Picking up the pace: variation in the structure and organization of learning school mathematics

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Abstract

What is it about curriculum and pedagogy that really makes the difference to pupil learning?[1] Do particular pedagogic features matter in teaching learners mathematics? Or is it rather the range of factors associated with making mathematics available to learners for learning? What makes the real difference: pedagogic style or opportunity to learn?

The paper discusses why it is plausible to study opportunity to learn (OTL) in South Africa. It outlines some of the methods used to operationalise particular dimensions of OTL and measure variation in the structure and organization of school mathematics. Data are presented on the mathematics knowledge made available to low SES grade 5 and 6 learners in the first three terms of 2003 in terms of content complexity and across grade developmental complexity. The effects of this availability on learning will be reported on in future papers.

The changing landscape of South African curriculum policy

1997 marked the adoption of a new curriculum framework that formed part of a range of policies designed to transform and restructure apartheid education in South Africa (Christie, 1999). Where the ‘apartheid’ curriculum was based on ‘traditional’ distinctions between subjects such as history and geography, the new South African curriculum, Curriculum 2005 (C2005), integrates traditionally separate subjects into eight ‘learning areas’ – Human and Social Sciences; Numeracy and Mathematical Sciences; Natural and Physical Sciences; Economic and Management Sciences; Technology; Communication, Literacy and Languages; Culture, Arts and Artistic Crafts; and Life Orientation.

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1 The type of mathematical learning being considered is learning which allows learners to successfully answer achievement tests designed to measure mathematics accomplishment.

Whilst the previous curriculum took the form of prescriptive national syllabi for each subject that emphasized "often ideologically distorted" academic subject content and disregarded the everyday realities of apartheid South Africa (Christie, 1999, p.282), the new curriculum is based on the concept of outcomes-based-education (OBE). Rather than outlining specific subject content and skills to be covered (inputs), C2005 provides the outcomes to be evaluated or assessed for each learning area. The critical outcomes underpinning the new curriculum are 'open-ended' in that they emphasize the higher order skills that are tied to underlying knowledge principles such as critical thinking, application of problem-solving, and communication (Taylor 1999). Strong integration between everyday and school knowledge is advocated, and a premium is placed on integration of knowledge and "transferability of knowledge to real life" (Department of Education, 1997, p.32).

In 1998, when C2005 was in its second year of implementation, the National Department of Education commissioned research through the President's Education Initiative (PEI) to investigate the implementation of the recent curriculum reform policies. The authors of the PEI Report found the new curriculum to be "vague in the extreme in the area of content" (Taylor, 1999, p.126). They concluded that curriculum efforts at integration had resulted in a "bewildering mix of concepts" where . . . "it seems most unlikely that learners will develop a systemic understanding of any of these ideas. In the hands of teachers whose own conceptual frames (of the subjects they teach: our addition) are not strong, the results are likely to be disastrous where school knowledge is totally submerged in an unorganised confusion of contrived realism" (p.121).

The PEI Report pointed to a curriculum driven by weak conceptual coherence in terms of specialized school knowledge and skills which was likely to exacerbate rather than reduce existing inequalities in learning outcomes that ensure access to further educational opportunities and better-paying occupations for disadvantaged learners. PEI research studies showed that:

> 'in historically disadvantaged schools . . . teaching through drill' had apparently been 'replaced by teaching about everyday life' which 'seldom translated into the mastery of sophisticated forms of knowing and thinking' or school knowledge (Fleisch, 2002, p.118).

In 2001, in response to the findings of the PEI Report, a Ministerial Committee was tasked with placing the curriculum on a more epistemologically sound footing. The Report of the Review Committee (Chisholm, Lubisi, Mahomed, Malan, Muller, Ndhlovu, Ngozi, Potenza and Volmink, 2000) took issue with the weak 'lateral demarcation' between school and everyday knowledge and between different school subjects (p.41). A key recommendation of their Report was the separation of 'integrated' learning programmes into distinct subjects. The Review Committee was also critical of the weak 'vertical demarcation' or under-specification of the curriculum in terms of grade level "sequence, pace and progression – what competences must be learnt" (p.40). They argued that the "lack of a conceptual roadmap for proceeding" (Taylor, Muller and Vinjevold, 2003, p.133) would principally disadvantage learners in schools where teachers' knowledge base was not strong. The Committee recommended stronger specification of the expected competence levels for each grade level in the Curriculum, especially for subjects such as mathematics and natural sciences.

C2005 has since been re-defined through Reviewed National Curriculum Statements (RNCS) specific to each learning area (Department of Education, 2002a). In the numeracy and mathematics learning area the development of subject knowledge has been foregrounded and the statements now express the skills, concepts and content learners are expected to have at each grade level. The review of C2005, certainly in the numeracy and mathematics learning area, marks a shift to a more coherent subject-based curriculum that focuses attention on the attainment of essential mathematics skills and knowledge competences.

It seems likely that in future there will be greater accountability to national assessment standards via national testing benchmarks. Indeed in 2000 the National Department of Education introduced a pilot project for systemic assessment at Grades 3, 6 and 9 (Department of Education, 2001 in Taylor, Muller and Vinjevold, 2003). The idea is that, in future, learners are to be assessed against national curriculum standards that indicate whether they are attaining a learning outcome at an appropriate level for each grade.

Clearly imperatives to improve the aggregate level of learner achievement in the country appear to be stronger than ever. However, recent research evidence in the country has revealed high levels of under-performance, particularly amongst South African learners at schools in high poverty areas (Howie and Hughes, 1998; Joint Education Trust, 2000; 2001; Department of Education, 2002c; Smith, 2004). Studies have shown that "many Grade 6 learners are not able to perform mathematics and reading tasks expected at the Grade 3 level" (Joint Education Trust, 2001, p.3).

In 2004 the Western Cape Education MEC announced that results of systemic literacy and numeracy tests administered to grade 6 learners in the Province in 2003[2] showed a clear relationship between poverty and achievement – "the poorer pupils, the more likely they were to lag" (Smith, 2004: p.9). Achieving greater equality in outcomes for South African learners will of necessity entail assisting schools across the system to 'deliver quality'. The question is: what delivers quality?

Addressing learner achievement inequality

The finding that achievement is related to the content and skills that are actually made available to learners in the classroom is one of the most consistent and logical empirical findings in international comparative educational research (Shavelson, McDonnell and Oakes, 1989; Burstein, 1993) as well as national educational studies in some developed countries.[3] Stevens (1996, p.1) points out that this finding is significant both "because race/ethnicity and poverty are not alterable variables" and because it confirms the view that schooling can play a role in providing low SES or disadvantaged learners with the academic competencies they need for further learning.[4]

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2 The Western Cape Education Department's (WCED) systemic evaluation of grade 6 learners' mathematics performance commenced in 2003.

3 Although OTL has received attention in international comparative studies such as the TIMSS and in developed country contexts such as the USA "its use to date in developing countries has been limited. Few studies of academic achievement have incorporated explicit measures of OTL (the curriculum made available to learners), and most have relied on indirect ones such as total days worked in the school or teacher subject-matter knowledge" (Marshall and White, 2001, p.7).

4 Hirsch (1999, p.43-44) argues that "since some children are apter and harder-working than others, equality of educational opportunity does not mean that all students will make very high test scores". He argues that, although, "good schools" "can never *entirely* (his italics) equalize educational opportunity" "because the home is also a school, where students spend more time than in the official one". . ."Other things being equal, students from good-home schools will always have an educational advantage over students from less-good-home-schools. Nonetheless, basic gaps in knowledge can be compensated for in the classroom, as the international data prove."

Opportunity-to-Learn (OTL) and learner achievement

Large scale across country studies of the International Association for the Evaluation of Educational Achievement's (IEA) such as the First International Mathematics Survey (FIMS), Second International Maths Study (SIMS) and the Third International Maths and Science Study (TIMSS) have uniformly shown that Opportunity-to-Learn (OTL) – the degree of overlap between the content of instruction and that tested (test-curriculum-overlap) – is "a consistent predictor of achievement scores" in mathematics and science (Rowan, 2002, p.16).

A key finding of the Second International Maths Study (SIMS) was that, when 'cultural and instructional practices among the countries' were investigated to explain differences in performance, 'the only classroom or school variable' found 'to be significantly related to achievement growth was opportunity to learn measured as content coverage' (the topics and subtopics actually taught) and 'content exposure' (the amount of time spent on mathematics contents) (Stevens, nd, p.1). Since the SIMS, OTL has increasingly been 'seen as a policy relevant curriculum variable' for national educational systems in developing countries (Floden, 2003, p.253). In the United States, 'the results of more than 15 years of research' that documented the empirical relationship between learner achievement and the content and the cognitive level at which the contents are taught, strongly indicate that "curriculum exposure could be an effective lever in efforts to improve student achievement and to distribute learning opportunities more equitably" (McDonnell, 1995, p.308).

The "large body of research on the determinants of student achievement" in international studies and the USA has also suggested that OTL is defined "not only by the curriculum content that learners are offered and the amount of contact time devoted to teaching the subject area" (McDonnell, 1995, p.308), but also by the sequencing and pacing of curriculum content that is made available to learners (Smith, Smith and Bryk, 1998). More recently, the OTL construct has been expanded to include measures of 'curricular coherence', that is, the degree to which domain-specific or disciplinary content is systematically presented to learners in terms of the conceptual coherence of its organization, and 'curricular pacing', the structuring and organization of curriculum across adjacent grades. The idea is that curricular pacing and coherence helps prevent a cumulative deficit in breadth and depth of domain-specific knowledge and conceptual advancement of specialized skills and concepts across grades improving the likelihood of learners having the pre-requisite content knowledge for the next year (Smith, Smith and Bryk, 1998).

OTL in the current South African context

Given the recent revisions to the South African curriculum framework, it is plausible to anticipate that policy makers and others involved in schooling in the country have a revitalized interest in the opportunities to learn that are being made available to low SES populations of learners. It is plausible to anticipate that OTL variables are variables of interest in their 'own right' (Floden, 2003, p.237), and that there is an interest in the opportunities that are being denied to particular learners because certain topics or subtopics are being omitted or given little attention (Schmidt, McKnight, Valverde, Houang, and Wiley, 1997).

Measuring variation

One purpose of the paper is to describe the methodological procedures used for collecting data on the following dimensions of OTL in the grade 6 mathematics curriculum:

a) *content coverage,* that is, the mathematics topics and subtopics actually taught during the course of the school year; and *content emphasis*, that is, the amount of time spent on the various contents (for example, variations in how many lesson periods devoted to particular topics or subtopics) (Husen, 1967 in Pelgrum, 1989; Gamoran, Porter, Smithson and White, 1997 in Floden 2003; Thompson and Senk, 2001; Porter and Smithson, 2001);

b) *curricular pacing* (pacing across adjacent grades), a measure of whether curricular content progresses at an appropriate level from grade to grade (Smith, Smith and Bryk, 1998; Rose 2002).

This is followed by descriptive results on content coverage and emphasis, and curricular pacing.

Capturing OTL

A standardised OTL data collection instrument was developed and used for ‘content coverage’, ‘content emphasis’ and ‘curricular pacing’ across two adjacent grades, namely grade 5 and 6.

Content coverage

The idea of a potential common curriculum detailing goals at the level of the intended curriculum for each grade is central to the notion of measuring ‘content coverage’. As Rowan (2002, p.16) notes “any serious attempt to measure content coverage begins with a basic categorization of curriculum in a particular subject area (e.g. maths, reading, writing, etc.). Such categorization schemes have been derived from many different sources, including curriculum frameworks or standards documents, textbooks, and items included in the achievement test(s) being used as the dependent variable(s).” Hence the first requirement for measuring ‘content coverage’ was the construction of a framework of potential curriculum content that ensured that data collected across grade 6 classes is comparable.

Curriculum 2005 (Department of Education, 1997a, b and c) does not express the core content, skills and concepts learners are expected to cover in the numeracy and mathematics learning area at each grade level. Hence it was not possible to use the curriculum-in-use for constructing a framework for establishing variations in learners’ opportunity to learn school mathematics contents.

Instead, a decision was made to use the RNCS for the numeracy and mathematics learning area as the primary tool for constructing a framework of potential curriculum content and for segmenting and categorizing ‘pieces’ of the framework into the most fine-grained elements possible.[5]

Since many South African grade 6 learners are performing at lower levels than their grade requirements (Joint Education Trust, 2001; Seekings, 2001), a further assumption in the study was that teachers have to address gaps in learner knowledge and skills whilst trying to cover grade 6 level mathematics.

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5 The curriculum document used for constructing a framework for measuring ‘content coverage’ was the Department of Education’s Revised National Curriculum Statements Grade R-9: Mathematics May 2002, the document available when instruments for the study were designed in 2002.

In other words, an expectation was that grade 6 teachers were likely to also cover content, skills and concepts that learners were expected to have covered at least at the grade 4 and 5 level. By implication, in order to measure learners' OTL more judiciously and accurately, the framework of potential curriculum content needed to include curriculum content outlined for the intermediate phase (grade 4-6) as a whole rather than only grade 6.

The main categories for the framework comprised the five learning outcomes (LOs) for the numeracy and mathematics learning area. Within each LO the assessment standards are organized into a number of 'clusters'. Table 1 from Page 2.11 from Draft number 2 of the Mathematics Learning Programme Policy Guidelines (MLPPG) provides the following 'clusterings' for outcomes in the Intermediate Phase:

Table 1: 'Clusters' for Learning Outcomes in the Intermediate Phase

LO 1: Number, operation and relationships	LO 2: Patterns, functions and algebra	LO 3: Space and Shape (geometry)	LO 4: Measurement	LO 5: Data handling
1. Recognising, classifying and representing numbers	1. Patterns	1. Shapes and Objects	4. Time	7. Collecting and Organising Data
2. Applications of numbers to problems	2. Equations	2. Transformations	5. Units and Instruments	8. Representing and Interpreting Data
3. Calculation types involving numbers		3. Position	6. Perimeter, Area and Volume	9. Chance
4. Properties of numbers				

Source: Department of Education, 2002b

The idea was to make the framework of potential curriculum content for the study as specific as possible so as to capture the most finely grained elements of each outcome or 'cluster' covered to allow for specific analysis of content covered rather than simply broad patterns of differences in mathematics content coverage. The idea was also to make it possible to capture details at specific grade levels for the intermediate phase.

For example, the framework describes LO1: Number, operations and relationships: Recognizing, classifying and representing numbers: Representing and comparing whole numbers including zero and fractions in the following topic complexity:

	Representing and comparing whole numbers including zero and fractions including:
	Whole numbers to
11	4-digit numbers (g4)
12	6-digit numbers (g5)
13	9-digit numbers (g6)
14	Odd and even number to 1 000 (g4)
15	Common fractions in diagrammatic form (g4)
	Common fractions with different denominators including
16	halves (g4)
17	thirds (g4)
18	quarters (g4)
19	fifths (g4)
20	sixths (g4)
21	sevenths (g4)
22	eighths (g4)
23	tenths (g6)
24	twelfths (g5, 6)
25	hundreds (g6)

G4, g5, g6 (in brackets) indicates that these units or elements are considered essential at the grade 4, 5 or 6 level – in other words, they reflect work that learners are, at a minimum, expected to cover at this level.[6] However, although certain elements of topics or subtopics are considered essential for a particular grade level (for example, element number 11, 12 and 13 above), there are

6 Although the RNCS include 'issue- or value-based' element such as 'Describing and illustrating various ways of counting in different cultures (including local) throughout history' (LO1 Intermediate Phase), for the purposes of the study the majority of issue-/value-based topics were not included on the framework of possible curriculum content as only those subtopics that are more aligned to features of the test items used in the larger study were selected.

other elements of topics or subtopics that are considered essential at all or more than one intermediate grade levels, for example element numbers 24 above and 48, 49 and 50 below:

	Using operations appropriate to solving problems involving:
	Rounding off to the nearest
48	10 (g4,5,6)
49	100 (g4,5,6)
50	1 000 (g4,5,6)

Once the outline of the Framework had been drafted and the grade levels indicated, a mathematics curriculum expert was asked to verify the grade level information on the Framework by indicating which of the elements related most specifically to minimum grade 6 level expectations. Thus the shaded numbers above indicate that elements of the 'minimum' intended grade 6 curriculum. What is important is that the Framework of Potential Curriculum Content is constructed so as to make it possible to capture 'content coverage' at the most specific grade and content levels and to describe curricular variations in macro pacing across classes in terms of content complexity.

Content emphasis

The second dimension of 'content coverage' data is 'content emphasis', or the estimated number of single mathematics lessons or periods spent on each element of the framework. Neither the original Curriculum 2005 nor the RNCS for mathematics prescribed or provided indications of the emphasis to be given to the various components of the curriculum in terms of time. An early draft (Draft number 2) of the MLPPG had provided the following framework for allocating time or emphasis for each of the five outcomes in the intermediate phase (Department of Education, 2002b, p.2.9):

Table 2: Draft intermediate framework for allocating time for each of the five mathematics outcomes

<table>
<tr><td>LO1
NUMBER</td><td>40%</td></tr>
<tr><td>LO2
PATTERNS & FUNCTIONS, ALGEBRA</td><td>15%</td></tr>
<tr><td>LO3
SHAPE, SPACE, POSITION, GEOMETRY</td><td rowspan="2">30%</td></tr>
<tr><td>LO4
MEASUREMENT</td></tr>
<tr><td>LO5
DATA HANDLING</td><td>15%</td></tr>
</table>

These guidelines indicating the emphasis expected at the intermediate phase were subsequently dropped from the official version of RNCS documents. In order to establish a more substantial notion of ideal time against which to measure the actual amount of time teachers spent on each element of content outlined in the framework, a highly experienced and competent academic head of intermediate phase mathematics at a high-performing school was asked to indicate the amount of time in terms of the number of single 30 minute periods she would 'ideally' devote to each element of the framework indicated as essential at the grade 6 level – as if the framework was the intermediate phase curriculum in-use.

In the absence of expressed expectations of content emphasis in curriculum documents, the idea is to have a more refined notion of the ideal amount of time teachers could be expected to spend on topics. For example, the following are the academic head's ideal notions of 'content emphasis' for some of the grade 6 level elements of LO 5 – Data handling:

	SECTION 5: DATA HANDLING:		
	5.1 COLLECTING AND ORGANISING DATA	Ideal time *Number of single 30 min periods*	
203	Posing simple questions and data sources that address human rights, social, political, cultural, environmental and economic issues in learners' school and family environment (g4,5,6)		
204	Making and using simple data collection sheets involving counting objects (requiring tallies i.e. ways of recording the number of items per category in a set of data by making a mark for each item) and simple questionnaires (with yes/no type responses) to collect data to answer questions posed by the teacher or learners (g5,6)		
205	Using tallies and tables to organise and record data (g5,6)	4	
	Using ungrouped numerical data (raw data which have not been grouped into classes or categories) to determine:		
206	the most frequently occurring score (mode i.e. the number or item that appears most frequently in a set of data) in order to describe central tendencies (g4,5,6)	1	
207	the midpoint (median i.e. if the data is written in order from smallest to largest, the median is either the middle number or the mean of the two middle numbers) in order to describe central tendencies (g5,6)	1	

* 203, 204 & 205 combined – four periods

Her ideal notion of 'content emphasis' was subsequently validated by two other experienced grade 6 mathematics teachers at high-performing schools who specified where they disagreed with the amount of time and indicated the number of periods they would expect to spend on the particular subtopics. Variations are indicated on the instrument as, for example, 4-6 (periods). This made it possible to compare the estimated actual amount of time teachers in the study spent on the various elements with an ideal notion of emphasis.[7]

Data collection methods for content coverage and emphasis

In an attempt to standardize data collection procedures, ensure more rigorous data gathering methods and as much uniformity as possible in the collection of data, an instrument to collate OTL data collected was developed. The first section of the instrument was used to capture content coverage and emphasis. The framework of potential curriculum content was used to identify the topics or subtopics covered and the estimated number of lessons spent on each topic/subtopic covered in each of the three terms. As classes sometimes cover a number of topics in one lesson, the instrument also made provision for estimates of less than one lesson as illustrated in the following extract of the grade 6 instrument:

7 'Ideal' is used in a modified way as 'ideal' for teachers in middle class schools may not be 'ideal' for teachers working in very different contexts. A limitation of the study is that it uses the judgment of only 3 expert grade 6 mathematics teachers regarding the amount of time teachers should ideally devote to sub-topics.

	SECTION 2: MEASUREMENT				
		Covered	Ideal time	Estimated number of lessons	
	2.1 TIME	Tick if yes	Number of single 30 min periods	Tick if less than one	If one or more, estimate how many (write a number)
	Reading and writing analogue, digital and 24-hour time including:				
	Analogue time (time read from a clock with a face and hands)				
92	to the nearest minute (g4,5,6)				
93	2. to the nearest second. (g4,5,6)				
	Digital time (time read from a clock that has a continually changing digit display rather than a clock face				
94	3. to the nearest minute (g4,5,6)				
95	4. to the nearest second. (g4,5,6)				
	24-hour time				
96	5. to the nearest minute (g4,5,6)		2		
97	6. to the nearest second. (g4,5,6)		2		

The research mainly relied on information gathered from an examination of the two most comprehensive of learners' workbooks or files in each class. Three other methods were used as supplementary sources for triangulation.

A highly structured teacher survey interview was used to collect teacher self-report data on the contents covered in grade 6 in each class in each of the first three terms as a supplementary method. A second supplementary method entailed an examination of each teacher's year or term plans. A third supplementary method used included an examination of learners' reports on the daily content of their instruction for the year. At the beginning of the year two learners in each class were asked and given incentives in the form of gift vouchers each term to keep diaries on the daily content of their lessons for the year.

In large-scale studies in developed country contexts reliance on teacher judgments through the use of survey questionnaires is the most common approach for measuring what is covered in each grade and the amount of time given to specific mathematics topics. The reason for mainly relying on information from learners' workbooks in the South African context is that self-report data are not generally considered sufficiently reliable. For example, the PEI report (Taylor and Vinjevold, 1999) reported that some studies showed disparities between what teachers actually did in terms of classroom practices, and what they said they did in their classrooms. In fact we have little knowledge of levels of agreement between teachers' and researchers' reports of information on the content of instruction.

The following routine was built into the data collection procedures. As the focus was on the mathematics actually covered, rather than the planned coverage, the examination of teachers' year plans or schemes of work (together with the interviews) were used primarily to orientate the data collector as to what she might expect to find in learners' workbooks before examining them. Once teachers had been interviewed and their year or term plans examined, the records of work in the two workbooks were closely checked against the framework of possible content to determine whether teachers had actually covered possible topics or subtopics. Teachers' reports in the interviews and learners' reports in the diaries were then used in instances where it was not clear from the workbooks whether or not teachers had covered topics or subtopics and there was unlikely to be any readily observable information in the primary sources (workbooks). If the teacher and/or learners reported covering them in the interviews or diaries, and the data collector judged the self-report data sufficiently reliable to make it reasonable to assume that subtopics had been covered, the assumption was made that the subtopics had been covered. The idea was to use the multiple data collection methods and sources to ensure greater reliability and establish and sort out discrepancies in the data collected.

The framework on the OTL Instrument was used first to indicate whether or not a subtopic had been covered, in other words simply to indicate the presence or absence of evidence that a subtopic had been covered, and then to estimate the amount of time actually devoted to a subtopic in terms of 30 minute periods (in other words, to estimate the relative emphasis given to a topic). Whilst the specific number of subtopics and lessons spent on them may not be precise, we believe they are fairly good estimates of coverage and emphasis.

Curricular pacing

Curricular pacing in the study is a measure of a school's structuring or pacing of curriculum across adjacent grades. The idea is that 'curricular pacing' provides a proxy measure of learners' curriculum exposure to mathematics contents with other teachers in previous years. Pacing across two adjacent grades, grade 5 and 6 was considered.

'Content coverage' and 'content emphasis' (the number of lessons spent on each of the topics or subtopics) in grade 5 classes at each school in 2003 was used as a proxy indicator of 'curriculum pacing' for the sample of grade 6 learners. Data on mathematics content coverage and emphasis' for the grade 5 classes were collected at each school through the use of an OTL Instrument developed for grade 5. This instrument used the same intermediate phase framework developed for the Grade 6 OTL Instrument but was constructed so that the focus was on grade 5 content coverage and emphasis. Thus shaded numbers on the grade 5 instrument indicate that elements are considered to be elements of the grade 5 curriculum. For example:

	1.1. RECOGNISING, CLASSIFYING AND REPRESENTING NUMBERS	Cover		Estimated number of lessons		
		Tick if yes		Tick if less than one	If one or more, estimate how many (write a number)	Ideal – number single 30 min periods
	Counting including:					
	Counting forwards and backwards in					
1	1. 2s (g4,5)					
2	2. 3s (g4,5)					
3	3. 5s (g4,5)					
4	4. 10s (g4,5)					1
5	5. 25s (g4,5)					1
6	50s (g4,5)					1
7	7. 100s (g4,5)					1
8	8. a variety of whole number intervals between 0 and 9. 10 000 (g4,5)					1
9	10. fractions (g5)					1
10	11. decimals (g6)					

Data collection methods for curricular pacing

A grade 5 teacher survey interview questionnaire on the topics and subtopics covered and the estimated number of lessons spent on each topic or sub-topic, the grade 5 teachers' year plans or schemes of work, together with an examination of learners' workbooks was used to determine 'content coverage' and 'content emphasis' at the grade 5 level. In the first term an interview was conducted with all or as many as possible of the grade 5 mathematics teachers at each school (where there was more than one grade 5 mathematics teacher) to ascertain whether all grade 5 teachers followed the same term/year plan and cover the same topics across the school year. In all cases, the Grade 5 teacher interviewed reported that they essentially tried to cover the same topics and spend similar amounts of time on topics. The information was then verified by examining two learners' workbooks from each grade 5 class to ascertain the extent of alignment in terms of content coverage and emphasis. In all cases it appeared that there was adequate evidence of sufficient conformity across grade 5 classes at each school to render it reasonable to collect one set of grade 5 data at each school as a proxy measure of 'curriculum pacing' for grade 6 learners in the sample. Data were collected at the end of each term for the first three terms.

Data analysis

From the data analysis it was possible to calculate the percentage of grade 6 learners who had covered each of the grade 6 level subtopics on the framework and to estimate the percentage of grade 6 learners who had probably been exposed to each of grade 5 subtopics in their first three terms in grade 5. It was also possible to calculate the estimated average number of lessons actually spent on the various subtopics where they were covered and to compare this with the estimated ideal number of lessons on the framework.

The following is an extract of aggregated results for grade 6. The content outlined in the framework is presented to assist the reader in interpreting the information. Subtopics covered by half (50%) or more of the grade 6 learners are shaded. In other words, shading indicates that at least 50% of grade 6 learners had an opportunity to learn that particular content. The numbered boxes of subtopics which are related most specifically to the minimum grade 6 expectations are also shaded. If grade 6 content (numbers 10 and 13), is not shaded this indicates that less than 50% of the sample of learners had an opportunity to learn that particular content.

Extract of aggregated results for grade 6 content coverage and emphasis

	SECTION 1: NUMBER, OPERATION AND RELATIONSHIPS:				
			Ideal time for Grade 6 content	Estimated average number of lessons spent on content	
	1.1. RECOGNISING, CLASSIFYING AND REPRESENTING NUMBERS	% of learners that covered	Number of single 30 min periods	Less than one	If one or more, estimated average no. single periods
	Counting including:				
	Counting forwards and backwards in				
1	• 2s (g4,5)	82		X	
2	• 3s (g4,5)	76		X	
3	• 5s (g4,5)	76		X	
4	• 10s (g4,5)	79			1
5	• 25s (g4,5)	71			1
6	• 50s (g4,5)	68			1
7	• 100s (g4,5)	74			1
8	• a variety of whole number intervals between 0 and 10 000 (g4,5)	50			1
9	• fractions (g5)	45			2
10	• decimals (g6)	26	38443		2
	Representing and comparing whole numbers including zero and fractions including:				
	Whole numbers to				
11	• 4-digit numbers (g4)	84			3
12	• 6-digit numbers (g5)	76			3
13	• 9-digit numbers (g6)	21	38506	X	

The above analysis indicates that at least 50% of the grade 6 learners covered counting forwards and backwards in 2s, 3s, 5s, 10s, 25s, 50s, 100s and a variety of whole number intervals between 0 and 10 000 which relate to grade 4 and 5 expectations. Greater emphasis (an estimated 1 period) was placed on counting in 10s, 25s, 50s, 100s and a variety of whole number intervals between 0 and 10 000 than was placed on counting in 2s, 3s, 5s (estimated as less than 1 period). Only 26% of the learners were exposed to ‘counting forwards and backwards in decimals’ which relates to grade 6 level expectations. Over 50% of the learners were exposed to representing and comparing 4–6-digit whole numbers (an estimated 3 periods on each) which relates to grade 4 and 5 level expectation as opposed to only 21% of the learners who were exposed to 9-digit whole numbers at the expected grade 6 level for on average less than 1 period as compared to the notional ideal of 6 periods.

In the following extract from the grade 5 analysis, subtopics likely to have been covered by at least 50% of the sample are shaded.

Extract of aggregated results from grade 5 content coverage and emphasis

	SECTION 2: MEASUREMENT:				
			Estimated average no. of lessons spent on content		
	2.1 TIME	% of classes that covered	Less than one	If one or more, estimated average no. single periods	Ideal no. single 30 min. periods
	Reading and writing analogue, digital and 24-hour time including:				
	Analogue time (time read from a clock with a face and hands)				
92	• to the nearest minute (g4,5,6)	50		2	2
93	• to the nearest second (g.4,5,6)	42		2	2
	Digital time (time read from a clock that has a continually changing digit display rather than a clock face				
94	• to the nearest minute (g4,5,6)	33		1	1
95	• to the nearest second (g4,5,6)	21		1	1
	24-hour time				
96	• to the nearest minute (g4,5,6)	29		1	38383
97	• to the nearest second (g4,5,6)	28		1	38383
	Solving problems involving calculation and conversions between approrpriate time units:				
98	• seconds (g4)	58		1	
99	• minutes (g4)	67		1	
100	• hours (g4)	63		1	
101	• days (g4)	63		1	
102	• weeks (g4)	50		1	
103	• months (g4)	50		1	
104	• years (g4)	42		1	
105	• decades (g5)	40	X		1
106	• centuries (g5)	0		0	1
107	• millennia (g5)	0		0	1
108	• time zones and differences (g6)	0		0	

The above analysis shows that, in grade 5, learners are commonly focusing on grade 4 level expectations relating to solving problems involving calculations and conversions between time units (numbers 98-103) and that an estimated average of 6 periods was spent on this overall. Little or no attention was paid to grade 5 level expectations (numbers 105-107). 40% of the sample spent an estimated average of less than one period on ‘decades’ and none of the learners appeared to cover ‘centuries’ or ‘millennia’.

Descriptive results

An analysis of ‘content coverage and emphasis’ in grade 5 and 6 reveals the following interesting patterns of curricular pacing. Data indicate that by the end of the third quarter

- in both grade 5 and 6, curricular attention was strongest for two of the five RNCS outcomes, namely LO 1: Number, Operations and Relationships; and LO4: Measurement. The mathematics curriculum made available to the sample of learners in grade 5 and 6 was primarily one of Number and Measurement.
- in grade 5 no one subtopic in three Learning Outcomes, namely LO 2: Patterns, Functions and Algebra, LO 3: Space and Shape (Geometry) or LO 5: Data Handling was covered by 50% or more of the 1001 learners. In grade 6, only one subtopic of LO 2: Patterns, Functions and Algebra and LO 5: Data Handling on the Framework was covered by 50% or more of the classes. None of the subtopics in LO 3: Space and Shape (Geometry) on the Framework was covered by 50% or more of the grade 6 learners. This shows that there is wider variability amongst the sample in terms of the subtopics covered or not covered for these three outcomes in both grade 5 and 6.
- on average grade 6 learners covered 29% of *all* the intermediate phase (IP) subtopics on the Framework of Potential Curriculum Content but the percentage of IP subtopics covered in grade 6 ranged from 12% to 70%.
- the average coverage of subtopics considered essential for the grade 6 level in grade 6 was 22% of those on the Framework of Potential Curriculum Content but the percentage of grade 6 level topics covered ranged from 5% to 55%.

- data on grade 5 content coverage and emphasis indicate that the average coverage of all the subtopics considered essential at the grade 5 level was 29%. However, the percentage of the grade 5 subtopics covered in grade 5 ranged from 4% to 70%.
- 71% of the subtopics covered by 50% or more of the learners in grade 6 were also covered in at least 50% of the classes in grade 5. Evidently only 29% of the subtopics covered by 50% or more of the learners in grade 6 were introduced for the first time in grade 6.

Discussion

Whilst the curriculum coverage and emphasis and adjacent grade curriculum pacing data reveal evidence of considerable variations in coverage across classes, that is, considerable cross-class differences, there are enough commonalities in terms of the outcomes covered and emphasized and the subtopics that predominate within and across both grade 5 and 6 to indicate the curriculum commonly made available to the sample of low SES learners grade 5 and 6 in the Cape Peninsula.

Although the common emphasis on Number and Measurement evident at the grade 5 and 6 level is in line with the very broad guidelines for allocating time for each of the five mathematics outcomes in the intermediate phase originally suggested in Draft number 2 of the MLPPG, overall curricular attention for the other three LOs in both grades appears to be much weaker. Certainly levels of commonly covered subtopics for the three outcomes are extremely low. As Floden (2003, p.255) points out the danger here is that, OTL in mathematics "is important for each topic area", not just for mathematics as a whole, because, if mathematics learning was "simply increasing mastery of a single skill, then it would not matter what topics were studied. Students who learned more mathematics would do better on topics."

The descriptive data also show that learners are spending more time on subtopics that they were expected to have covered in earlier grades than they do on subtopics at the level expected for their grade. Data reveal evidence of slow curricular pacing across grades 5 and 6. In other words, the study shows evidence of slow across grade curricular pacing and that learners are studying topics lower than grade level expectations.

In fact, data appear to mirror Smith, Smith and Bryk's (1998) findings in the U.S. described in *Setting the Pace: Opportunities to Learn in Chicago Public Elementary Schools*, where there was found to be "frequent repetition of topics across one or more years" (p.19). This Chicago study arose out of the fact that classroom observations had revealed that similar lessons and concepts were being taught "again and again" (website abstract) so that the "classroom life" of some learners appeared "to consist of repetitive cycles of basic skills instruction" (p.22) as well as "gaps in instruction" (p.26). Together with a "steady exposure to slow pacing" across grades, this appeared to be leaving certain learners 'farther and farther behind' (p.2).

A key conclusion of the Chicago study was that teachers, particularly at high poverty schools, often "lacked a shared conception of the instructional program overall, and of their own particular set of responsibilities for advancing it" (p.13). Indeed, curricular pacing was seen to reflect "the way teachers do or do not work together in the school" (p.24). The researchers found that "unaligned and incoherent instructional programs emerge. Students who pass through these programs experience delays, repetitions, and/or skips in core knowledge and skills in ways that seriously diminish their chances for success in school and, in particular, on tests used to measure their knowledge and their progress" (p.29). Smith, Smith and Bryk (1998) argue that, although "official learning goals and standards that articulate what students are expected to know at various grade levels", are "a necessary first step", "external guidelines and mandates do not, by themselves, prevent troubling differences in teaching and learning from occurring" (p.29).

They assert that the problem lies in how schools "organise and pace instruction and how this structure affects students" opportunities to learn" (p.15) and conclude that schools need "to keep the curriculum moving forward" and co-ordinated, "both across grades and across classrooms within a grade" (website abstract). However, the researchers are at pains to emphasise that their concern "is not that instruction be mindlessly speeded up or that more is necessarily better", rather it is that learners "should experience a sequence of instruction that exposes them in a systematic and developmentally challenging fashion" (p.12).

Underlying the OTL construct is the notion that curriculum frameworks and curriculum guides potentially act as inclusionary mechanism for ensuring that high status mathematical knowledge and skills are made equally available to all learners. What the above analysis of the Cape Peninsula data suggests is that, whilst the new curriculum framework and the assessment standards in South Africa have potential for improving the quality of learners' OTL, their potential for reducing inequality in OTL may depend on additional guidance to schools and teachers in ensuring within and across grade content complexity and across grade developmental complexity. For example, although teachers have control over the level of detail and degree of emphasis content is given, the current new frameworks provide little in the way of guidance in relation to content emphasis. The Cape Peninsula data indicate that even the very broad guidelines (for allocating time for each of the five mathematics outcomes) that were subsequently dropped from curriculum documents, may be insufficient for teachers' needs. More guidance may be required in ensuring curriculum coverage and pacing within and across grades.

Preliminary findings indicate that policy documents such as curriculum frameworks and guidelines in South Africa may need to provide schools and teachers with a concrete picture of the entire trajectory of each learning phase (across grade framing over pacing) and more in the way of guidance in relation to the pace they should maintain in order to cover the grade level expectations. Teachers appear to need greater signaling as to how much time learners should be given to work on topics or subtopics. Such pacing signals would be of particular value to inexperienced and less qualified teachers and could serve as mechanisms for assisting schools and teachers in ensuring that all learners receive an equivalent curriculum. Indications are that schools and teachers may also require more direct and focused assistance with planning work schedules and learning programmes across grades and school phases, for example, through school level support that focuses on the organization and pacing of the curriculum across learners' learning careers.

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References

Burstein, L. (Ed.). 1993. *The IEA study of mathematics III: student growth and classroom processes.* Tarrytown, NY: Pergamon Press.

Chisholm, L., Lubisi, C., Mahomed, H., Malan, B., Muller, J., Ndhlovu, T., Ngozi, L., Potenza, E. and Volmink, J. 2000.A South African Curriculum for the 21st Century: Report of the Review Committee on Curriculum 2005 presented to the Minister of Education, 31 May. Pretoria: Ministry of Education.

Christie, P. 1999. OBE and unfolding policy trajectories: lessons to be learned. In Jansen J. and Christie P. (Eds). *Changing curriculum: studies on outcomes-based education in South Africa*. Kenwyn: Juta, pp.279-292.

Fleisch, B. 2002. *Managing educational change*. Heinemann: Johannesburg.

Floden, R. 2003. The measurement of opportunity to learn. In Porter A.C. and Gamoran, A. (Eds). *Methodological advances in cross-national surveys of educational achievement*. Washington, DC: National Academy of Sciences. Retrieved 14 May 2004 from the World Wide Web: http://books.nap.edu/catalog/10322.html

Hirsch, E.D. 1999. *The schools we need: and why we don't have them*. New York: Anchor Books.

Howie, S. and Hughes, C. 1998. Mathematics and science literacy of final-year students in South Africa. A report on South African students in the TIMSS. Pretoria: HSRC.

Joint Education Trust. 2000. Mahlahle: the bright morning star. A report on the Phase 2 baseline study. Johannesburg: JET.

Joint Education Trust. 2001. SAILI Project: Grade 3 and Grade 6 Learner Assessment Study 2001. Johannesburg: Joint Education Trust.

Marshall, J. and White, K. 2001. Academic achievement, school attendance and teacher quality in Honduras: an empirical analysis. Unpublished preliminary draft, May.

McDonnell, L. 1995. Opportunity-to-learn as a research concept and policy instrument. *Educational Evaluation and Policy Analysis*, 17(3): pp.305-322.

National Department of Education. 2002a. Revised National Curriculum Statement Grades R to 9 (Schools) Policy. Pretoria: Department of Education.

National Department of Education. 2002b. Draft number 2 of the Mathematics Learning Programme Policy Guidelines. Pretoria: Department of Education.

National Department of Education. 2002c. Foundation Phase Systemic Evaluation (Mainstream): National Report. Pretoria: Department of Education.

National Department of Education. 1997a. Curriculum 2005 Foundation Phase (Grades 1-3) document. Pretoria: Department of Education.

National Department of Education. 1997b. Curriculum 2005 Intermediate Phase (Grades 4-6) document. Pretoria: Department of Education.

National Department of Education. 1997c. Curriculum 2005 Senior Phase (Grades 7-9) document. Pretoria: Department of Education.

Pelgrum, W. 1989. Educational Assessment: Monitoring, Evaluation and the Curriculum. Published PhD dissertation presented to the Department of Education University of Twente, Enschede, the Netherlands. De Lier: Academish Boeken Centrum.

Porter A. and Smithson, J. 2001. Are content standards being implemented in the classroom? A methodology and some tentative snswers. In Fuhrman, S. (Ed.). *From capitol to the classroom: standards-based reform in the States*. National Society for the Study of Education: University of Chicago, pp.60-80.

Reeves C. 2005. The effect of 'Opportunity-to-Learn' and classroom pedagogy on mathematics achievement in schools serving low socio-economic status communities in the Cape Peninsula. Unpublished PhD thesis presented to the School of Education, Faculty of Humanities in February. Cape Town: University of Cape Town.

Rose, D. 2004. Sequencing and pacing of the hidden curriculum: how Indigenous learners are left out of the chain. In Muller, J., Davies, B. and Morais, A. (Eds). *Reading Bernstein, researching Bernstein*. London: RoutledgeFalmer, pp.91-107.

Rowan, B. 2002. Conceptual paper: what large-scale survey research tells us about teacher effects on student schievement: insights from the Prospects Study of Elementary Schools [online article]. Paper on the Consortium for Policy Research in Education, Study of Instructional Improvement website: Retrieved 1 November 2002 from the World Wide Web: http://www.cpre.org/Publications/ (A version of this paper can also be found on the University of Michigan website at http://www.sii.soe.umich.edu/LargeScaleSurveyResearch.pdf)

Schmidt, W., McKnight, C., Valverde, G., Houang, R., Wiley, D. 1997. *Many visions, many aims: volume 1, a cross-national exploration of curricular intentions in school mathematics*. Dordrecht, Netherlands: Kluwer Academic Publishers.

Seekings, J. 2001. Making an informed investment: improving the value of public expenditure in primary and secondary schooling in South Africa. Report to the Parliament of South Africa, commissioned by the Standing Committee on Public Accounts.

Shavelson, R.J., McDonnell, L.M., and Oakes, J (Eds). 1989. *Indicators for monitoring mathematics and science education.* Santa Monica, CA:RAND

Smith, T. 2004. Pupils not making the grade. *Cape Argus,* Wednesday 26 May: p.9.

Smith, J.B., Smith B. and Bryk A.S. 1998. Setting the pace: opportunities to learn in Chicago public elementary schools. Consortium on Chicago School Research Report [online article]. Retrieved 1 October, 2001, from the World Wide Web: http://www.consortium-chicago.org/publications/pdfs/p0d04.pdf

Stevens, F. 1996. Opportunity to learn science: connecting research knowledge to classroom practices. *Journal of Teacher Education,* 48(3): pp.222-232 [online article]. Retrieved 3 August 2001 from the World Wide Web: http://www.temple.edu/LSS/ lsspub966.htm

Stevens, F. nd. Teacher evaluation of the sustainability of Opportunity-to-Learn assessment strategies. ERIC Clearinghouse on Urban Education. Retrieved 2 August 2001 from the World Wide:http://eric-web.tc.columbia.edu/teachers/teachereva/#burstein1989

Taylor, N. 1999. Curriculum 2005: finding a balance between school and everyday knowledges. In Taylor, N. and Vinjevold, P. (Eds). *Getting learning right: report of the President's Education Initiative*. Johannesburg: Joint Education Trust. pp.205-130.

Taylor, N. and Vinjevold, P. (Eds). 1999. *Getting learning right: report of the President's Education Initiative*. Johannesburg: Joint Education Trust.

Taylor, N., Muller, J. and Vinjevold, P. 2003. *Getting schools working: research and systemic school reform in South Africa.* Cape Town: Maskew Miller Longman/Pearson Education South Africa.

Thompson, D. and Senk, S. 2001. The effects of curriculum on achievement in second-year algebra. *Journal for Research in Mathematics Education,* 32(1): pp.58-84.

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