Audit of mathematics curriculum policy across 12 jurisdictions

Commissioned Report

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NCCA

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Executive Summary

A Summary of Key Findings

- It is now timely to review and revise our mathematics curriculum.
- Our curriculum structure and banding arrangements are typical of international curricula.
- Ireland's current five mathematical strands are typical of international curricula.
- By international comparisons, Ireland has a limited range of contemporary curriculum supports.
- Ireland lags behind other countries in their articulation of attainment expectations and provision of illustrative work samples/exemplars.

Mathematics Curricula around the world, have recently undergone substantial revisions, and improvements. These revisions take account of new emphases in mathematics education and assessment – it is now timely for NCCA to take account of the changed educational landscape and begin a review of our current primary mathematics curriculum.

A positive starting point for our 1999 Mathematics Curriculum is the homogeneity between our curriculum structure and banding arrangements, when compared to those of other high-achieving mathematics curricula. Ireland's year by year system of progression in mathematics learning, has obvious benefits when it comes to the provision of more age appropriate content, and facilitation of year on year longitudinal assessment.

Similar to Ireland, a 'Strand-based' structure is evident in the vast majority of curricula. When considering the content of our five curricular strands, and contrasting with those of our neighbours, there is considerable uniformity in terms of what we teach: *Number*, *Measures*, *Geometry* and *Data* can be considered ubiquitous across all jurisdictions. Whilst Ireland specifies *Algebra* as a distinct strand, many other countries choose to integrate it with *Number*. Some countries have chosen to specify particular non-content strands. These strands are typically aimed at prioritising much vaunted higher-order thinking skills amongst pupils, and can certainly be seen as significant contributors to increased levels of attainment in these countries. Such higher order skills are specifically addressed in our own Mathematics Curriculum through the promotion of the six core skills: *Reasoning; Integrating & Connecting; Communicating and Expressing; Implementing; Understanding and Recalling; and Problem-Solving.*

Whilst NCCA and the PDST (Professional Development Service for Teachers) have delivered a huge amount of curriculum supports for teachers to help implement all aspects of the curriculum effectively, Ireland still has some ground to make up. Encouragingly, the sheer scale and variety of international supports available gives us much good practice that we can learn from, some examples include: focused resource hubs and dedicated on-line libraries, teacher video demonstrations, detailed assessment guidance and exemplars, research and relevant industry connections linking in to mathematics teaching at all levels, and finally, state-sponsored teacher networking/learning communities.

One of the main strengths of our existing Mathematics curriculum is the succinct articulation of content objectives at each of the eight class levels, for each of the five curricular strands. As a further aid to enhanced assessment techniques, the articulation of specific observable learning outcomes, or *Expectations*, is now considered a key component of effective curriculum design. In some cases, these *Expectations* are combined with useful assessment rubrics and adjoining curricular manuals to allow for detailed judgements about the varying abilities of pupils.

This audit reveals the comparative strength of our current mathematics curriculum and the relative homogeneity with other high performing education systems, while simultaneously highlighting possible directions for future amendments. We should not hesitate in combining the best of both aspects - this is the balancing act for future curriculum designers.

Introduction

This paper is a reflective commentary based upon the author's desk-top audit of twelve international primary school mathematics curricula, and a further amalgamated curriculum framework from the United States referred to as the *Common Core State Standards for Mathematics*. It attempts to identify examples of contemporary and innovative curriculum design, including structural and content components, associated teacher supports, and finally, instruments for standards, assessment and planning in classrooms. Points of discussion attempt to compare international trends with current curricular elements in the Irish context, and point towards possible future directions for consideration by the National Council for Curriculum and Assessment.

A broad range of countries were chosen by the NCCA for inclusion in the audit, each with a particular attraction: neighbouring British systems due to their obvious cultural similarities, Scandinavian and other European Nations owing to their traditionally strong showing in international mathematics assessment programmes, North American curricula incorporating their strong emphasis on research-driven approaches, and finally Pacific and Asian countries who appear to continue to maximise attainment whilst exploiting more traditional curriculum content and teaching emphases. Primary school curricula from each of the chosen countries were examined individually under three distinct headings: *Curriculum Structure, Curriculum Content and Supports,* and *Assessment and Standards*. This was followed by an analysis phase which sought to identify common trends, and also to pinpoint unique and exceptional innovation. This analysis forms the bedrock of the paper.

The need for curriculum content to keep pace with the rapid advances in mathematics education is acknowledged by the glut of recently revised or redrawn curriculum statements – all such documents date from the mid or late part of the last decade **(see Table 1)**. Curricula revisions in neighbouring British Isle education systems, more so than others, demonstrate that it is now timely for Ireland to review its primary mathematics curriculum – Northern Ireland (2007), Wales (2008), Scotland (2010) and presently, England (2014). This imperative is further strengthened by the innovative inclusion of mathematically significant skills within the themes of *Exploring and Thinking*, and *Communicating* in *Aistear: the Early Childhood Framework* (2009). This new approach to addressing curriculum content through interconnected themes, provides food for thought for future primary curriculum revisions.

Table 1: Implementation Dates for Selected Mathematics Curricula

Year of Implementation	Jurisdiction
2002	Hong Kong S.A.R.
2004	Finland
2005	Ontario
2006	The Netherlands
2007	Northern Ireland, New Zealand
2008	Wales
2010	Scotland, Common Core Standards
2011	Queensland, Massachusetts
2013	Singapore
2014	England

Curriculum structure

The imperative for curriculum authors to organise content in a logical, coherent and accessible manner is a key challenge. The structure of curricula is typically understood to be the headings of content categories which set out the desired knowledge, understandings, capacities and dispositions of the particular discipline. There is a surprising homogeneity across most curricula studied in the structure (and organisers) exploited **(see Table 2)**. With the exception of the Netherlands, which opts for a number of general *Core Objectives*, most curricula deviate little from the current over-arching "strand-based" Irish structure; both Australia and Scotland have a minimalist 3-strand framework, whilst at the opposing end of the range, the new English document specifies six "*Programme of Study*" elements. Many systems elaborate upon these broad domains with an extensive array of strand sub-divisors: Northern Ireland and Ontario clearly demonstrate that such divisors can often over-complicate an initially simple structure; the writer found such curricula difficult to navigate and suggests that this would pose challenges for an integrated approach to the planning and teaching of mathematics. In terms of presentation, the audit reveals that most countries (including the most-recent revisions) still prefer to specify content (and content objectives) on a year-(grade)-by-year basis (as is the case in Ireland). However, there are some notable exceptions: the obvious multi-year *Key-Stage* structure of British systems, and, New Zealand's unique flexibility, which attempts to pace its pupils through the content at a rate that best meets their needs and capacities. This flexibility is evidenced by a continuum ranging from targeted special education provision in mainstream settings, through to culturally-proofed mathematics curriculum content, and cumulating in the availability of accelerated learning programmes[1] for high achievers in numeracy. Of particular interest to an Irish audience is the fact that the newly revised Mathematics Curriculum in England has lessened the influence of defined Key Stages, instead opting for a more fluid path of progression for pupils.

Table 2: Curriculum Structure & Banding (Excludes Infant/Foundation Band as part of primary education unless specified)

Jurisdiction	Number of Bands	Total Duration	Composition	Primary School Starting Age
England	2	6 years	2+4	5
Finland	3	6 years	2+3+1	7
Hong Kong S.A.R.	6	6 years	1 Year per Band	6

[1] http://nzcurriculum.tki.org.nz/System-of-support/School-initiated-supports/PfS

Jurisdiction	Number of Bands	Total Duration	Composition	Primary School Starting Age
Massachusetts	8	8 years	1 Year per Band	6
New Zealand	4	8 years	2+2+2+2 (May Vary)	5
Northern Ireland	3*	7 years	2+2+3	4/5
The Netherlands	2*	8 years	2+6	4
Ontario	8	8 years	1 Year per Band	6
Queensland/***	2*	8 years	1+7	5
Scotland	3*	8 years	2+3+3	5
Singapore	6	6 years	1 Year per Band	6/7
Wales	2*	7 years	3+4	5

* (incl. specified Foundation Stage)

** (In Queensland, the curriculum structure is particular to Mathematics)

*** (In Queensland, unlike the remainder of Australia, 7th Grade is considered a primary school grade)

1. Content strands

Number is omni-present across all systems, although seven jurisdictions elect to combine it with a related domain, typically *Number & Algebra*, as evidenced by Singapore, New Zealand, and Australia. This sets an interesting contrast with the very distinct and separate strands of Number and Algebra, which is a feature of the Irish system. This does raise the issue of whether or not the Irish approach helps or hinders integration within mathematics content itself – (an area examined further on page 14). Finland has combined *Number* with the execution of calculation skills, thus creating a clear inter-dependence between the two: *Number & Calculations*. The 2010 Scottish framework infuses an element of real-world application; *Number, Money & Measures*. Its Curriculum Support Section builds upon this integrated approach across the various exemplars it provides, thus giving strong emphasis to the fact that numeric competency is important because of its real-world applications. *Geometry, Measures and Data*, in one guise or another, are present across all twelve curricula (see Table 3). This is even true in the aforementioned Dutch Core Objectives which, upon closer examination, do have considerable similarities in content when compared to the more traditional "Strand" or "Unit of Work" structure, despite their unusual presentation.

Table 3: Key Content Areas

Content Area	Number of Curricula that include this content area (out of 13)
Number	All
Measures	All
Geometry	All
Algebra (as a stand-alone)	9
Data Handling/Statistics	12
Processes in Mathematics	5
Other additional areas such as Early Mathematical Activities	2

2. A differentiated structure

A notable trend in the more recent curriculum statements (2005 onwards, including the newly published Mathematics Curriculum in England) is the movement towards a differentiated curriculum structure as children progress from pre-school through to upper-primary level. Wales has taken the recent step of re-designing its early childhood phase (*Foundation Level*) into a stand-alone (mathematics) syllabus that seeks to address the learning needs of children at that specific stage of their lives and development, not solely with the objective of building skills that will be applied sometime in the future. It should be noted that Ireland's early childhood curriculum framework, *Aistear* compares favourably in this regard – it's thematic approach and integration of play as a key teaching and learning approach, allows for the early development of mathematically significant competencies such as understanding the meaning and use of numbers, and building a sense of time and other measures. Less ambitiously, but in a similar vein, The United States' *Common Core Standards*, Ontario's Curricular Framework and the newly rolled-out English Mathematics Syllabus all tailor the content domains to particular age groups – interestingly, whilst New Zealand exploits a 3-strand structure for all elementary grades, it is the only one of the twelve nations to specify clear recommendations on what percentage of instructional time should be devoted to some strands, principally *Number*. This recommended time for number decreases as children progress beyond 4th grade, and again at 7th grade and upwards. Hong Kong also makes similar suggestions to teachers but such recommendations do not seem to be key features of more recent teacher support documentation from this country. It would appear that the vast majority of countries, despite their universal mandating of curriculum content, do provide local autonomy to allow schools adjust internal subject time allocations as they see fit to meet pupils' mathematical needs. With a recently increased mathematics (but not internal) time allocation, Ireland plots a middle ground that is in keeping with a minority such as Ontario, Singapore and Finland.

3. Process strands

A final feature of innovative curriculum structure noteworthy of mention is the inclusion of non-content specific focused strands: Singapore's *Mathematical Processes* strand, Finland's *Thinking Skills* domain, The Netherlands' *Mathematical Insight (and Operations)* objective, and although a feature of the now obsolete 1999 Mathematics Curriculum, England's *Using and Applying Mathematics* content areas are all appealing as they allow the teacher to present mathematics as a method of enquiry, an instrument for application, not just a series of procedural competencies underpinned by vast reams of mathematical theory. Other typical components employed by various curriculum-design agencies to broaden the curricular appeal of mathematics include the use of *Standards for Mathematical Practice* (e.g. Construct Viable Arguments and Critique the Reasoning of Others - Common Core Standards), *Core Aims* (e.g. Reason Mathematically – Wales) and *Mathematical Processes* (e.g. Reasoning and Proving - Ontario). Use of verbs such as those highlighted contrast with the rather theory-laden and unattractive presentation of Ontario, Northern Ireland and Hong Kong. Ireland's current dual emphasis on *Skills Development* and *Content Objectives* would appear to compare quite favourably in this regard. In addition, the *Aistear* framework, although thematically-based, does in a manner continue this trend by use of broad over-arching *Aims*, supplemented by more specific *Learning Goals* that encompass specific skills and dispositions.

Curriculum content and supports

The sheer scale of curriculum supports across the international spectrum is awesome – online resource hubs (e.g. England and Northern Ireland), dedicated *i-Tunes* and digital television channels (e.g. Hong Kong, Wales and Australia), discussion forums (such as in Scotland), time-efficient curriculum planning tools (e.g. New Zealand and Australia) and professional learning portals (e.g. Ontario and Massachusetts) all underscore our digital age (see Table 4). Ontario[2] is one of the few systems to furnish video footage of real teachers teaching in real classrooms – the short clips give a realistic basis to the content, and provide a more appealing option for educators searching for new lesson ideas. Interestingly, Massachusetts and New Zealand (along with Ontario) are among a small number who provide online and face-to-face supports to teachers who require content-specific upskilling that seeks to build competence and confidence in using mathematics. The audit revealed a noticeable dearth of mathematical language promotion supports. Although virtually all curriculum documents extol the benefits of developing such a competency, it is again only Ontario that provides supports to enhance "Math-Talk" in primary schools. Most national systems provide a recommended glossary of mathematical terms for pupil and/or teacher use, but the presentation is often remote and detached from the objectives of the syllabus, thus giving the impression of being a mere after-thought. In the case of the new Mathematics Curriculum in England, one suspects that the currently small number of teacher resources will be supplemented handsomely as full implementation is reached in 2016.

Table 4: Range of Teaching Supports Available* per Curriculum

Explanatory Legend**: R.H.:** Resource Hubs/Search Tools, **A.V.:** Audio-Visual Demonstrations, **CSAA:** Curriculum Support Agency Aids, **AG:** Assessment Guidance, **R/IL:** Research/Industry Links, **TNO**: Teacher Networking Opportunities

(*An empty cell merely denotes that such resources were not apparent during the audit, but may exist elsewhere or may have been subsequently added)

	RH	**AV**	**CSAA**	**AG**	**R/IL**	**TNO**
England	✓	✓	✓	✓	✓	✓
Finland			✓	✓	✓	✓
Hong Kong S.A.R.	✓	✓	✓	✓	✓	
Massachusetts/Common Core Standards	✓	✓	✓	✓		✓

[2] http://www.eworkshop.on.ca/edu/core.cfm

	RH	AV	CSAA	AG	R/IL	TNO
New Zealand	✓		✓	✓	✓	✓
The Netherlands	✓	✓	✓	✓		✓
Ontario	✓	✓	✓	✓	✓	✓
Queensland	✓	✓	✓	✓	✓	✓
Scotland	✓		✓	✓		✓
Singapore	✓	✓	✓		✓	✓
Wales	✓	✓	✓	✓		

4. Mathematics in immersion settings

Supports for mathematics teaching and learning in immersion settings ranged from generalised references to non-native language learners (such as Massachusetts), to the availability of translations of curriculum-support materials (such as Northern Ireland and Scotland to an extent), with culturally-proofed native language curricula (such as New Zealand) at the other end of the spectrum. A closer analysis of the immersion supports in Wales, due to its obvious similarity with Ireland, revealed a rather ad-hoc collection of Welsh-medium supports (including textbooks, websites, official reports, Dept. of Education support documents and resource hubs) that were quite scatter-gunned in addressing the content objectives of the curriculum. It appeared to this writer that the provision of outdated and predominantly textbook-based supports clearly preceded the revised curriculum drafting process in Wales, and therefore congruence between the two is not evident. For Ireland, real-time development of áiseanna as Gaeilge will be vital to ensure their relevance to the emerging content objectives, and the contemporary needs of teachers.

5. Integration

Integration supports in curriculum handbooks rarely exceed aspirational statements on the importance of integrating mathematics with other subjects. The provision of exemplars, which are typically presented as stand-alone and disjointed case-studies of classroom practice, appear in at least ten of the countries, but are exclusively cross-curricular. The Welsh Curriculum emerges as perhaps the most comprehensive supporter of integrated planning and learning with its *Numeracy and Literacy framework* providing a context (and coherent rationale) for the many exemplars and suggestions it makes. As noted in the 'Assessment and standards' portion of the audit, Northern Ireland's solitary cross-curricular skill of *Using*

Mathematics suggests a similar approach is gaining traction in other parts of the United Kingdom.

6. ICT supports

In general, ICT supports are confined to websites that provide a multitude of digital resources and lesson enrichment activities, many with interactive and feedback capacity. Both Hong Kong and the Netherlands are amongst a very small minority that still provide software downloads for teachers. Websites and applications built upon a gaming concept, but related to curriculum content, emerge as being particularly contemporary; Scotland, in particular, is pioneering this field. In fact, the sheer variety of web-links can be off-putting and curriculum agencies that recommend a small selection of carefully chosen websites (with brief descriptions) do seem to strike a better balance. Entry-restricted online portals (such as *Scootle* in Australia, *iShare* in Singapore, *GLOW* in Scotland, along with the publicly accessible Dutch *WIKI-Wiskunde* Reference Library and *Smart Classrooms* in Queensland) provide gateways to vast arrays of classified digital aids that are devised, rated and recommended by teachers for teachers. The oversight of regulatory committees ensure that the content is appropriate and educationally sound. However, no country appears to have satisfactorily organised its recommended digital resources in line with its grade and strand structure – this makes trawling through dozens of websites very time-consuming for the teacher who is trying to address a very specific need. Encouragingly, the audit revealed that Massachusetts[3] has just begun a "Grade by Grade" guide to its available digital resources for mathematics. Finally, Finland is noteworthy for its provision of high quality ICT supports for mathematics teaching of special needs pupils.

[3] http://www.ixl.com/standards/massachusetts/math

Assessment and standards

The assessment and standards strand of this audit best illustrates how Ireland has fallen behind its international partners: with the exception of Singapore, all countries articulate clear expectations for children's mathematical learning at set points in their schooling (see Table 5). This is also true for countries which exploit a state-wide formal mathematics assessment programme (such as Northern Ireland and The Netherlands). Whilst there is obvious variation in the terminology and frameworks used, most countries have opted for "*Can Do*" statements that are built upon clearly identifiable skills, competencies, and in some cases, attitudes. Scotland's framework details skills and competencies written in the first person (e.g. *I have explored…*) – this sets a very striking contrast with other systems who favour a formal teacher imposed-judgement. The Scottish emphasis is clearly an attempt to formalise and strengthen self-assessment capacity.

The "set points" for cataloguing the child's development typically correspond to each grade level, however the *Attainment Target Levels* (used in England and in Wales to an extent) do provide a degree of flexibility to accommodate learners who may be performing above or below the expected norm for their grade (age) level. The *Common Core Standards*[4,] which themselves originated from an imperative to devise shared expectations of pupil progress, present their content in two separate styles: a grade-by-grade approach similar to the Irish documents, but alternatively via detailed descriptions of content in the eleven elementary school mathematical "domains". The later style of presentation is particularly useful for maximising integration within the mathematics curriculum. Finland has chosen to carry out their "assessments" at three specified points in a child's elementary schooling; at the conclusion of Grades 2, 5 & 8. Paradoxically, the previously lauded curricular content flexibility evident in New Zealand does not carry through to its rigid grade-by-grade, strand-by-strand application of its *Maths Standards*. Ontario's Achievement Charts[5] are supplemented by fully expanded user-friendly descriptors (*Limited – Some – Considerable – Thorough*) to allow teachers make more specific judgements about their pupils. Australia[6] uses a more simplistic, yet equally effective, *Above/Below & Satisfactory* rubric. Based on the audit, this paper sees a substantial benefit in exploiting some form of "Expectation Framework" to offset the

[4] http://www.corestandards.org/Math
[5] http://www.edu.gov.on.ca/eng/curriculum/elementary/math18curr.pdf
[6] http://www.australiancurriculum.edu.au/Mathematics/Achievement-standards

growing school and parental fixation with standardised test scores, and their inadequacy in providing a holistic overview of a child's mathematical development.

7. Examples of children's work

As an aid to teachers in exploiting such "Expectation Frameworks", the provision of work samples is considerable, if not completely widespread. However, there is much variation in their value for two key reasons. Firstly, exemplars of pupils' work are provided that bear no relationships to the framework that is set out by the very same curriculum document (e.g. Northern Ireland). Such exemplars only serve to provide ad-hoc and ultimately inapplicable snatches of insight. Secondly, work samples and judgements are provided but without a commentary piece that allows the teacher explore a rationale, and benchmark their own thought-process against best practice. These detractions do not account for countries that undermine a solid "Expectation Framework" by the complete non-provision of pupil work samples (e.g. Finland and England, as of now). Best practice in this key curriculum component is provided by The Netherlands ("*The Calculator Line"* [7] - an excellent interactive tool that is attractive and beneficial in visually reinforcing the concept of a continuum of improvement and skill acquisition), and by Australia and Ontario whose guidelines and work samples are eminently transferable to the busy classroom setting. More specifically the Canadian exemplars, organised on a per grade basis, demonstrate the value of carefully chosen tasks from a range of strands, demonstrating a realistic range of mastery in the pupil responses annotated, and, providing clear guidance for teachers when applying a succinct "Expectation Framework".

Table 5: Articulation of Learning Expectations & Inclusion of Work Samples

	Inclusion of Expectations	Expectations expressed via	Inclusion of Work Samples
England	Yes	*Attainment Target Level Descriptors* in the relevant *Programme of Study*	No
Finland	Yes	*Description of Good Performance* for each *Core Content* area	No
Hong Kong S.A.R.	Yes	*Basic Competencies Framework*	No
Massachusetts/Common Core Standards	Yes	*Standards Framework*	Yes
New Zealand	Yes	*Maths Standards*	Yes

[7] http://www.fi.uu.nl/rekenlijn/

	Inclusion of Expectations	**Expectations expressed via**	**Inclusion of Work Samples**
Northern Ireland	Yes	The specified skill of *Using Mathematics*	No
The Netherlands	Yes	*Reference Levels for Mathematics*	Yes
Ontario	Yes	*Achievement Charts for Mathematics*	Yes
Queensland	Yes	*Achievement Standards*	Yes
Scotland	Yes	*Experiences & Outcomes* Framework	No
Singapore	No	n/a	No
Wales	Yes	*Attainment Target Level* Descriptors	Yes

Concluding remarks

This audit has highlighted international trends in curriculum policy across twelve countries, and one further amalgamated framework from the Unites States. It has highlighted similarities and differences between Ireland's current primary mathematics curriculum, and that of many countries that have undertaken recent revisions. It is now timely for Ireland to undertake an extensive review of its mathematics curriculum: a positive starting point is the apparently similar curriculum content of many countries whose students consistently achieve to very high standards on international assessments (Hong Kong, Singapore and Finland). However, content is only one component of modern curricular provision: this paper clearly demonstrates the equal importance of curriculum supports, and assessment and standards mechanisms. On the basis of this audit, both of these components require significant research and development in order to keep pace with international best practice. More specifically, the provision of resources to assist in curriculum implementation in Ireland will have to take account of the digital and new-media age we now live in; the notion that a once-off publication of a "Teachers' Guidelines" document can match the longevity of the curriculum is itself outdated. The ability of web sources to constantly update, expand and virtually "put" us into the classroom of other teachers makes it an obvious conduit for teacher support. The provision of clear and applicable "Expectation Frameworks" illustrated and bolstered by carefully chosen pupil work samples is now an accepted component of primary mathematics curricula internationally – this represents the biggest challenge, and opportunity, for Ireland's policy makers and curriculum designers.

It is also important to acknowledge obvious limitations of the audit; the sample of countries chosen is relatively small and could not possibly take account of "emerging" curricula that are showing significant improvements in TIMSS and other international assessment programmes, albeit if from a low base (such as Slovakia and Portugal). Secondly, the centralised nature (and mandated-curricular dependence) of the Irish system does reveal a unique cultural identity that no other nation fully mirrors in all aspects. Thirdly, although many of the nations studied could be considered at least bilingual, the availability of materials in the English language was not always guaranteed, thus depriving this desktop audit of potentially key data. The Netherlands exemplifies this obstacle. In a related point, restricted access to various on-line resource and "Learning Community" portals (such as in Scotland and Australia) did minimise the scope of available material. Finally, the voice of the teacher, the implementer at the coalface, is absent from the paper. The view of educators in the high-achieving Asian countries, for example, could assist in providing some insight into the considerable and sustained success of seemingly orthodox and common-place syllabi. The success or otherwise of any curriculum, including the applicability of its various components and supports, is determined by the experiences of the teacher in his/her classroom; policy-makers should consider how this vital perspective can be accessed.

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www.corestandards.org/Math/Practice/

Url links to mathematics curricula included in the audit are provided as footnotes throughout the report.