in NAPLAN tests, shown within mathematics strands

	Number & Algebra				Measurement & Geometry				Statistics & Probability			
	U	F	PS	R	U	F	PS	R	U	F	PS	R
Year 5	49	39	17	26	28	26	22	20	7	6	0	9
%	37%	30%	13%	20%	29%	27%	23%	21%	32%	22%	0%	41%
Year 9	86	91	25	14	59	40	19	26	19	7	2	10
%	40%	42%	12%	6%	41%	28%	13%	18%	50%	18%	5%	26%

Many links to the Proficiency strands are represented in Table 5, with Understanding the most frequent. In Year 9 the proportion of Problem Solving links was smaller for Year 5, reflecting a greater emphasis on Understanding. The strands Problem Solving and Reasoning may be difficult to assess in a time-constrained situation, but if NAPLAN tests are to be taken as a proxy for attainment of the mathematics curriculum there needs to be suitable prominence.

Depth in the NAPLAN Tests

Each question was coded as Recall, Single-step operation or Complex operation. The results, as totals for all questions asked of the year level, are given in Table 6.

Table 6 Comparison of question depth between Year 5 and Year 9, within strands

	Number & Algebra			Measurement & Geometry			Statistics & Probability		
	R	S	C	R	S	C	R	S	C
Year 5	5	17	35	16	6	27	4	3	7
Year 5 %	9%	30%	61%	33%	12%	55%	29%	21%	50%
Year 9	16	36	57	19	6	38	3	8	9
Year 9 %	15%	33%	52%	30%	10%	60%	15%	40%	45%

Table 6 reveals that for Year 5 the two strands Measurement & Geometry and Statistics & Probability had a far higher percentage of Recall questions than Number & Algebra. In Year 9, Recall questions occurred at twice the rate in Measurement and Geometry compared with the other two strands. In both Year 5 and Year 9, a high proportion of the Measurement & Geometry questions were Recall. This may indicate a propensity to favour activities such as *naming*, and to avoid *applications* of Measurement & Geometry in the NAPLAN tests. It is already noted that the Year 9 NAPLAN tests give greater importance to Measurement & Geometry questions, and this section reveals that the Measurement & Geometry questions tend to favour Recall over more complex intellectual demands.

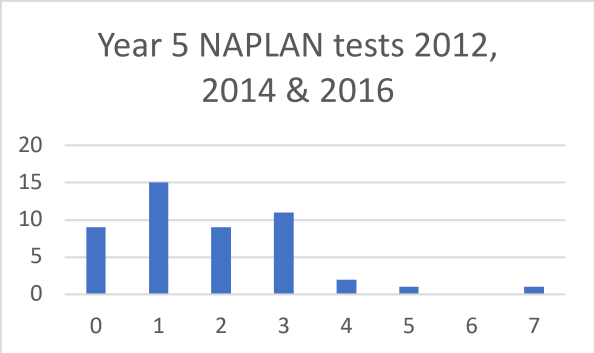
Comparison of Calculator Permitted or not in Y9 NAPLAN Questions

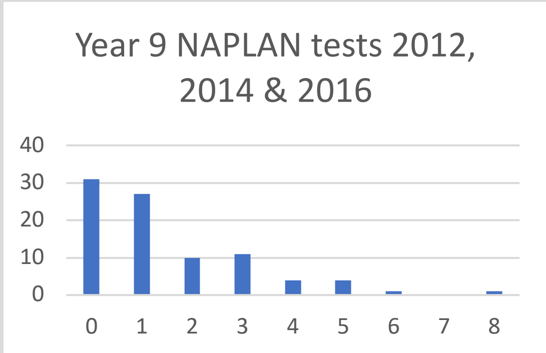
Six Year 9 NAPLAN tests were coded, three where calculators were expected to be available and three where calculators were not permitted. The distribution of questions across the three content strands is uneven, hence analysis was made within each strand.

For Number & Algebra, questions of greater depth demands are provided when calculators are available (63%) compared with non-calculator questions (43%). A higher number of operations is required to solve the questions employed in tests where calculators are available, except in Statistics & Probability. However, there was little difference in the questions in terms of the curriculum proficiencies addressed. The tests where candidates had access to calculators provided similar levels of focus on problem solving and reasoning as the tests where no calculator use was permitted. Without calculator access, these were 14%, 33% and 39% for Number & Algebra, Measurement & Geometry and Statistics & Probability respectively. With calculators allowed, the figures were 22%, 19% and 20% respectively.

Curriculum Content Descriptions in the NAPLAN Questions

By combining three years of NAPLAN tests, an analysis was made of the incidence of CDCs which the questions addressed. Many CDCs escaped having questions which could be ascribed to them, while other CDCs proved popular. The graphs below show the results of combining the 120 questions of the three Year 5 NAPLAN tests which were coded and the 192 Year 9 questions. The horizontal axis is the incidence of each of the CDCs. The outlier which occurred seven times in Year 5 is ACMNA082: "Solve word problems by using number sentences involving multiplication or division where there is no remainder". The Year 9 outlier is ACMNA188: "Solve a range of problems involving rates and ratios, with and without digital technologies".





A notable feature of these graphs is the large number of CDCs which did not appear in the three years of NAPLAN tests analysed. In the mathematics curriculum for Years 3 and 4 there are 48 CDCs, nine of which were not represented in the three Year 5 tests. These include ACMNA077 on equivalent fractions used in contexts and ACMSO094 on events where the chance of one will not be affected by the occurrence of the other. In the mathematics curriculum for Years 6, 7 and 8 there are 88 CDCs. In the six Year 9 tests, 31 of these CDCs were not represented. These include ACMNA182 on the index laws, ACMMG196 on perimeters and areas of quadrilaterals such as trapeziums and ACMSP293 on variation of statistics in random samples drawn from the same population.

By frequency of CDCs, in three years of NAPLAN tests 19% of the mathematics topics Year 5 students should be able to do was not tested and 35% of the mathematics topics Year 9 students should be able to do was not tested. Only 23% of the Year 5 questions and 28% of the Year 9 questions were not multi-choice, but only numerical responses were permitted anyway. This inhibits testing of some topics, such as the ability to draw a graph or to explain a plan for drawing a random sample. Of course, some CDCs from different years have similar applications, some CDCs may be difficult to cover in a test format, or there may be other explanations, but the level of untested intended curriculum is significant.

Conclusions

A significant proportion of the intended mathematics curriculum topics were not covered in the three years of NAPLAN tests analysed. Those topics covered are often at a much younger age level than the school year level of the students. The curriculum proficiency strands of Problem Solving and Reasoning have very limited coverage, as may be expected in what are mainly multi-choice questions.

Limitations and Suggestions for Further Research

Care was taken in the coding of questions, but this is not a task which can be done with complete objectivity and reliability. Partitioning a curriculum into discrete CDCs is unlikely to result in equal weightings for each content description. This study therefore reports only on differences which are quite large in scale. In terms of readability, appropriateness and proportionate representation of the curriculum it would be interesting to compare the NAPLAN questions with questions employed in textbooks and in online teaching resources.

Data for this study was obtained from the most recently released NAPLAN test questions, up to 2016. Subsequent tests have not been publicly released so that a Rasch question-selection system can be implemented in online tests. Future auditing of NAPLAN online tests may be more difficult as they will employ large banks of test items. It is a major change that the NAPLAN can be sat online and many opportunities for research present themselves. Students may regard computer-hosted tests as having less importance than a booklet where their own name is printed on the cover. Without something to write on, students may approach questions differently, perhaps being more likely to guess answers. The ACARA website contains a link to a report commissioned from market research agency Colmar Brunton (2019) which relies on parent perception of the difficulties students faced in the trial online tests, but a more direct appreciation is possible.

Acknowledgements

This research was funded by a grant from the Curtin University School of Education. The authors are grateful to research assistants Dianne Sumich and Ian Hailes for their coding work.

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