Comparison of the Learning Expectations for School Mathematics across Several Asian Countries and U.S. States

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Abstract

This study analyzes learning expectations in grade 1-8 mathematics across several U.S. states and high performing TIMSS Asian countries, including Singapore, Taiwan and Japan. In order to narrow and focus the investigation, only one topic within the strands is reported. Based on the official curriculum documents, results of this study indicate that the mathematics content, grade placement and cognitive level of learning expectations related to selected topic might vary markedly across documents. This variability in learning expectations results in striking differences in students' opportunity to learn.

Key words: learning expectation, opportunity to learn, TIMSS.

Study Purpose

This study examines one topic within the strands in the official documents. More specifically, this study addresses the following research question:

"*To what extent and in what ways are learning expectations associated with one topic such as area/volume in the measurement strand similar or different in emphasis and grade placement in some Asian countries and U.S. states as described in their official mathematics curriculum documents?*"

This analysis may partially explain differences in performance among students in several countries and states, particularly if the intended curriculum is an important contributor to what students have an opportunity to learn.

Educational Significance

International studies of mathematics and science achievement have consistently reported that students in Asian countries such as Singapore, Taiwan and Japan demonstrate higher levels of mathematics achievement than students in the United States(Mullis et al., 2004; Wilson & Blank, 1999). Although the reasons are complex, educators generally agree that opportunity to learn (OTL) is a contributing, if not major, factor. Floden (2002) argued that "If OTL is not taken into account, its effect may be mistakenly attributed to some other attributes of the educational system."

The Third International Mathematics and Science Study (TIMSS) used a model called Potential Educational Experience (See Figure 1, Schmidt et al., 1997) to capture different aspects of how educational opportunities are shaped and how they are potentially related. In this model, national/regional curriculum goals at the system level represent the intended curriculum which contains what students are expected to learn. However, little is known about how the curricula described in the official documents differ from state or Asian country curriculum frameworks.

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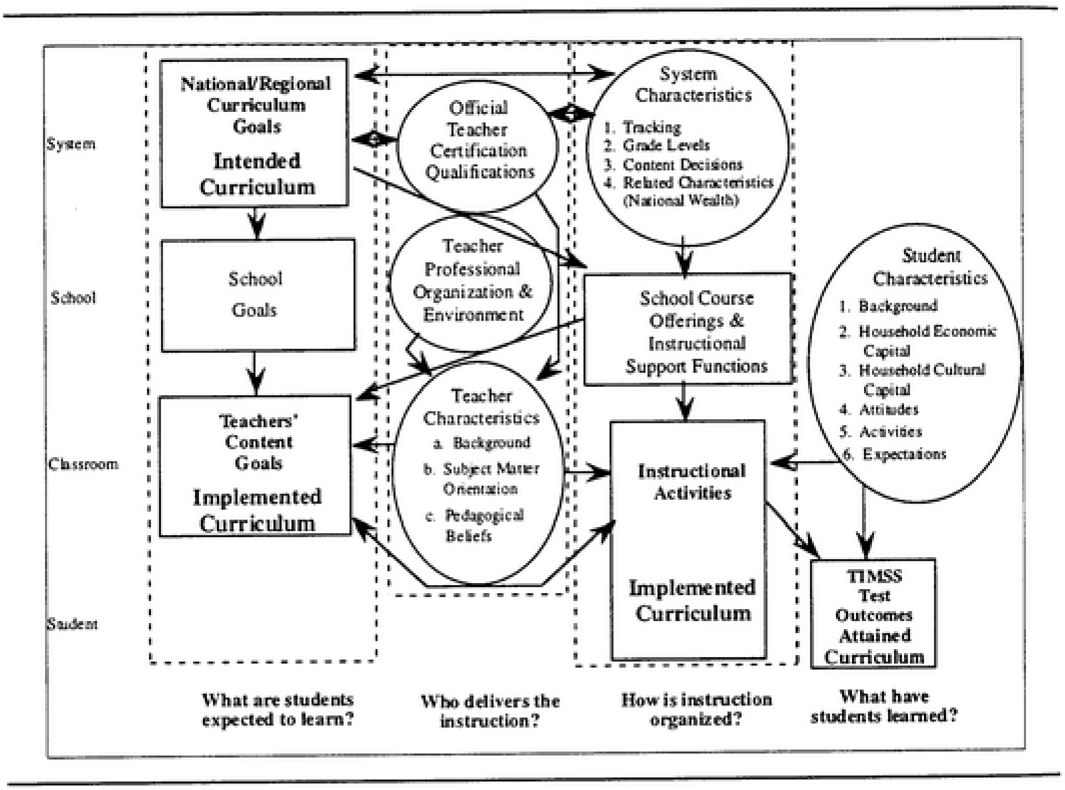

Figure 1: The Model of Potential Educational Experiences.

Source Documents

The primary data sources for this study are the state or country official mathematics curriculum frameworks. These include the following documents:

Singapore: *Primary Mathematics Syllabus* and *Lower Secondary Mathematics Syllabus* (Implemented from 2001).

Taiwan: *Mathematics Curriculum Guidelines for Grade 1 to Grade 9* (Published in 2003).

Japan: *Mathematics Program in Japan* (including Elementary, Lower Secondary & Upper Secondary Schools) (Published in 2000).

Minnesota: *Minnesota Academic Standards in Mathematics K-12* (Published in 2003).

Missouri: *Mathematics Grade-Level Expectations* (Published in 2004).

California: *The California Mathematics Content Standards* (Published in 2000).

In addition, k-8 mathematics expectations developed by Achieve were also reviewed because they represent a new proposal for curricular emphases by an independent national organization which was created by governors and corporate leaders in 1996 to help raise states' standards and student performance.

Achieve: *Mathematics Achievement Partnership (MAP) K-8 Mathematics Expectations* (Published in 2004).

National documents, such as the *Principles and Standards for School Mathematics* (NCTM, 2000), identify some content strands, such as number, algebra, geometry, measurement, and data analysis and probability. Table 1 illustrates how these strands are reflected in the various documents that were analyzed in this study. This table briefly summarizes the organization of curriculum frameworks.

Table 1: Summary of Strand Organization in Curriculum Standards.

Country/State	Year	Grades	Strands
Taiwan	2003	Grade 1, 3, 4, 5, 6	Number & Quantity; Geometry; Algebra; Statistics & Probability.
		Grade 2, 8	Number & Quantity; Geometry; Algebra.
		Grade 7	Number & Quantity; Algebra.
Japan	2000	Grade 1- Grade 6	Number and Calculations; Quantities and Measurement; Geometrical Figures; Math Relation.
		Lower Secondary 1 & 2	Numbers & Algebraic Expressions; Geometrical Figures; Math Relations.
Singapore*	2001	Grades 1-5	Whole Number
		Grades 1-8	Measurement, Statistics, Geometry
		Grades 2-5	Fractions
		Grades 3-5	Decimals
		Grades 6-8	Algebra
Minnesota	2003	Grade 1 - Grade 8	Mathematical Reasoning; Number Sense & Computation and Operations; Patterns & Functions, and Algebra; Data Analysis & Statistics, and Probability; Spatial Sense & Geometry, and Measurement.
Missouri	2004	Grade 1 - Grade 8	Number and Operations; Algebraic Relation; Measurement; Data & Prob.
California	2000	Grade 1 - Grade 7, Grade 8-12**	Number Sense; Algebra and Functions; Measurement and Geometry; Statistics & Data Analysis, and Probability; Math Reasoning.
Achieve, Inc.	2004	Grade K - Grade 8	Algebra; Data & Measurement; Geometry; Number & Operations.

*Other strands are emphasized in the Singapore framework on one or two grades levels. These include: Ratio/proportion, percentage, problem solving and trigonometry.

**Note that a Geometry course is also provided in Grade 8~12.

In addition to differing by strand organization, the “grain size” of level of specificity of the statements of learning expectations also differ. This can be illustrated, in part, by examining the number of learning expectations related to measurement at each grade in the documents. The following Table 2 summarizes the number of learning expectations related to measurement, by grade, in each of the documents analyzed.

Table 2: Number of learning expectations within the measurement strand of each document by grade.

Grade	1	2	3	4	5	6	7	8	Total
Singapore*	1	3	11	9	5	5	4	5	43
Taiwan	2	5	7	5	6	3	0	0	28
Japan	2	2	6	5	2	5	0	0	22
Minnesota	4	5	6	3	3	3	1	2	27
Missouri	4	4	5	7	5	6	7	5	43
California**	6	7	10	15	7	6	13	-	64
Achieve	10	19	10	8	4	0	0	2	53
Total	29	45	55	52	32	28	25	14	280

*The number of learning expectations from Singapore EM1/EM2 and Special/Express stream.

**California counts Geometry & Measurement strands together.

-The CA document includes learning expectations at grades 1-7.

Methodology

The selection of countries for this study was based on the performance on the TIMSS assessment. The selection of U.S. states was based on student performance on the NAEP-2000 (Kloosterman & Lester, 2004) assessment and on the evaluation of official state curriculum documents by the Fordham Foundation. Measurement was selected for analysis because U.S. students perform relatively poorly on items related to this strand, compared to students in other countries and compared to their performance on other strands of mathematics.

A coding system was developed which consisted of the general categories: *Object, Action, Tools, and Cognitive Domain.* For each learning expectation (LE) in the selected topic of the curriculum documents, the following information was coded:

- Object-the main noun(s) in the learning expectation.
- Action-the main verb(s) in the learning expectation.
- Tools-equipment specified for use within the learning expectation.
- Cognitive Domain-identification of cognitive level of learning expectation based on the *Survey of Enacted Curriculum* protocol (CCSSO, 1999), see Table 3.

Table 3: Cognitive level of learning expectation

Level #	Main Goals
Leve 1	Memorize facts/definitions/formulas. • Recite basic mathematics. • Recall mathematics terms and definitions. • Recall formulas and procedures.
Level 2	Perform procedures. • Use numbers to count / order / denote.

	• Do computational procedures or algorithms. • Follow procedures / instructions. • Solve equations / formulas / routine word problems. • Organize or display data. • Read or produce graphs and tables. • Execute geometric constructions.
Level 3	Demonstrate understanding of mathematical ideas. • Communicate mathematical ideas. • Use representations to model mathematical ideas. • Explain findings and results from data analysis strategies. • Develop or explain relationships between concepts. • Show or explain relationships between models, diagrams and other representations.
Level 4	Conjecture / generalize / prove. • Determine the truth of a mathematical pattern or proposition. • Write formal or informal proofs. • Recognize / generate or create patterns. • Find a mathematical rule to generate a pattern or number sequence. • Find and investigate mathematical conjectures. • Identify faulty arguments or misrepresentations of data. • Reason inductively or deductively.
Level 5	Solve problems / make connections. • Apply and adapt a variety of appropriate strategies to solve problems. • Apply mathematics in contexts outside of mathematics. • Analyze data / recognize patterns. • Synthesize content and ideas from several sources.

A sample of how learning expectations were coded is provided in Table 4.

Table 4: Sample of coded learning expectations

Learning Expectation (LE)	Grade	Action	Object	Cognitive Demand	Tools
Pupils can understand the meaning that two triangles are congruent through construction with straightedge and compass. (Taiwan).	8	Understand	Congruent triangles	Level 3	Straightedge/ compass
Student will identify congruent and similar figures. (Minnesota).	4	Identify	Congruent and similar figures	Level 1	--
Solve problems involving surface areas and/or volume of a rectangular or triangular prism, or cylinder (MO).	8	Solve problems	Volume and surface area	Level 1,4	--

Find the volumes and surface areas of cubes, cuboids, prisms and cylinders.(Singapore).	7	Find	Volume and surface area	Level 2	

Analysis of the Learning Expectations

The general strategy for analysis was based on the "topic tracing" method developed by TIMSS researchers. That is, for each topic, all LEs related to that topic within each curriculum document (Singapore-SP, Taiwan-TW, Japan-JP, Minnesota-MN, Missouri-MO, California-CA, Achieve-AC) were identified and the following information was compiled:

- A description of the focus of the topic by grade level and document.
- The grade where the topic is intended to be first introduced to students.
- The range of grades during which instruction was intended to take place on the topic.
- Any grade for which the topic was to be a special emphasis.

<u>Summary of Content Related to "Area/perimeter and Volume/surface area"</u>

In all, 88 learning expectations related to "area/perimeter and volume/surface area" were identified across the seven documents.

The earliest LEs related to this topic appeared in grades 1 and 2:

> Compare the length, weight, and volume of two or more objects by using direct comparison or a nonstandard unit (California, grade 1).
>
> Pupils can recognize the "area" and make direct comparison (Taiwan, grade 2).
>
> Explore a variety of ways to measure perimeter/circumference (Achieve,Gr.2).

Sample LEs from grades 3-5 include:

> Pupils should be able to calculate the perimeter of a rectilinear figure in centimetres and in metres (Singapore, grade 3).
>
> Determine the perimeter of polygons (Missouri, grade 3).
>
> Measure the area of rectangular shapes by using appropriate units, such as square cm, square m, square km, square inch, square yard, or square mile (CA, grade 4).
>
> Pupils can understand the volume formulas of cubes and cuboids (Taiwan, G5).

Sample LEs from the middle grades include:

> To think about finding the volume of a cube or a rectangular parallelepiped, and to make use of them (Japan, grade 6).
>
> Pupils should be able to solve problems involving the perimeters and areas of squares, rectangles, triangles, parallelograms, trapeziums and circle(Singapore, grade7).
>
> Describe how to solve problems involving surface area and/or volume of a rectangular or triangular prism, or cylinder (Missouri, grade 8).

Figure 2 illustrates the number and grade distribution of the set of LEs related to perimeter, area, volume and surface area. As noted, the LEs span grades 1-8.

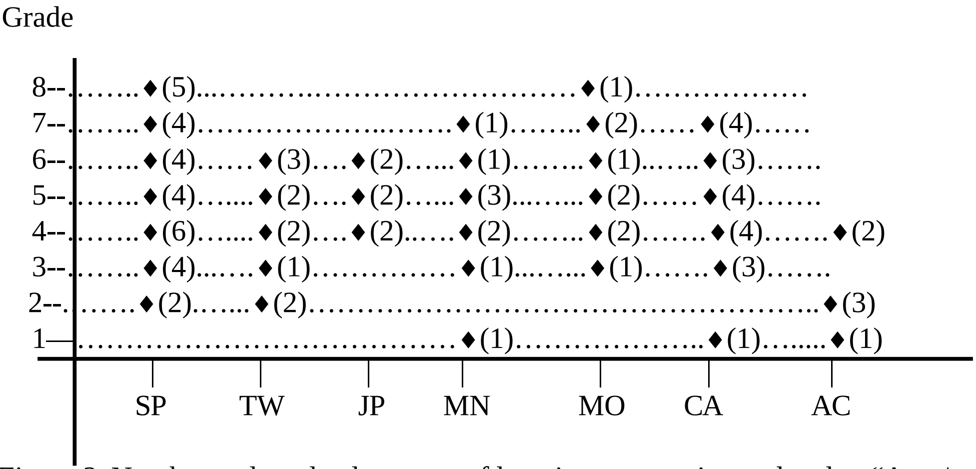

Figure 2: Number and grade placement of learning expectations related to "Area/perimeter and Volume/surface area" within Measurement strand.
(Remark: The number inside parentheses indicates the number of learning expectations).

Common learning expectations related to this topic include: measuring the perimeter and area of a rectangle/square and circle; measuring the area of a triangle; and measuring the volume and surface area of a cube/cuboid. Four common learning goals were noted within the set of LEs (see Table 5).

Table 5: Grade placement of common learning expectations related to the "area/perimeter and volume/surface area" topic.

Common Learning Expectation	SP	TW	JP	MN	MO	CA	AC
To find the area/perimeter of a rectangle/square	G3, G4	G4	G4	G6	G3, G4	G5	G2
To find the area of a triangle	G5	G5	G5	G5	G4	G5	-
To find the area/perimeter of a circle	G6	G6	G5	-	G7	G6	-
To find/realize the volume/surface area of a cube/ cuboid	G4	G5	G6	G5	-	G5	G4

Note: 1. G3 means the learning expectation is provided for Grade 3.
2. "-"represents no specific statement in the LEs.

Based on the analyses of the collected documents, Table 6 summarizes the grade at which the topic receives special emphasis. The term "special emphasis" indicates that the common learning expectations of this topic are addressed and that a substantial amount of time (in proportion to other topics from measurement) is devoted to the perimeter, area, volume and surface area. In general, attention to this topic is concentrated in Grades 4 - 7.

Table 6: Grades for special emphasis on "area/perimeter and volume/surface area" topic.

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8
Singapore			√	√	√	√	√	√
Taiwan		√		√	√	√		
Japan				√	√	√		
Minnesota				√	√			
Missouri				√	√		√	
California			√	√	√	√	√	
Achieve		√		√				

<u>Weight of Topic within Measurement Strand</u>

In order to gauge the relative emphasis (weight) of “area/perimeter and volume/surface area” within the measurement strand, Table 7 provides a summary of the number of learning expectations associated with this topic (See Figure 2), and the percent with respect to the total number of LEs within the Measurement strand. It shows Singapore has the highest percentage of LEs related to this topic within the Measurement strand.

Table7 : The Weight of topic-Area/perimeter and Volume/surface area.

	SP	TW	JP	MN	MO	CA	AC
Number of LEs	29	10	6	9	9	19	6
Percent of Total Mea. LEs	67.4%	35.7%	27.3%	33.3%	20.9%	*	10.3%

Remark: CA counts Geometry & Measurement strands together.

<u>Cognitive Level of Learning Expectations Related to Area/perimeter and Volume/surface area</u>

Recall that the cognitive level for each learning expectation was coded using the Survey of Enacted Curriculum (SEC) protocol (CCSSO, 1999), Table 8 provides a summary of the distribution of levels in cognitive demand.

Table 8: Number and Distribution of Level in Cognitive Domain for LEs related to “Area/perimeter and Volume/surface area” topic.

SEC Country/State	N	Memorize Fact, Def. & Formula	Perform Procedures	Demonstrate Understanding	Conjecture, Generalize & Prove	Solve Problems, Connect
Singapore	29	3%	72%	3%	-	21%
Taiwan	10	-	40%	90%	10%	-
Japan	6	-	67%	33%	-	-
Minnesota	9	-	89%	11%	11%	-
Missouri	9	78%	22%	-	33%	44%
California	19	16%	79%	21%	11%	5%
Achieve	6	50%	17%	33%	33%	-

(Note: Some LEs might be double-coded in the levels, so the totals in each row might be greater than 100%).

Coder Reliability

Coder reliability is an important issue. Inter-coder (or inter-rater) reliability is a particularly important consideration for research in content analysis. It represents the extent to which independent coders evaluate a characteristic of a statement and reach the same conclusion. Kolbe and Burnett (1991) argued that inter-coder reliability was often perceived as the standard measure of research quality. “High levels of disagreement among judges suggest weaknesses in research methods, including the possibility of poor operational definitions, categories, and judge training” (p.248).

Although there are many different “agreement indices” available, this study uses two measures of reliability: (1) percent agreement between coders and (2) Cohen’s kappa (Yaffee, 2005). Note that a second index is considered because most often it can account for agreement expected by chance. Some methodological experts contend that percent agreement overestimates true inter-coder agreement, however it is widely used because of its simple calculation. Bakeman (2000) argued that Cohen’s kappa should be the measure of choice and this index is generally used in research that involves the coding of behavior. Indeed, Cohen's kappa is the only index included in the Statistical Package for the Social Sciences (SPSS) software.

The basic procedures utilized in this study to check reliability of coding included:

- Prepare the coding guidelines, including the description of each of the categories listed in the coding schemes.
- Invite four doctoral students including the researcher as two-team coders. Each coder independently applies the given guidelines to the same samples (randomly chosen) of the data.
- Calculate the pilot test of reliability, including percent agreement and Cohen's kappa.
- Whenever disagreement of coding items occurred, coders discussed and reached final consensus.
- Based on discussions, the original coding guidelines and/or coding schemes were revised to clarify as needed.
- Code new test samples and measure reliability.
- Loop continued until coding description was clarified and an acceptable level of coder reliability was reached.

Initially, coders were given a coding guide and form developed by the researcher but no consultations or training was provided to coders. This provided a measure of reliability that could be expected based only on the materials prepared by the researcher. Next, the researcher and coders met together to discuss the coding guide and form and to practice coding a set of learning expectations. This discussion led to clarification of the coding guide and a common understanding of its use. Coders then independently coded a second set of learning expectations. These processes were applied and the second round of coding led to measures of reliability. Clearly, the reliability of the second round was much improved from that of the first round.

Concluding Remarks

Mathematics curriculum frameworks typically contain statements that specify the subject content for particular grades. These statements can be used to describe the nature or judge the quality of a mathematics curriculum. That is, these statements are intended to be a set of expectations for mathematics curriculum development and assessment. They indicate the scope of content and highlight the specific topics at all levels for students to learn.

Several approaches and lenses will be used to analyze the learning expectations in each document. Based on the analyses of the set of LEs associated with this topic, we will learn that some content similarities and differences are evident across the different documents. In general, each document might have its strength and weakness depending on the topic chosen. We hope that the results of this study will provide insight into learning expectations as specified in the official curriculum documents analyzed. Understanding the attention focused on the topic in the intended curriculum may help clarify the context for differences in students' opportunity to learn.

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