K-12 MATHEMATICS IN OHIO: WHAT DISTRICTS INTEND TO TEACH, WHAT TEACHERS TEACH

A REPORT OF A SURVEY FOR THE OHIO MATHEMATICS AND SCIENCE COALITION

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TABLE OF CONTENTS

LIST OF TABLES

List of Figures

K-12 Mathematics in Ohio: What Districts Intend To Teach, What Teachers Teach

A Report of a Survey for the Ohio Mathematics and Science Coalition

When I learn, my students learn.
an Ohio teacher, November 1999

Introduction

The Ohio Mathematics and Science Coalition (OMSC) is an alliance of leaders from the education, business, and public sectors, working toward the common goal of systemic and sustained revitalization and improvement of Ohio's mathematics and science education at all levels—preschool to university. OMSC and its partners are building a consensus on the goals and attributes of world-class mathematics and science education systems for Ohio and laying out a continuous improvement plan to get there.

The North Central Regional Educational Laboratory (NCREL) was asked by OMSC to describe and compare the current state of Ohio's mathematics and science education systems.[1] Central to NCREL's vision for this work is an awareness of the structure of the educational enterprise, a focus on the core issues that drive it, and an acknowledgement of the structural levels involved. At minimum, these include the student, the classroom, the school, the district, and the state. Each of these supports and constrains the work of teaching and learning. Above these are regional and national structures. Parallel to these structures are contingencies associated with parents and communities.

Within this context, four key questions shape an education system:

1. What should students learn?
2. Who delivers instruction?
3. How is instruction organized?
4. What have students learned?

Put another way, these questions address an educational system's *content*, its *capacity* to deliver that content, the organizational and pedagogical *cultures* and *conditions* that govern and constrain the delivery of content and the exercise of capacity, and the *consequences* it achieves.[2]

This report treats the first three of these questions in turn.[3] Our work in this report presents Ohio with some new evidence, based on the surveys NCREL conducted statewide in Ohio's schools. The surveys identified the topics in local schools' mathematics curricula; the topics teachers teach; and aspects of how mathematics is taught in Ohio. These surveys are excerpted from ones used by the Third International Mathematics and Science Survey (TIMSS) in 1995.[4]

Method and Procedure

NCREL's proposal to OMSC recommended that a sample of Ohio schools be surveyed in May 1999. This proved optimistic and the survey was distributed in September 1999. The bulk of responses were received by late October 1999; the last survey was returned in February 2000.

Survey Questionnaires

Four survey forms were used. The first of these was a slightly modified version of the Generalized Topic Trace Mapping (GTTMs) instrument that each nation participating in TIMSS used to outline its curriculum. We asked the curriculum leader at each school in our sample to complete this form. It listed the topics in the TIMSS math framework, provided an extended definition for each, and asked the respondent to mark the grade(s) in his or her school at which each topic was taught. The form took about 30 minutes to complete in most cases.

We excerpted the other surveys from the longer TIMSS teacher surveys. Our surveys focused on the following:

- topics taught in math
- number of lessons devoted to each topic
- resources used for planning teaching and assessment;
- textbook use;
- descriptions of some of the classwork students do;
- homework assignments;
- grades and subjects taught, teachers' qualifications, sex, and race.

We prepared mathematics questionnaires for teachers working in grades 3, 4, 7, 8, and 12.[5] Each survey took from 30 to 45 minutes to complete.

Designing the Sample

The surveys were to be distributed to a random sample of Ohio public schools. Ideally, the sample should generalize to all Ohio schools. Standard procedures to assure this are well known. The ones we adopted are described below.

However, the sample should also generalize to the educational career of Ohio students matriculating from grade to grade anywhere in Ohio. We wanted to capture the full extent of exposure to mathematics that a student being educated in Ohio's schools currently might expect over 13 years. To do this, we needed data from kindergarten through the senior year of high school. Clearly, we could not draw a sample of kindergarteners and wait 13 years (although that might be the best approach).

To solve these problems, we devised the following procedures to build a sample meeting our requirements:

1. Collapsing time
   To maximize the likelihood that we would tap a typical pattern of instruction from kindergarten to grade 12 over the educational career of a typical student in a sampled district,
   - We sampled 100 public high schools from Ohio's (then) 611 public school districts.[6]
   - For each high school, we randomly selected one middle school feeding students to it.
   - For each middle school, we randomly selected one primary feeder school.
   - In the few cases where there was no middle school, we randomly selected one K-8 school sending students to the sampled high school.
2. Sorting by geography
   Our population comprised all public high schools in Ohio.[7] To assure equal likelihood of selection across the geography of the state, we implemented a geographic serpentine. What this means is that on a map of Ohio, we drew a single line connecting every county systematically,
   - We started with Williams County in northwest Ohio.
   - From there, a line was drawn due south to Hamilton County in southwest Ohio
   - The line then stepped one county east to Clermont, and turned northward
   - The line continued this way, snaking through each Ohio county exactly once, until it reached Ashtabula County in the northeast corner.

   We then arranged the list of high schools by county according to this serpentine. We could now be sure our sample covered the full geography of the state without bias.
3. Sorting by school size
   School size is an obvious characteristic of high schools that affects the probability of selection of both students and schools. Within each county we sorted the high schools by size of enrollment, from smallest to largest in the first county (Williams) on the serpentine, largest to smallest in the second county (Defiance), smallest to largest again in the third, and so on, reversing the sort

order for each county on the list. This generated a serpentine of size within the serpentine of geography, thereby reducing the selection bias favoring smaller schools.

4. Selecting the schools
   The last step was to select every seventh high school from this ordered list, beginning with a random number smaller than 7.

While this process cannot guarantee precise accuracy with respect to our need to be able to generalize to districts, schools, and students and over student careers, it represents a cogent compromise. The final sample contained 280 schools from 97 districts.

Collecting and Analyzing the Data

We mailed one mathematics GTTM survey to each school. For the other teacher surveys, we sent each school a number calculated from grade-level enrollments, with the instructions that all teachers responsible for mathematics instruction in grades 3, 4, 7, 8, and 12 complete and return them. To assure promptness and confidentiality, shipment both ways was arranged through Federal Express.

Since it was critical we be able to link the subsequent data back to the school from which it came, each survey was stamped with an identification code marking the school to which it was sent. In addition, the surveys asked the respondents to fill in the name of their school and district.[8] Teachers were not asked to identify themselves. However, we did request the curriculum leaders who completed the GTTMs to write in their names. Nearly all did. The cover letter attached to each survey, teacher or curriculum leader, promised complete confidentiality. On top of the entire package of forms was placed a letter from Dr. Susan Tave Zellman, endorsing the survey and the OMSC project.

Given the complexity of the sample and survey designs, no single overall figure for response rate makes sense. For the mathematics GTTMs, 99 schools located in 70 districts returned usable forms. That is a district return rate of 72 percent and a school return rate of 35 percent.[9] Five-hundred-six (506) mathematics teachers returned surveys. These teachers worked in 157 schools in 80 districts. The response rate for each of the teacher surveys was as follows:

Grade 3 and 4:	59 percent
Grade 7 and 8 mathematics:	62 percent
Grade 12 mathematics:	51 percent[10]

We entered the GTTM survey data into pre-formatted Microsoft Excel© worksheets, which generated a variety of data transformations, calculations, summaries, and plots. The teacher survey data were entered into the statistical package SPSS© and analyzed using its procedures.[11]

Mathematical Content:
What Should Ohio's Students Learn?

Ohio's teachers have numerous sources of guidance to assist them to determine what to teach in mathematics. Central among these are the model curricula prepared by the Ohio Department of Education.[12] While classroom teachers do find these useful, they are targeted at district staff charged with curriculum development. Another source is the Learning Outcomes that Ohio's Proficiency Tests measure;[13] teachers in the affected grades know these very well. District and school curricula and syllabi also are prevalent.

This report cannot do justice to each of Ohio's districts, let alone each of its math teachers, in terms of what they feel should be taught. It can, however, provide perspective on how these choices come together in aggregate.

The content of a mathematics curriculum may be treated as a finite number of topics. The TIMSS mathematics framework, for instance, contains 44 topics. The topics as defined in TIMSS are conceptual: each topic brings with it new content and new procedural demands. Using this framework, it is possible to count the number of topics that nations, states, districts, or schools expect to be taught each year at each grade. Our GTTM survey estimates these numbers for Ohio. To provide context, we compare them to data drawn from the 1995 TIMSS data set.

Figure 1. **Number of Topics in Ohio Districts' Mathematics Curricula**

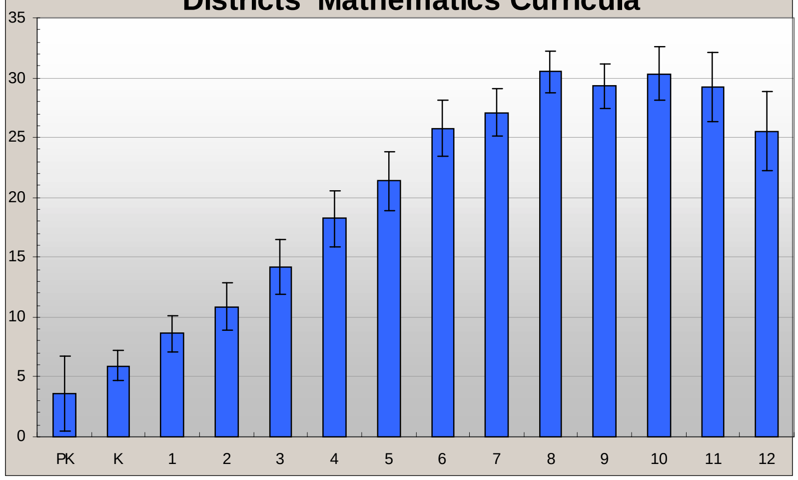


Figure 1 shows the rapid growth from grade to grade in the number of topics in mathematics that Ohio's districts intend teachers to teach and students to learn. Each bar in Figure 1 gives the average number of curriculum topics for a specific grade.[14]

In grade three, where mastery of basic mathematics operations is the focus for most students, Ohio's districts expected 14 mathematics topics to be taught. That represents about 32 percent of all the mathematics topics in the framework. By grade eight the number has increased to 31, or 70 percent of the topics. That represents a lot to teaching, and a lot to learn presumably. It requires presentation of approximately one topic each week of the school year. This pace continues the first three years of high school. But, it is reasonable to ask, is this too much, too little, or about right?

Before addressing this question, however, we need to confirm that the averages do speak for most Ohio districts. Ohio prides itself on being a local control state. This could mean that local districts construct different curricula, fashioning instructional models that best suit local circumstances. That is not evident in these survey data. Well over 90 percent of the districts report that they intend to teach the same 33 topics.

The less common topics tend to be the most advanced content—binary arithmetic, vectors, calculus, etc.—typically reserved for Advanced Placement classes in high school, which some small districts do not have the resources to offer. But even these smaller districts share the high number of intended topics in grades eight through eleven. The question remains, is this pace too slow or too rapid?

Ohio Compared to the U.S. and Japan

One way to address this question is to compare Ohio's curricular intentions to intent elsewhere. We concentrate on two issues: focus and challenge. By focus, we mean clarity and consistency in the pattern of teaching and opportunity to learn over time and across districts. By challenge, we mean the level of content teachers are expected to teach and the amount of learning expected of students.

We compare Ohio first to the U.S. and to Japan. By comparing to the U.S., it is possible to see if the charges of lack of focus and content "a mile wide, an inch deep" leveled against the U.S. mathematics curriculum (Schmidt, McKnight & Raizen, 1997, p. 62, 121-3) also apply to Ohio. In many of the international TIMSS analyses, Japan has been held up as an example of a high-performing nation that structures curriculum and instruction differently and successfully (Stevenson, 1998; Stevenson & Stigler, 1992; Stigler & Hiebert, 1999).

Figure 2. **Number of Mathematics Topics, by Grade**

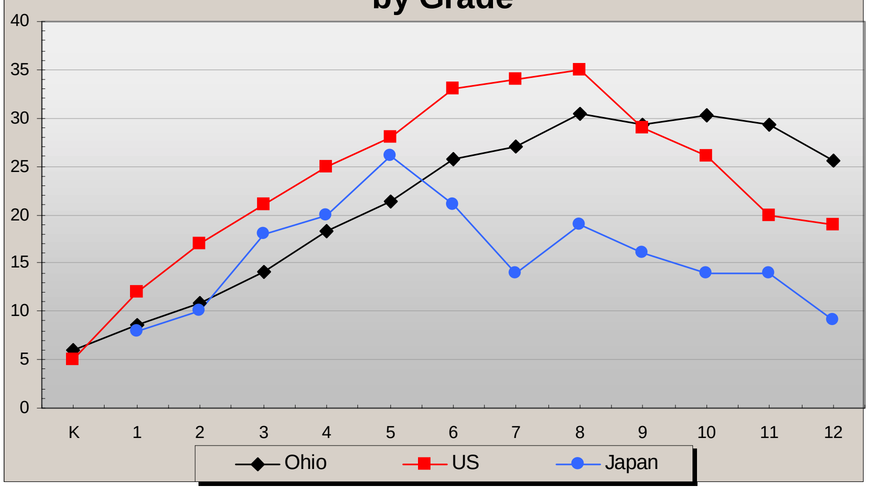


Figure 2 illustrates that in grades one to eight, Ohio (indicated by black diamonds on the chart) intends to teach fewer topics than does the U.S. (the red squares), usually about seven or eight fewer each year. However, in high school, Ohio's districts intend to teach more topics, especially in the junior year. Shifting the comparison to Japan (blue circles), the higher number of topics in Ohio from grade seven onward is pronounced.

It is worthwhile to examine the Japanese pattern a little further. Like the U.S. and Ohio, the number of topics grows rapidly over the early grades. However, after grade five, the number of topics declines steadily with each higher grade. The U.S. reaches its maximum at grade eight and then declines rapidly. The Ohio topics peak at grades eight and ten and fall hardly at all from there.

The Japanese curriculum is often interpreted as one that establishes the basics thoroughly before middle school and thereafter focuses the curriculum each year on a small number of new topics. The U.S. and Ohio patterns appear more consistent with systems that introduce many topics early on, but teach none deeply. Thereafter, they repeat topics annually, intending to deepen instruction each time. This is the "spiral" pattern of curriculum exposure so common in U.S. schools. But is this really what is going on in Ohio's schools?

Figure 3, on the next page, provides one set of answers to this question. However, an explanation of the graph is in order first. To the left appear the names of the categories and topics of the TIMSS mathematics framework. For each topic, there are three data points on the graph. The red diamond indicates the average grade level, across the districts responding to our survey, at which a topic is taught. From this diamond, a line extends to the left until it reaches the grade level that represents where, on average across the districts, the topic is first introduced. To the right of the diamond, a line extends to the highest average grade level where the topic is intended to be taught. Narrow widths from left to right suggest that students' exposure to a topic is focused tightly, within few grades; broad bands suggest topics are taught repeatedly over multiple grades.

The most striking thing about the Figure 3 is the broad range of grades for many topics. Seven mathematics topics each remain in the curriculum for over ten consecutive grades, including:

- meaning of whole numbers
- operations of whole numbers
- common fractions
- estimating quantity and size
- estimating computations
- measurement units
- data representation and analysis.

Compare this to Japan, where only one topic—three-dimensional geometry—is scheduled to be taught over ten grades.[15]

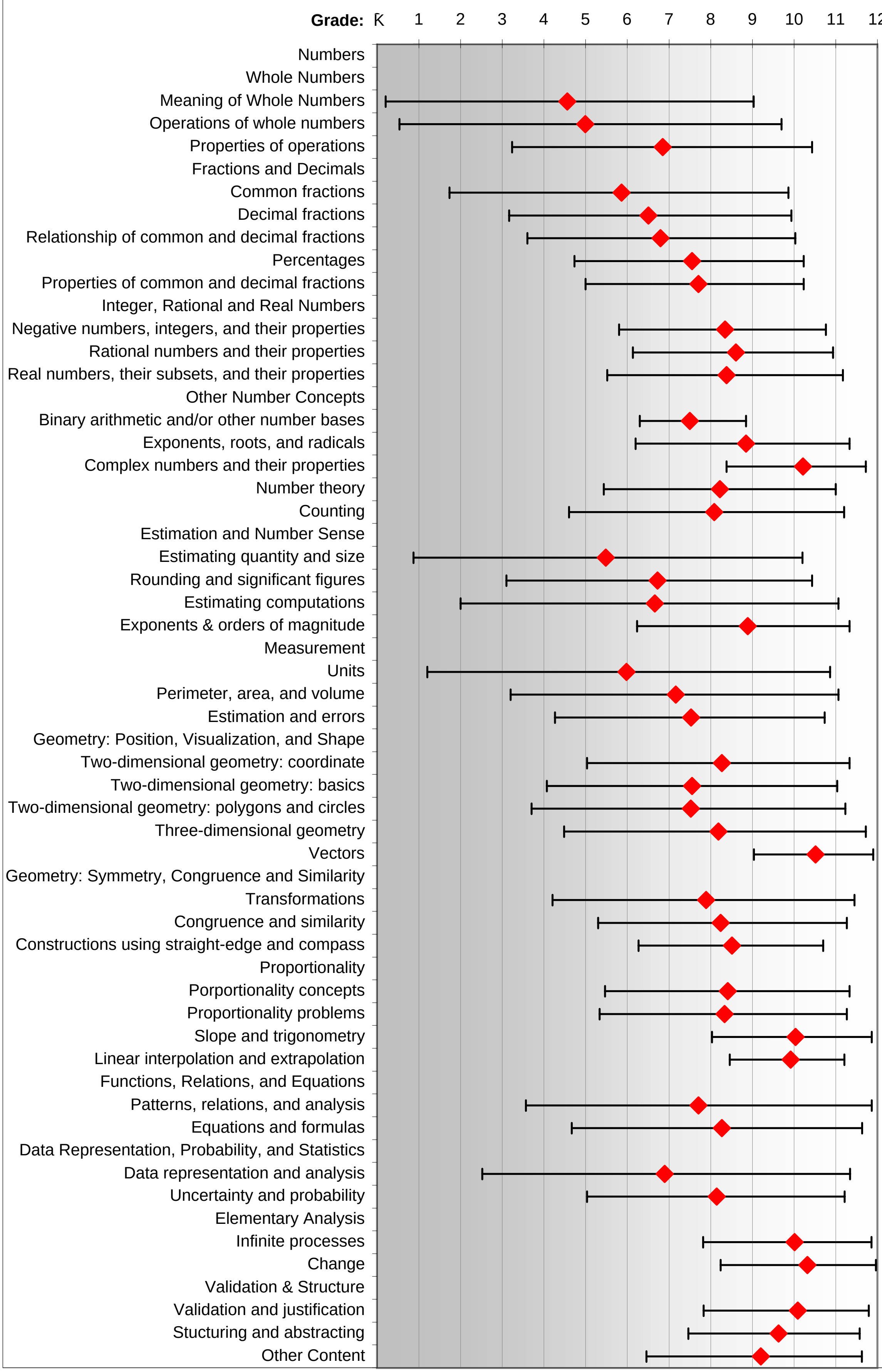


Figure 3. **Grade Range of Topics in Ohio Districts' Mathematics Curricula**

While multi-dimensional geometry is a complex topic, changing with increasing sophistication of the students, some of the topics Ohio's districts' curricula address over and over again—including whole number operations, working with common fractions, or estimating the likely result of a computation—are basic arithmetic skills. It is not clear that they should still require explicit teaching at grade seven, not mention grade ten.

In Ohio, only nine math topics are intended to be taught in five or fewer grades, and six of these are topics commonly taught with or after analytic geometry or calculus. Again, compare this to Japan where 31 of the mathematics topics are addressed in five or fewer grades.

Figure 3 also shows that in Ohio only five topics have an intended average grade level at or below grade six. Japan's math curriculum lists 18 mathematics topics intended to be taught (and mastered) on average at or below grade six. This suggests a large difference in the level of instructional challenge that Ohio's K-12 mathematics system presents to its students.

Figure 4, on the next page, makes this comparison directly. It presents the average intended grade for each mathematics topic for Ohio (the black diamonds), the U.S. (the red squares), and Japan (blue circles). Despite the differences just discussed, at first glance, Figure 4 appears to show remarkable similarity among Ohio, the United States, and Japan in terms of the average grade at which each expects that most topics will be taught. However, looking closer, it is clear that Ohio's pattern is different, especially for the foundation skills. Consistently, Ohio's curricula expect such topics as whole numbers, fractions and decimals, estimation and number sense, measurement, and two-dimensional geometry to be delivered later in a student's educational career.

There are some other patterns worth observing in Figure 4. Quite often, Japan focuses related introductory skills in one or two grade levels, while the U.S. pattern (and Ohio's) is to introduce them sequentially over time over many grades. Look at whole numbers, all intended to be taught in grade three in Japan. In this case, the U.S. pattern exactly matches the Japanese. However, Ohio's average intent is much later, and the sub-topics are introduced sequentially over grades. It can be strongly argued that the Japanese and U.S. pattern makes more sense: the meaning and operations of whole numbers need to be understood at the same time, the two kinds of facts are inextricably intertwined. Learning how to operate with the whole numbers helps to set the meaning.

Look next at fractions: Japan intends the topics common fractions, decimal fractions, relationships among common and decimal fractions, percentages, and properties of decimal and common fractions all to be taught in grades four and five. The U.S. pattern stretches these topics sequentially from grade four to late grade

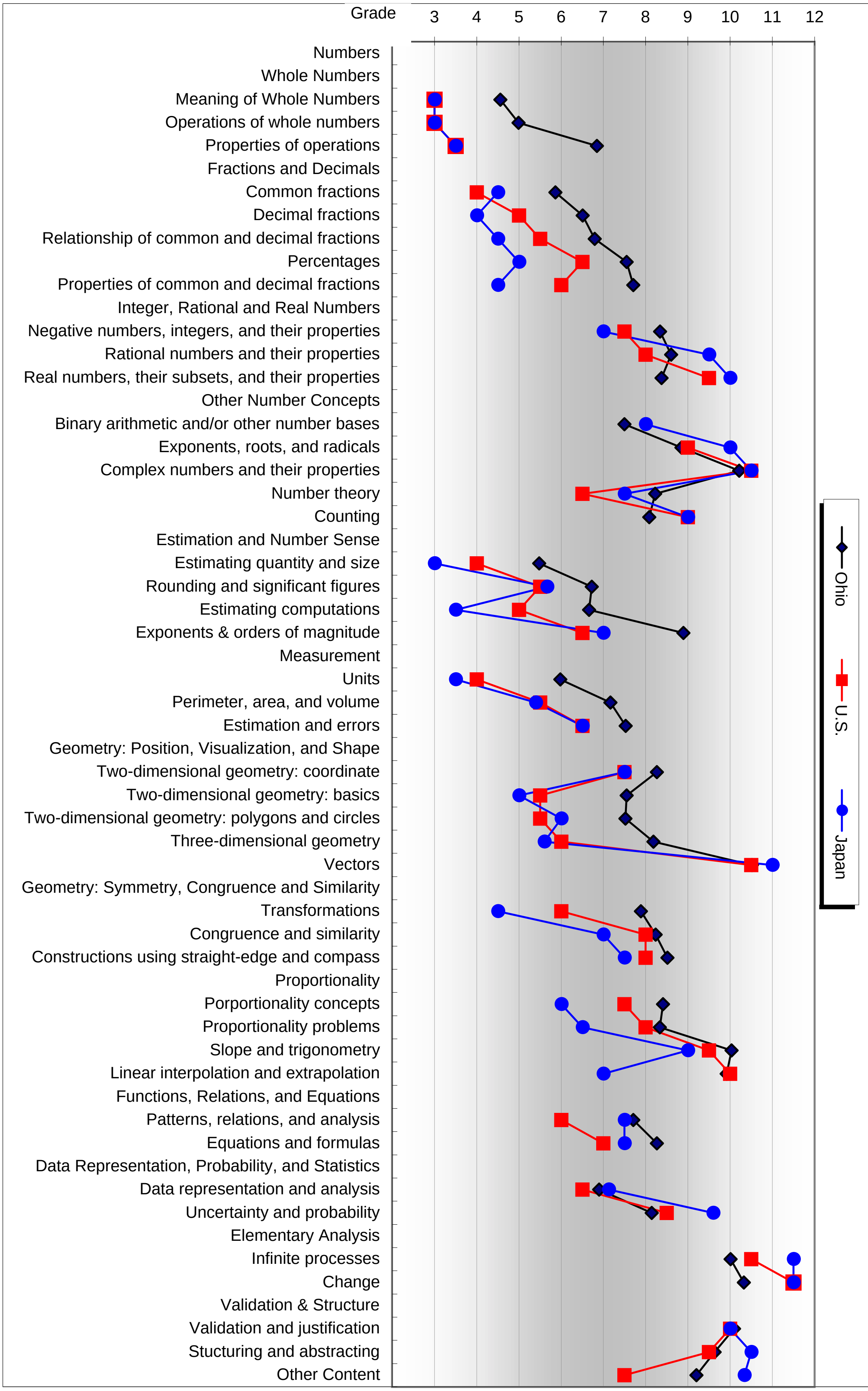


Figure 4. **Average Intended Grade for Mathematics Topics, Comparing Ohio, U.S., and Japan**

six. Ohio replicates the U.S. pattern, but at even higher grade levels. Again, it can be argued that the concept of fractional parts, regardless of how expressed, is the principle that needs establishing. The teaching of the different procedural steps that are used to operate with common fractions, decimals, or percentages should not cloud the underlying concept of fractional parts.

The central algebraic topics of functions, relations, equations, and formulas all appear in grade seven in Japan. The U.S. pattern here is earlier, but sequential. Patterns and relations appear in grade six, but equations and formulas in grade seven. In our Ohio sample, the pattern too is sequential, but in grades seven and eight.

Much of the basics of geometry in Japan appears in grades five and six. This almost exactly matches the U.S. pattern, right down to the later focus on coordinate geometry. The Ohio pattern, while it matches the U.S. and Japan in shape, occurs in later grades starting in late seventh.

There are exceptions. For instance, Ohio expects teachers to treat the three advanced elementary number topics—negative, rational, real and other number properties—together in grade eight. In the Japan and the U.S. these are typically introduced in grade seven and continued through grade nine. In this instance, the Ohio may be more defensible. However, we cannot tell from this presentation what the depth of this teaching may be. And that makes much difference.

Three points summarize the foregoing discussion of what Ohio's districts' mathematics curricula expect:

- Ohio's school districts' mathematics curricula do not appear to strongly challenge students, or teachers. The average intended grade level for 24 of the 44 TIMSS math topics falls in grade seven or eight. Ohio's students appear not to be expected to learn much in the elementary grades. Topics are repeated over and over. Much of what seventh grade teachers teach appears similar to what eighth grade teachers teach; worse, much of what seventh grade teachers teach appears to repeat what third grade teachers taught.
- Ohio's school districts' mathematics curricula are not well articulated. The expectation that certain skills will be mastered early to serve as foundations for subsequent instruction appears not to be enforced. Students receive similar instructional opportunities year after year after year.
- Ohio's school districts' mathematics curricula are usually not deep. How can they be, when from fifth to twelfth grade over half of the possible math topics are scheduled to be taught each year? That many topics each year implies repeated review and limited time for rich study of new material.

Some of Ohio's students no doubt are taught mathematics well and with substance. However, the data about curricular intentions from this statewide survey suggest that most receive much less. But, districts' curricular intentions are not necessarily the same as what teachers really teach. We turn next to what the teachers told us about their teaching.

Mathematical Content:
What Are Ohio's Students Taught?

On the next three pages, Figures 5, 6, and 7 identify the mathematics topics Ohio's teachers teach at grades 3 and 4, 7 and 8, and 12. The topics on these charts fit the TIMSS framework, although somewhat different subtopics appear on each chart, given grade differences. The overall length of the horizontal bars on the charts indicates the percentage of Ohio's teachers who say they teach the topic. The shading within the bars indicates the number of lessons they devote to each topic, on average, with more teaching to the left.

Grades 3 and 4

Ohio's primary school mathematics teachers tend to concentrate their instruction on the topics the district or school curriculum has identified. In Figure 5, we can see that over 80 percent of teachers of mathematics in grades three and four teach the following topics:

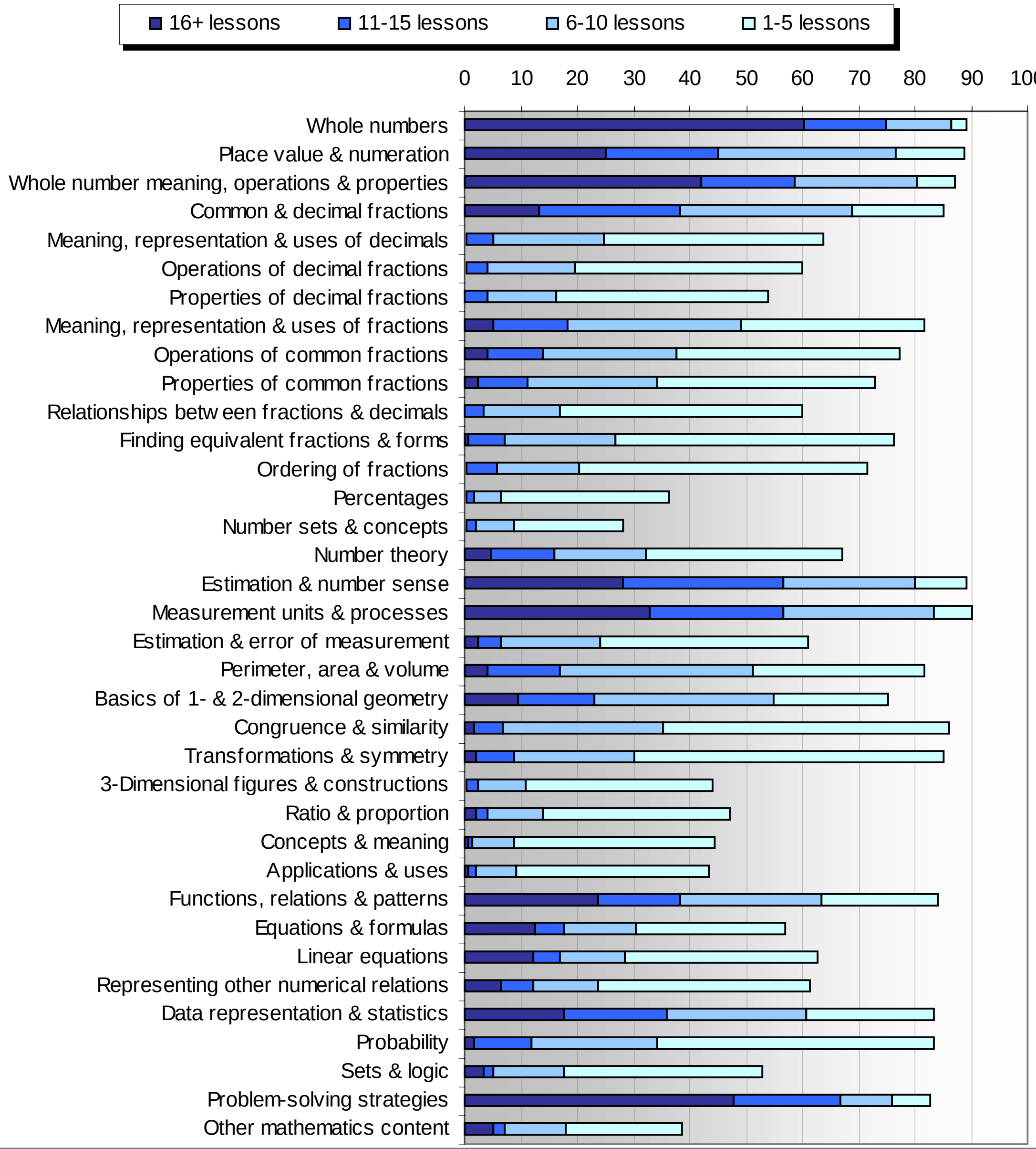
- whole numbers and whole number operations
- estimation
- measurement
- patterns
- problem solving.

Understanding numbers and their uses is the dominant theme at this level in Ohio. Of these mathematics teachers:

- 60 percent teach more than 15 lessons each year on whole number issues
- 40 percent teach more than 15 lessons on whole number operations
- 30 percent teach more than 15 lessons on estimation and measurement
- about half teach more than lessons on problem solving.

On the other hand, for two-thirds of the topics in Figure 5, the proportion reporting "1 to 5 lessons" is larger than any other segment: more primary teachers skim math topics than treat them in depth seems an obvious conclusion. Given that this is when students are expected to reach firm mastery of the mathematical basics and need to begin to be exposed to the richer, deeper aspects of mathematical thought, skimming quickly over many topics may not be an optimal strategy.

Figure 5. **Math Topics**
Percent of Ohio Teachers, Grades 3 and 4

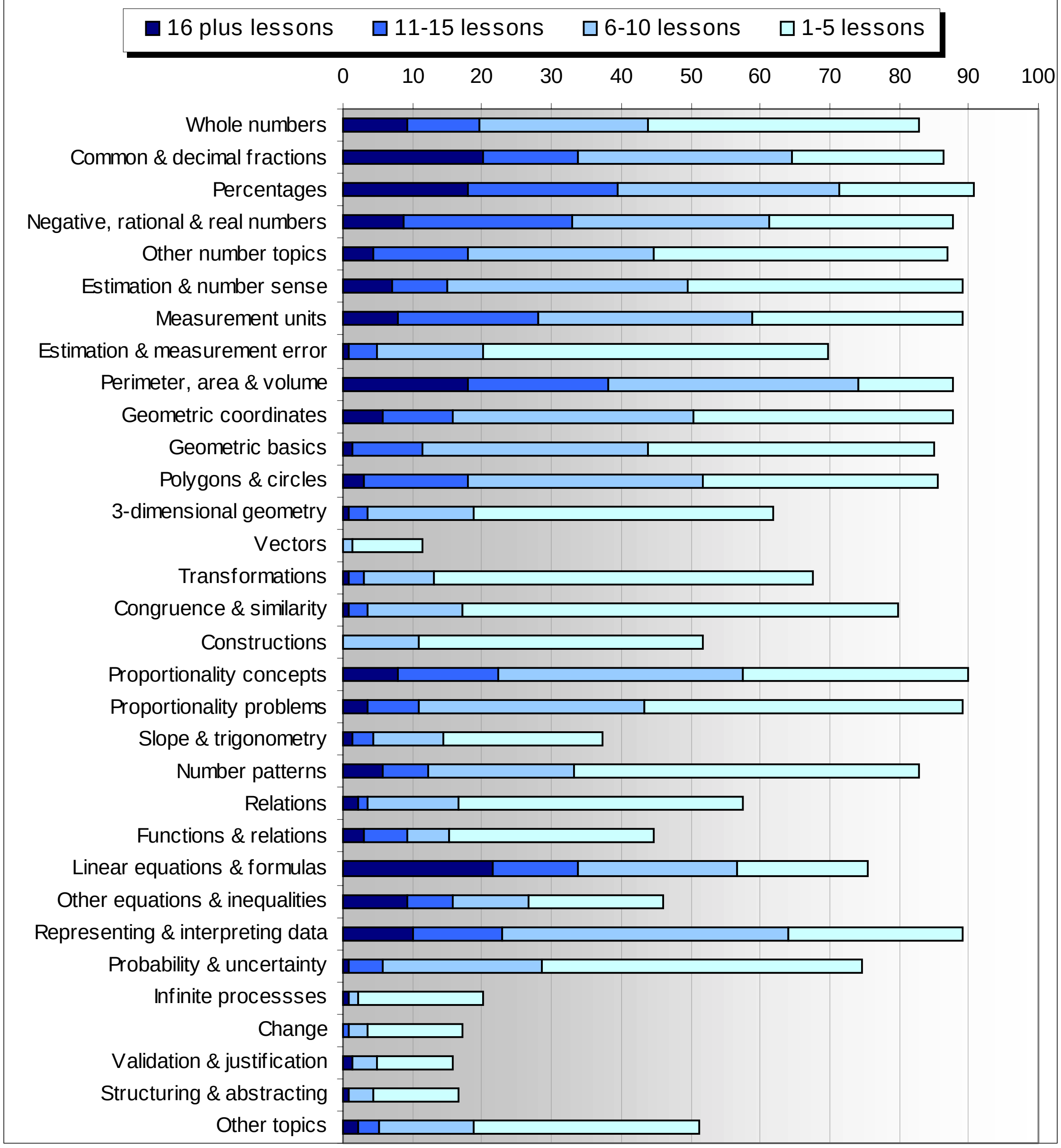


Grades 7 and 8

Ohio's middle school mathematics teachers teach more topics than do the primary teachers. Over 80 percent of Ohio's seventh and eighth grade teachers say they teach 16 or more math topics.

Figure 6. **Math Topics**

Percent of Ohio Teachers, Grades 7 & 8



While this is less than the number of topics the curriculum suggests, it is a significant workload. Included are most of the topics emphasized in the primary grades. In addition, Ohio's middle schools also bring in new, more diverse, and intellectually challenging topics:

- Numbers and their operations
- fractions and decimals
- percentages
- estimation

- measurement
- geometric coordinates
- two- and three-dimensional figures
- area and volume
- congruence and similarity
- proportionality
- number patterns
- equations and formulas
- data representation
- probability
- uncertainty.

Not surprisingly, these teachers too are forced to skim the mathematical surface for the most part. There simply isn't time to treat all the topics. Figure 6 points out that for almost three-quarters of the math topics at this level, the "1 to 5 lessons" category is larger than any other segment. There are only two topics where more than 20 percent of the teachers say they teach at least 16 lessons each year. These two are fractions (21 percent), and equations and formulas (22 percent).

That fractions remains a major issue at grades seven and eight reminds us of the need Ohio's teachers observe for repetition and remediation. Recall from Figure 4 that Japan expects this skill set to be taught and mastered before grade five. The U.S. average across all the states is by grade six at the latest. Ohio's districts delay this expectation until grade eight. If the TIMSS data can support the charge that the general U.S. pattern of teaching mathematics in the elementary and middle grades fails to challenge students, this charge would appear to apply even more to Ohio.

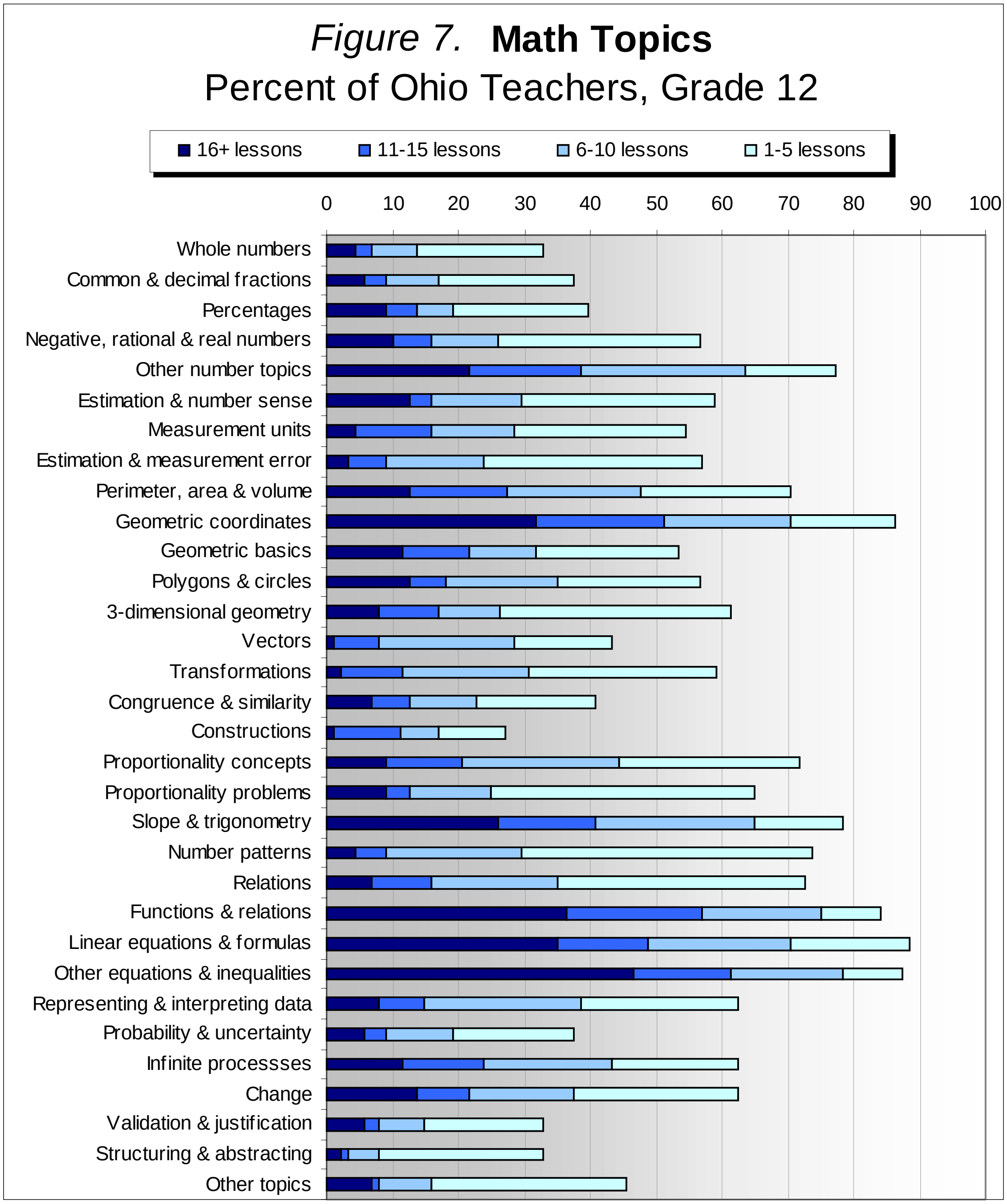
That equations and formulas are included among the most taught topics in Ohio's middle schools appears to support the "Algebra for all" concept. However, 78 percent of Ohio's seventh and eighth grade math teachers say they spend less than 16 lessons (less than three weeks) on algebra. That is simply not enough time to teach even the rudiments of algebra well.

Grade 12

Grade 12 mathematics in Ohio is appears a mixed bag. There are Advanced Placement classes in calculus and other subjects. There also appear to be remedial classes in numerous subjects, even in grade 12.

Figure 7 shows only four topics that at least 80 percent of all grade twelve math teachers teach:

- functions,
- relations



- equations
- coordinate geometry

These twelfth grade teachers, unlike the middle and primary school teachers, tend to concentrate on their specialties:

- at least one-third teach more than 16 lessons of algebra and geometry topics
- some 60 percent teach calculus or pre-calculus, although most spend relatively little time of their teaching time on these topics.

On the other hand, about 30 to 40 percent spend time teaching whole numbers, fractions, and percentages, with more than half spending at least a week on each of these topics—in the twelfth grade!

Contrasting Ohio's Teachers to the U.S. and Japan

As with curricular intentions in mathematics, it is useful to contrast the efforts of Ohio's teachers to those of the U.S. generally and to Japanese teachers.

Figure 8 on page 18 displays the topics U.S. teachers say they teach at grades three and four. It should be compared to Figure 5 for Ohio. Clearly, Ohio's third and fourth grade teachers emphasize the same general mathematical topics as other teachers in the U.S. However, compared to the U.S., it can be seen that more of Ohio's teachers say they also teach some of many other topics.

The contrast to Japanese third and fourth grade teachers is striking, as evident in Figure 9, page 19. Japanese teachers focus almost without exception on whole number meaning and operations, fractions, decimals, and percentages. A smaller number add problem solving strategies or explore some geometric ideas. However, almost no other topics are taught, by anyone. This clarity about what should be taught is striking compared to both the U.S. and to Ohio.[16]

In the middle grades, the differences between Ohio and the U.S. patterns are minimal, as may be seen by comparing Figures 6 and 10. Figure 10 is on page 20. Both concentrate on basic arithmetic skills supplemented by attempts to teach some basics of measurement, area and volume, proportionality, the basics of equations and algebra. Most teachers try to teach all of these topics with fairly few lessons devoted to each.

The Japanese, see Figure 11 on page 21, emphasize two-dimensional geometry and algebra in middle school, although the number of lessons appears to be similarly distributed. One obvious difference occurs in the teaching of congruence and similarity. One-third of Japan's middle school math teachers spend more than 15 lessons on this; almost no U.S. or Ohio teacher spends more than five lessons on this critical conceptual topic.

In sum, these data suggest that Ohio's elementary and middle school teachers of mathematics do limit the topics they try to teach somewhat more than their curricula suggest they should. Overall, their instructional choices suggest they are severely constrained in providing their students with a deep, meaningful, and satisfying introduction to mathematical knowledge and skill.[17] Whether their choices are based on what they believe they can accomplish, the time constraints they face, knowledge of the quality of their students, or their understanding of the professional literature on instruction is unclear. What is clear is that Ohio's

Figure 8. **Math Topics**
Percent of U.S. Teachers, Grades 3 and 4

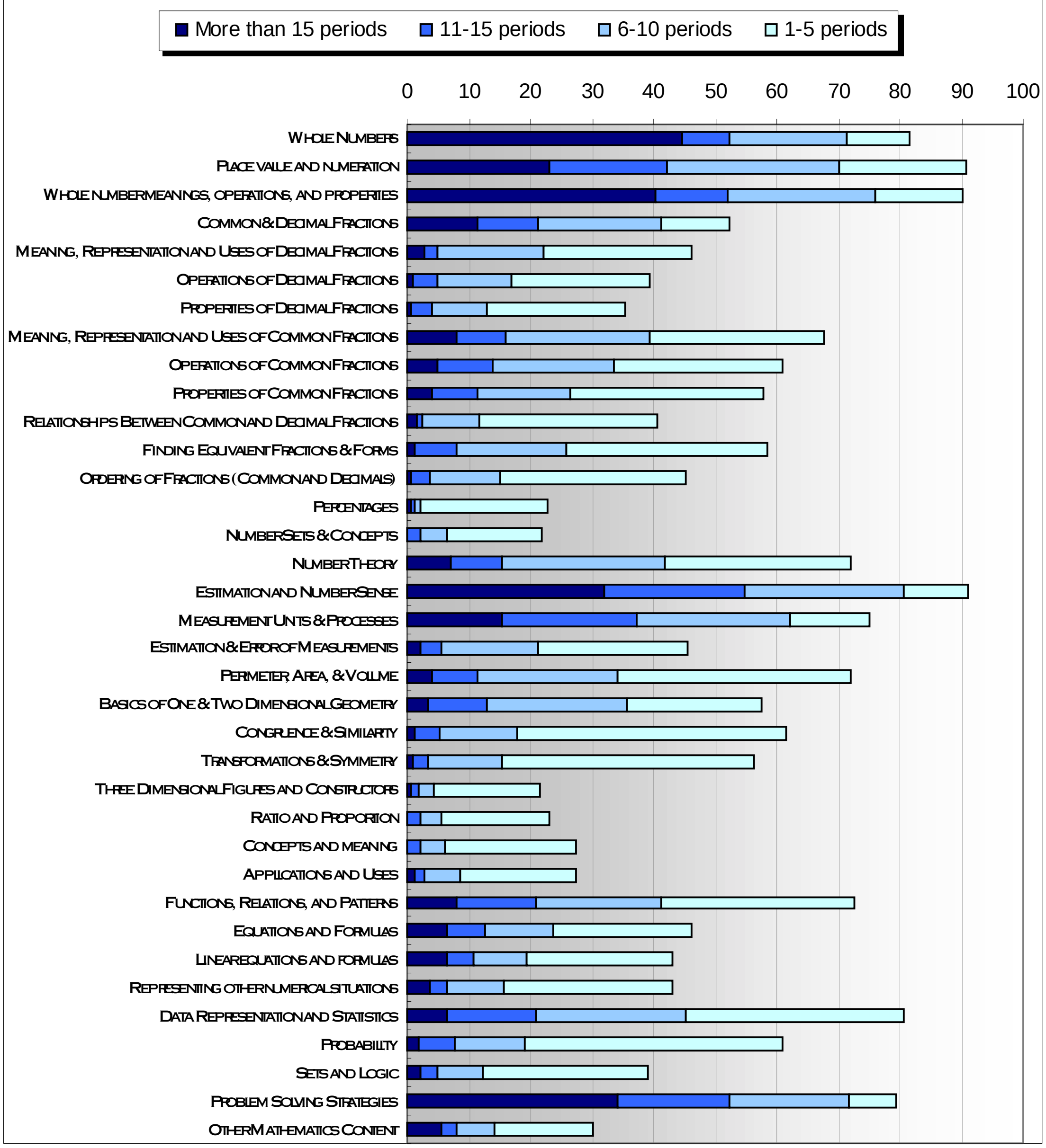
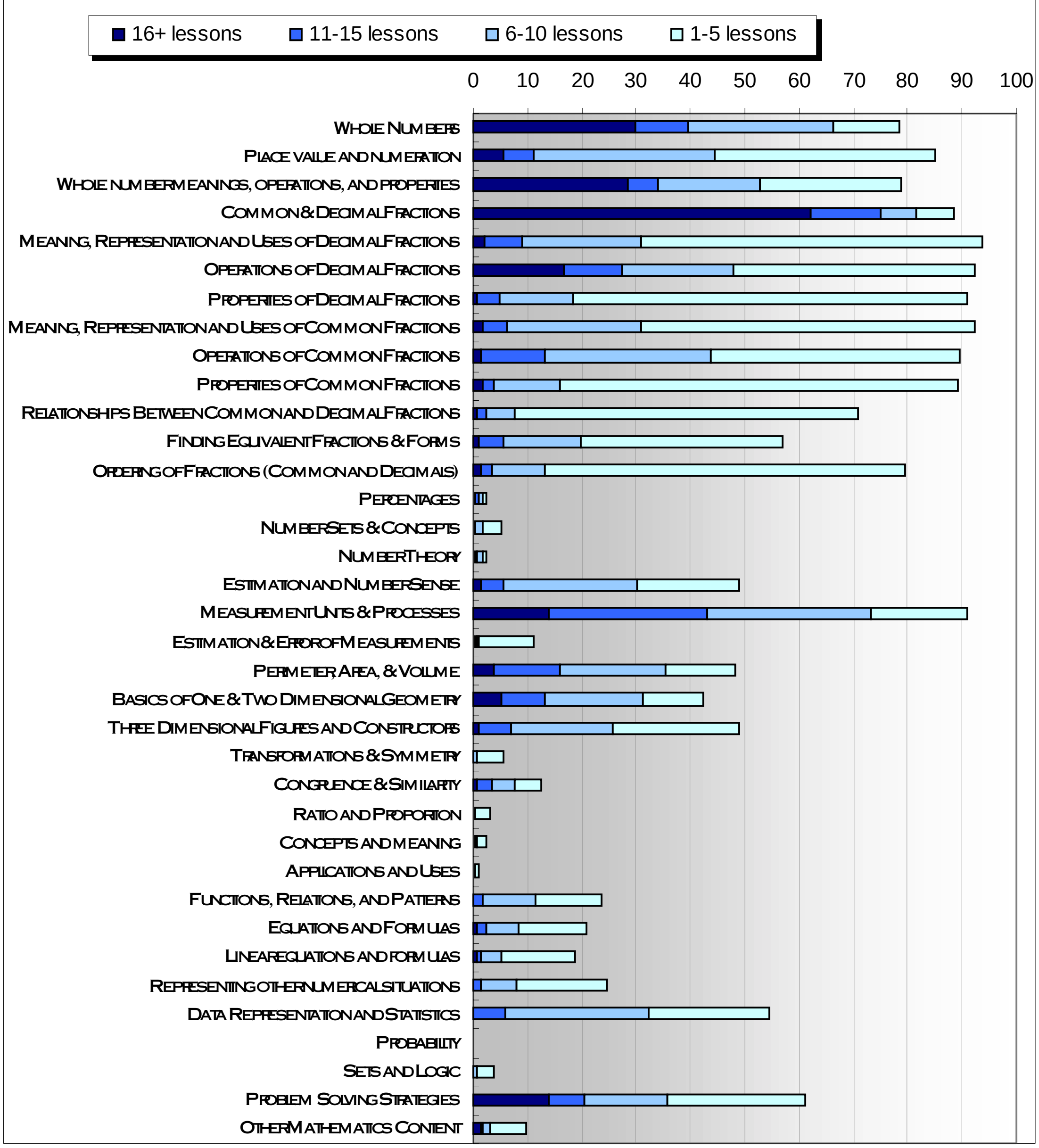


Figure 9. **Math Topics**

Percent of Japanese Teachers, Gr. 3 and 4



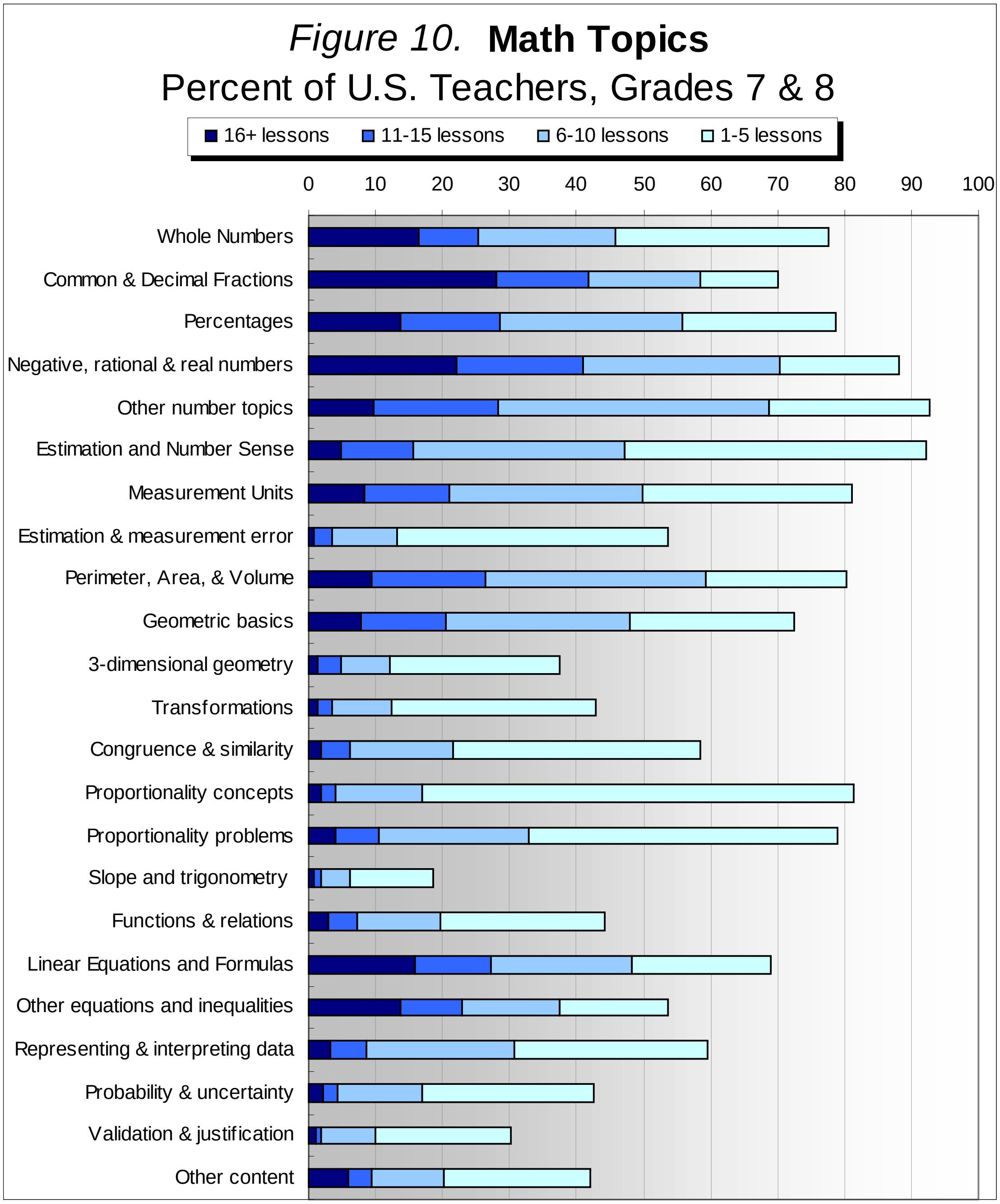


Figure 10. Math Topics
Percent of U.S. Teachers, Grades 7 & 8
16+ lessons
11-15 lessons
6-10 lessons
1-5 lessons
0
10
20
30
40
50
60
70
80
90
100
Whole Numbers
Common & Decimal Fractions
Percentages
Negative, rational & real numbers
Other number topics
Estimation and Number Sense
Measurement Units
Estimation & measurement error
Perimeter, Area, & Volume
Geometric basics
3-dimensional geometry
Transformations
Congruence & similarity
Proportionality concepts
Proportionality problems
Slope and trigonometry
Functions & relations
Linear Equations and Formulas
Other equations and inequalities
Representing & interpreting data
Probability & uncertainty
Validation & justification
Other content

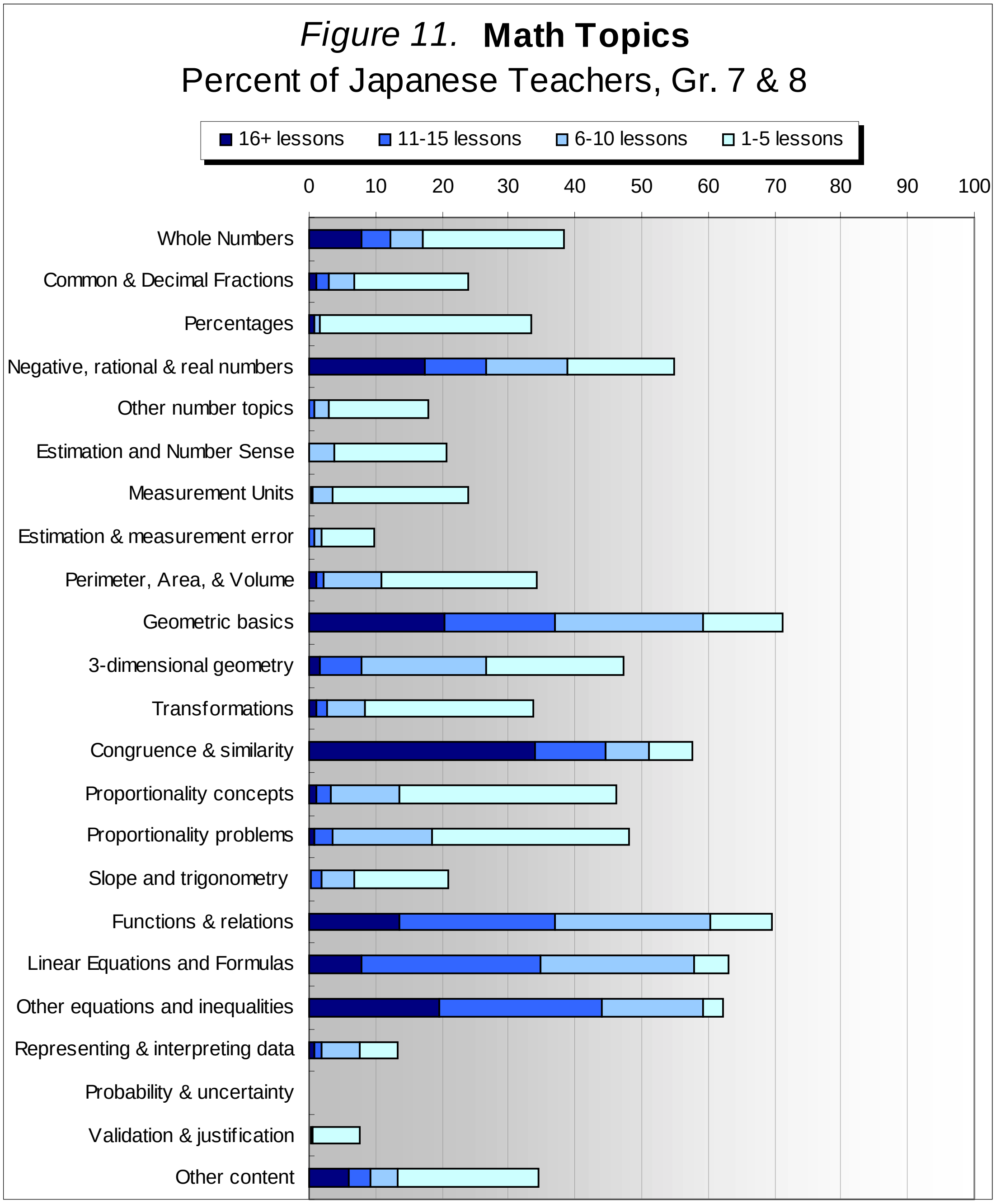


Figure 11. Math Topics
Percent of Japanese Teachers, Gr. 7 & 8
16+ lessons
11-15 lessons
6-10 lessons
1-5 lessons
0
10
20
30
40
50
60
70
80
90
100
Whole Numbers
Common & Decimal Fractions
Percentages
Negative, rational & real numbers
Other number topics
Estimation and Number Sense
Measurement Units
Estimation & measurement error
Perimeter, Area, & Volume
Geometric basics
3-dimensional geometry
Transformations
Congruence & similarity
Proportionality concepts
Proportionality problems
Slope and trigonometry
Functions & relations
Linear Equations and Formulas
Other equations and inequalities
Representing & interpreting data
Probability & uncertainty
Validation & justification
Other content

teachers choose continually to repeat, or reinforce, or remediate the learning students bring them each year. From the perspective of the teachers, students appear never to know all they should already know. From the perspective of students, school becomes a bore, an irrelevance. From the perspective of the public, neither result is acceptable.

Better alternatives are possible. Ohio has many teachers who creatively and diligently seek better ways and means to provide more opportunity and greater mastery for their students (Otto, van der Ploeg, and Blakeslee, 2000). There exist in Ohio and elsewhere numerous efforts to enhance the quality of the supply of teachers and to recast teacher education (American Council on Education, 1999; K-16 Teacher Education Task Force, 2000; National Commission on Teaching and America's Future, 1996). As Hess (1999) suggests, local effort with judicious and consistent policy support will make the difference.

The Capacity of Ohio's K-12 Mathematics System: *What Resources Do Teachers Use? What Do We Know about the Quality of those Resources?*

A primary determinant of the capacity of Ohio's mathematics system to deliver quality instruction is, of course, its teachers. We did not in this study directly investigate the training, skills, capacity, capability, motivation, or other characteristics of Ohio's teaching force.[18] Nor did we investigate the quality of the formal support structures in place for teachers and teaching, such as the Regional Professional Development Centers, the Ohio Department of Education, and districts' and schools' efforts to hire skilled staff, train and motivate them. We also did not examine Ohio's teacher preparation institutions. Each of these deserves close scrutiny, and we know that much can be done to improve them (American Council on Education, 1999; Belden, 1999; Darling-Hammond, 1999; National Commission on Teaching, 1996; National Science Board, 1999; National Research Council, 2000*a* & 2000*b*).

We focus here instead on where teachers seek support in their daily work and what resources they use to decide the details of the mathematics they choose to teach and how to teach it. One question in our survey asked "In planning mathematics lessons, what is your main source of written information?" The teachers were to choose one of the following eight options: NCTM[19] or other national standards document, the Ohio Proficiency Test guidelines, Ohio's model mathematics curriculum, the local district curriculum, a school curriculum document, the teacher edition of a textbook, the student edition of a textbook, or some other resource. Table 1 presents the responses.

District and school curriculum guides dominate teachers' decisions about what to teach, accounting for between 40 and 50 percent of the teachers. This is supportive of Ohio's vision of itself as a local control state. However, state-mandated accountability, e.g. the Proficiency Tests, is engaging teachers' attention: the Learning Outcomes are the primary decision resource for over a quarter of the teachers at the grade levels where these tests are given.

Table 1. **Main Source of Information Teachers Use to Decide What Math Topics to Teach** (in percent)	**Grade**		
	3 & 4	**7 & 8**	**12**
NCTM standards	1	5	11
Ohio proficiency test guidelines	27	30	4
Ohio model curriculum	17	11	7
School district curriculum guide	38	33	30
School curriculum guide	8	9	17
Textbook, teacher edition	7	10	18
Textbook, student edition	1	2	7
Other resources	0	1	5

Teachers do not appear to rely much on the model mathematics curriculum prepared by the Ohio Department of Education. However, this document is not aimed at classroom teachers, but rather at district and school leadership for curriculum development. That 17 percent of the primary math teachers directly acknowledge this document shows its support at that level. It could also suggest that local curricular materials need supplementation, particularly on such issues as problem solving, stressed in the model curriculum.

National mathematics standards, such as those published by NCTM, play an important role in very few Ohio K-8 teachers' decisions about what to teach. Textbooks too play only a small role. In high school, both of these are more influential, but school syllabi play an even larger role.

Knowledge about how teachers choose *what* they teach may be less enlightening than how teachers choose *how* they teach. Individual teachers typically are more involved in pedagogical than in curricular decision making (Cohen, 1990; Lortie, 1975). In most schools, the latter is an external charge or the result of group choice. In relatively few schools is the former consistently prescribed.

Table 2 presents data on these choices about practice in Ohio. Clearly, textbooks dominate decisions about how to teach for 40 to 60 percent of the teachers. The next most important resource, say the teachers, is not on this list, especially not in secondary school. Teachers do not appear to find the available state, district, and school curriculum

Table 2. **Main Source of Information Teachers Use to Decide How to Present a Math Topic** (in percent)	**Grade**		
	3 & 4	**7 & 8**	**12**
NCTM standards	2	14	10
Ohio proficiency test guidelines	11	10	1
Ohio model curriculum	4	2	5
School district curriculum guide	3	5	1
School curriculum guide	1	2	1
Textbook, teacher edition	54	39	40
Textbook, student edition	6	5	10
Other resources	18	23	32

resources helpful for these kinds of decisions. We need to know more about the other resources that teachers do use. They provide a direct opening to influencing teacher decision making—and we do not know what this avenue is.

Textbook Use

Teachers' ideas about mathematics, mathematics teaching, and mathematics learning will directly influence what mathematics they teach and how they teach it (Bransford, 1999, p. 152). If the teacher's knowledge of mathematics is deep, if the teacher's pedagogical skills are broad and well-practiced, if the teacher's knowledge of how students—one by one and in groups—learn is well-founded, if the teacher remains at all times alert to the information flow in and around her class, then it is likely that learning will occur optimally and for all.[20] But, those are a lot of *if*s. In most mathematics classes, life will be somewhat less than optimal. Good instructional resources will be a necessity.

If how teachers present mathematics is, for most, based on a textbook's selection and presentation of material and pedagogical suggestions, then we need to know how much time teachers devote to textbook-based instruction, and we need to know about the content and quality of the chosen textbooks.

We asked teachers to tell us the textbooks they used and how often they used them. Table 3 confirms that math teaching in Ohio is heavily influenced by textbooks, particularly in high school. Four of five twelfth grade teachers say they use a textbook over half the time; two of these five use them more than three-quarters of the time. At the primary level, over half the teachers base half or more of their teaching time on textbooks. In middle school almost two of every three teachers use textbooks half the time or more.

Table 3. **What Percent of your Weekly Math Teaching Time Is Based on your Textbook?** (in percent)	**Grade**		
	3 & 4	**7 & 8**	**12**
No text used	8	8	1
Less than 25% of the time	13	11	3
26-50% of the time	18	17	13
51-75% of the time	35	36	45
76-100% of the time	26	28	38

On the other hand, one in twelve of Ohio's K-8 math teachers does not use a textbook at all. In addition, it can be seen in Table 3 that in two of every five primary math classes, in one of every three middle school math classes, and in one of every six high school classes more than half of all instructional time is based on resources other than textbooks. These numbers suggest considerable variability in coverage and focus among districts, schools, even teachers. This pattern of textbook use (or lack of use, as the case may be) is, however, quite typical of what occurs throughout the U.S. (Kimmelman, 1999, p. 20).

Given the frequently poor reputation of textbooks, not using a textbook may be a sign of more enlightened teaching. Hence, it makes sense to ask, do teachers who rely on textbooks less think differently about *what* they choose to teach? The answer appears to be, not much in the primary grades, a little in the middle grades.

In grades three and four, teachers who use textbooks less are a little more likely to base their teaching choices on the district curriculum or on the Ohio model math curriculum, but the difference is very small. In grades seven and eight, teachers who use textbooks less are somewhat more likely to depend on the Proficiency Test guidelines and the Ohio model math curriculum. They are also less influenced by their district's curriculum guide than are teachers who rely more on textbooks.

What resources do the teachers who rely on textbooks less turn to in order to decide *how* to teach? Are their decisions based on different resources? Here the answer is a qualified "yes."

About a third of the primary and middle grade teachers who make little use of texts turn to "other resources," considerably more than do the teachers who depend more on textbooks. Another third turn to teacher's editions of textbooks, even if they rarely expose their students to these texts. Again, it becomes clear that we need to know more about teachers' pedagogical resources if we are to affect their practice. It is also clear that textbooks and teacher editions of textbooks are a critical resource in most districts and for most teachers of mathematics in Ohio.

Textbook Choice and Textbook Quality

Table 4 lists the mathematics textbooks used by the teachers we sampled in grades three and four. Almost half the teachers used one of three textbooks. One-quarter of the teachers used Addison Wesley's *Mathematics*. However, 13 other texts were cited, confirming considerable variability in textbook use.

Table 4: **Mathematics Textbooks in Use in Grades 3 and 4 in Ohio**

			Ratings[a]	
Publisher	**Textbook**	**Percent of Teachers**	**DoE**	**MC**
Addison Wesley	Mathematics	25.1		B
Scott Foresman	Exploring Mathematics	12.6		
McDougal Littell	(Heath) Connections	10.7		
Saxon	Math 3; Math 4; Math 54; Math 65	8.4		B
Silver Burdett Ginn	Mathematics: Exploring your World	7.4		
Harcourt Brace	Mathematics Plus	6.0		
Houghton Mifflin	The Mathematics Experience	6.0		
MacMillan/McGraw-Hill	Mathematics in Action	6.0		
Harcourt School	Math Advantage	4.2		B
Houghton Mifflin	Math Central	4.2		
Silver Burdett Ginn	Mathematics: Path to Success	2.8		B
Houghton Mifflin	Mathematics	2.3		
Everyday Learning	Everyday Mathematics	1.9	P	C
Dale Seymour	Investigations	0.9		F
Harcourt Brace	Mathematics Unlimited	0.9		
McGraw-Hill	Math in my World	0.5		B

[a] The "DoE" column lists mathematics programs identified as *exemplary* (E) or *promising* (P) by a U.S. Department of Education expert panel. Mathematically Correct assigned letter grades to the texts it reviewed. The MC reviews targeted textbook editions intended for grades 2, 5, and 7. This chart interpolates to grades 3 and 4. None of the agencies reviewed all the mathematics textbooks schools use.

Recently, several comparisons of school mathematics textbooks and programs have been conducted. Middle school texts have received the most attention, but primary and secondary texts have not gone ignored. These reviews and critiques provide opportunity to compare textbooks from consistent perspectives. The groups funding these comparisons possess pronounced differences in beliefs and attitudes about what constitutes good schooling, good practice, and good curriculum. It is easy to become distracted by heated discussion of viewpoint rather than remain focused on what the comparisons can tell us about the content, intent, and procedure of the texts. Nevertheless, we will attempt to extract some guidance from this work.

Project 2061 of the American Association for the Advancement of Science (AAAS) has completed evaluations of middle grade mathematics and algebra textbooks (2000). Its program of textbook evaluations continues. An expert panel convened by the U.S. Department of Education (1999) identified exemplary and promising programs. These two efforts differ in their purposes and use different criteria, but both support the NCTM math standards (1989, 1991, 2000) and endorse constructivist and discovery principles in the learning mathematics. Providing a counterpoint is Mathematically Correct, a coalition of scientists, mathematicians, and others of a more traditional persuasion. A sense of the distance between the two viewpoints rests in the fact that Project 2061 and the U.S. expert panel both gave their highest ratings to Dale Seymour Publications' *Connected Mathematics*. Mathematically Correct gave *Connected Math* a failing grade.[21]

To date, only Mathematically Correct has reviewed primary textbooks, and only at grades two and five.[22] About half the textbooks that Ohio's third and fourth grade math teachers named in our survey were from reviewed textbooks series. The most common text, Addison Wesley's *Mathematics*, received a B^+ rating in its grade two incarnation. All the other rated texts used in Ohio, except two, also received various level of B. Everyday Learning's *Everyday Mathematics* received a C and Dale Seymour's *Investigations* received an F. The U.S. Department of Education's expert panel gave a promising program designation to *Everyday Mathematics*; however, as can be seen in Table 4, this program is rarely used in Ohio's schools.

Overall, it is not clear that Ohio's districts' textbook choices align well with experts' choices. What is clear is that the districts make use of a large variety of mathematics textbooks in the primary grades.

Table 5 lists the mathematics textbooks used by the Ohio seventh and eighth grade teachers we sampled. A striking aspect of this list is its length: this sample of teachers uses over 30 textbooks. Of these, two are somewhat more popular than the others, together accounting for almost one-third of all math classrooms.

"Algebra for All" has become a key slogan in the movement to reform mathematics education, including in Ohio. Ten of the textbooks listed in Table 5 focus specifically on algebra, three more on pre-algebra. Several others contain significant algebra content. Still, textbooks focused on pre-algebra and algebra are used by only about one-fifth of the teachers in our sample, suggesting most Ohio middle grade students receive little exposure to algebra.

The expert evaluations appear to offer little help. Project 2061 rated the two texts most often used in Ohio's middle schools as "unsatisfactory." The U.S. panel judged one "promising." Mathematically Correct graded one "B" and the other "C."

Table 5. **Mathematics Textbooks in Use in Grades 7 and 8 in Ohio**

Publisher	Textbook	Percent of Teachers	Ratings[a] DoE	2061	MC
Glencoe	Mathematics: Applications & Connections	20		U	B
Scott Foresman/Addison Wesley	UCSMP Transition Mathematics	12	P	U	C
Harcourt Brace	Mathematics Plus	6		U	
Glencoe	Algebra 1: Integration, Applications, Connections	5		LP	B
Prentice Hall	Middle Grades Math: An Interactive Approach	5		U	B
Dale Seymour	Connected Mathematics	4	E	S	F
Holt Rinehart & Winston	Mathematics Unlimited	4			
Houghton Mifflin	Mathematics: Structure & Method	4			
Scott Foresman/Addison Wesley	Middle School Math	4		U	B+
McDougal Littell	(Heath) Connections	3		U	
Saxon	Math 76; Math 87	3			C+
Scott Foresman	Exploring Mathematics	3			
Glencoe	Pre-Algebra: A Transition to Algebra	2			A
Harcourt School	Math Advantage	2		U	B
Houghton Mifflin	Algebra: Structure & Method, Book 1	2			A
McDougal Littell	Middle Grades Math Thematics	2		S	D+
Silver Burdett Ginn	Mathematics: Exploring your World	2			
AMSCO	Achieving Proficiency in Mathematics	2			
Holt Rinehart & Winston	Algebra	2			C
MacMillan/McGraw-Hill	Mathematics in Action	2			
Prentice Hall	Algebra 1	2			
Saxon	Algebra 1: An Incremental Development	2			A
Scott Foresman/Addison Wesley	Algebra I: Expressions, Equations, and Applications	2			A
Houghton Mifflin	Pre-Algebra: An Accelerated Course	1			
McDougal Littell	(Heath) Algebra 1: An Integrated Approach	1			C
McDougal Littell	(Heath) Passport to Algebra & Geometry	1		U	A
McDougal Littell	Gateways to Algebra and Geometry	1			
Merrill	Pre-Algebra	1			
Prentice Hall	Algebra 2 with Trigonometry	1			
South-Western	(COMAP) Mathematics: Modeling Our World	1		P	

[a] The "DoE" column lists programs identified as *exemplary* (E) or *promising* (P) by a U.S. Department of Education expert panel. AAAS Project 2061 rated textbooks as *satisfactory* (S) or *unsatisfactory* (U), and classified algebra texts as *excellent* (E), having *potential* (P), or *little potential* (LP) to help students learn algebra. Mathematically Correct assigned letter grades to the texts it reviewed. Mathematically Correct reviewed editions targeted for grades 2, 5, 7, and Algebra 1. None of the agencies reviewed all the mathematics textbooks available.

Overall, mathematics textbooks rated "satisfactory" or "having potential" by Project 2061 are used by only seven percent of Ohio's middle school teachers. More than one half the teachers report textbooks that Project 2061 rates as "unsatisfactory" or having "little potential." The U.S. Department of Education's expert panel identified two exemplary and two promising programs with content suitable for the middle grades. Two appear on this list: the *University of Chicago School Mathematics Project* and Dale Seymour Publications' *Connected Mathematics*. About 16 percent of Ohio's seventh and eighth grade mathematics teachers use one or the other of these.

Turning to the Mathematically Correct reviews, the most frequently used text in Ohio, *Mathematics: Applications and Connections*, received a "B" grade: for use in seventh grade mathematics classes, but considered suitable only for up to "pre pre-Algebra." If "Algebra for All" is the goal in Ohio for grade eight, this text may not be the way to go. The second most used text nets a "C," of "questionable ability to support student achievement at moderate levels." However, the group does consider this text to contain content for a first course in algebra. Mathematically

Correct gives three middle school math texts and two algebra texts "A" grades. These "A" textbooks are used in seven percent of Ohio's classrooms.

In grade 12, too, there are many textbooks in use. Ohio's teachers reported 43 texts.[23] No single text is dominant. But then, math is not a required course for Ohio's seniors in many high schools.[24] Moreover, the mathematics courses that are offered at this level range from remedial arithmetic to Advancement Placement calculus. Almost 40 percent of the textbooks the teachers used taught trigonometry and advanced algebra. Another 40 percent were devoted to pre-calculus and the calculus. About 10 percent were geometry texts, just under five percent were for a first algebra course, and six percent were remedial in nature.

In summary, despite the clarity of Ohio's model mathematics curriculum and the specificity of the Proficiency Test guidelines,[25] the large number and considerable variety of mathematics textbooks in use throughout the state appears to suggest that there is little, if any, consensus among Ohio districts, schools, and teachers about what constitutes a good textbook.

The experts too have trouble agreeing on what constitutes a good math textbook, that is clear. But, the textbooks that experts—of whatever persuasion—favor, Ohio's districts rarely adopt and Ohio's teachers rarely use. Most of the mathematics textbooks commonly used in Ohio's schools appear not to be well-respected by the experts.

The textbooks in use in Ohio also vary by age. The NCTM standards first published in 1989 and 1991 announced the arrival of a new consensus about what math to teach and how to teach it. These standards have been very influential in changing the focus and content of textbooks—although textbook publishers also respond to numerous other influences. It takes several years for such changes to make it through the production process and appear in print in textbooks.

From Table 6 we can see that half to two-thirds of the math texts that Ohio's students opened in the fall of 1999 were printed before 1996 and likely to have been little influenced by the NCTM consensus.[26] Only about one-quarter of the textbooks in use were printed in 1998 or 1999 in the primary grades and in grade 12. The middle grades fared somewhat better: 40 percent of the teachers were using recent textbooks. Almost certainly, the national pressure concerning the "mile wide, inch deep" middle school curriculum (Peak, 1996) that the first TIMSS results decried, played a role in moving school districts to

Table 6. **Publication Dates of Ohio's Math Textbooks**

Year	**Grade 3 & 4**	**Grade 7 & 8**	**Grade 12**
1999	9.0	12.4	8.5
1998	17.0	28.1	14.6
1997	1.4	7.4	8.5
1996	3.3	3.3	11.0
1995	6.1	10.7	2.4
1994	7.1	7.4	11.0
1993	8.5	1.7	7.3
1992	26.4	14.9	11.0
1991	20.8	9.9	7.3
Older	0.5	4.1	18.3

seek newer textbooks at this level. Still, as discussed above, whether districts chose well remains to be seen.

Understanding the Evidence about Textbooks

We want to believe, and teachers want to believe, that textbooks make a difference. Still, the foregoing discussion raises a variety of doubts and concerns that need to be addressed.

- Is it possible that there are no substantive differences among textbooks? Given that Ohio's districts, by and large, do not choose the few textbooks that experts find to have merit, school staff may be selecting among textbooks that do not meaningfully differ. A critical question, of course, is whether the teachers who make up textbook adoption committees are aware that different, and possibly superior, textbooks exist. Then again, it is possible that the mathematics teachers who sit on adoption committees prefer middle-of-the-road textbooks.
- Is there no "hard" evidence to compare textbooks? Expert panels' opinions may be on the mark, but they disagree. Teachers' choices may be good ones. But how are we to know? Textbook publishing is a marketing-driven business. New, updated books by prestigious authors sell. States encourage textbooks to touch each standard they write. Clear omissions create failed sales. What is not available is unbiased, empirical evidence that shows how much and what learning a particular textbook produces.[27]
- Is it possible Ohio's teachers are not well qualified to select mathematics textbooks? Most school districts are small, often with fewer than 100 professional staff. Finding staff who have the time and the will to remain current with the literature and with new releases of textbooks is difficult for many districts.[28] Many staff members have taught for decades. Their focus has been on the classroom, not the profession. Their ties to professional associations, educational research, expert debate will have thinned. In addition, some claim that the professional training teachers receive is itself deficient (Gross, 1999). Recent evidence on U.S. teachers' knowledge of the fundamentals of mathematics and mathematical reasoning suggests that this knowledge is limited, often too limited to support more than surface-level teaching of mathematics (Ball, 1990; Ma, 1999).
- Is it possible that we have reached a point where the accumulated wisdom about learning and learning mathematics is no longer correct? The past century has seen startling developments in how we understand learning: from Freud's psychiatry to Watson's behavior therapy, to Skinner's free operant conditioning, to Piaget's stages—and somewhere in all that is the thought and influence of John Dewey. Over the past two decades that accumulated wisdom has seen dramatic and accelerating reshaping in the

hands of constructivist educators and cognitive scientists (Bransford, 1999; Bruer, 1993).

The average Ohio teacher is now in his or her forties. S/he obtained the teaching credential 15 or more years ago. Unless the teacher has been very diligent, s/he will be ignorant of the full scope and consequences of these changes in understanding for mathematics instruction (Bailey, 1996; Devlin, 2000). Their accumulated repertoire of tools and practices—more precisely, their personal understanding about why, when, and how to employ these tools and practices—may not be consistent with the reasons now being offered to justify changed practice (Cohen, 1990). Under these conditions, they cannot make wise decisions about textbooks and other instructional supports.

Other nations face this issue as well. And some have tools and practices to assure teachers remain stay well versed and motivated. In Japan, for instance, research lessons (Lewis & Tsuchida, 1998) bring teachers together around critical issues in applied pedagogy. These lessons focus the attention of groups of teachers over time as they engage in jointly designing and building effective demonstration lessons. The lesson must be justified both theoretically and practically, enforcing links to the research and what is known of best practice. Because this work focuses closely on teachers' own practical needs, because it brings the resources of teachers from different schools together, because it extends the work and the conversations about the work over time and across the daily boundaries of the single classroom, the research lesson concept bodes well for helping teachers generate new solutions, supported by applied and theoretical research, and empowered by the energy of a fellowship of peers (see Stigler & Hiebert, 1999).

- Is it possible that most U.S. mathematics textbooks do not contain the right material? As part of TIMSS, samples of mathematics textbooks for all participating nations were analyzed. This confirmed that most American texts contain far more material covering far more topics per grade than is the case in most other nations (Schmidt et al, 1999). Moreover, American textbooks appeared disjointed and are highly repetitive from grade to grade. Teacher editions typically add little more than correct answers for the student exercises.

  Textbooks in several other nations are much richer for teachers and students, providing numerous worked-out examples and illustrated processes. Materials for teachers focus more often on underlying principles and other materials suitable for self-study and guided lesson development. Over three-quarters of the space in Japanese seventh grade student math texts, for instance, is devoted to detailed, worked-out, alternative solution strategies and procedures. This rich help occurs on only about one-third of the pages of U.S. texts. Instead, almost half the space is devoted to unsolved exercises and another fifth to largely irrelevant illustrations (Mayer, Sims, & Tajika, 1995).

- Is it possible Ohio's mathematics teachers should use textbooks more? If Ohio's districts were consistently to use the best textbooks—whatever those are—and to depend on them for most instruction, would that improve teaching and learning? Recall the discussion above about the amount of textbook use. Only about one-fifth of third and fourth grade teachers, one quarter of seventh and eighth grade teachers, and less than forty percent of twelfth grade teachers base more than three-quarters of their teaching time on textbooks. This distribution is similar to what is true in much of the U.S.

  However, one set of very high performing school districts, the First in the World Consortium outside Chicago, presents a very different profile. There are no eighth grade math teachers there who do not use a textbook. Nearly all (90 percent) of the eighth grade teachers base over half their teaching time on textbooks. Over half (55 percent) base more than three-quarters of their teaching on textbooks (Kimmelman, 1999, p. 20). Recall that this group of 20 districts outperformed all nations in TIMSS, except Singapore. Surely, more than textbook use was responsible. However, these districts' consistent curriculum supported by good textbooks and skilled teachers clearly made a difference.

What if all these doubts are true? Then, in the effort to improve mathematics education, are we not in fact asking teachers to do what they have not been trained to do? With limited tools? With the wrong tools? Under difficult conditions? With no time? And little support? Fortunately, the answer to each of these questions is not an unqualified negative. However, there is a <u>lot</u> of uncertainty. Textbooks and teachers, with students, are at the core of the learning enterprise (at least as we know it in schools). Textbooks need to be the best they can be. Teachers need the best support we can supply, especially if we are also asking that their teaching must change.

Next, we examine closely some aspects of teaching and learning in Ohio today, aspects that are central to the changed teaching being urged.

The Culture of Teaching Mathematics: *How Is Instruction Delivered?*

We asked the teachers how often they had their classes work as a single unit, as groups of students, or as individuals; how often they assigned homework; and how often they asked their students to do certain classroom tasks, such as practicing computation, using computers, writing equations, analyzing relationships by using tables, charts, and graphs, and explaining the reasoning behind their ideas.

Because these questions were also asked in TIMSS, they permit comparison of Ohio's teachers' classroom practices to other teachers in the U.S. as well as those from other nations. They also permit some sensing of where Ohio's teachers' practice stands with respect to the NCTM standards and other calls for reforming practice.

Authoritative reviews of research confirm that two factors are most influential in student learning: instructional quantity and metacognitive opportunities (Wang, 1990). Hardly surprisingly, more opportunities to learn and to work at learning are predictive of greater learning. When these opportunities include practice in having children monitor their own learning, such as planning to learn more effectively and testing alternative learning strategies for themselves, learning begins to accelerate. The latter factor tends to occur more frequently and to have greater impact when students are actively engaged in their work, when the challenge presented "grabs" them and focuses their attention and minds, and when they have opportunity to build their own solutions rather than simply regurgitating givens (cf. Brown & Campione, 1996). Classrooms that encourage this factor tend to be more collaborative in nature, less teacher-dominated than others.

The Organization of Instruction

The way teachers organize classroom instruction and the relationship between teacher and student and among students are indirect estimates of the collaborative nature of the instruction that takes place there.[29] Nevertheless, inspection of the patterns observed and comparing them to patterns elsewhere may help us understand the condition of mathematics teaching and learning in Ohio.

Table 7 compares whether instruction is teacher-led, in three work clusterings: whole class, small student groups, or individual work. Teacher-led or assisted instructional patterns predominate at all levels, very closely split between whole class and individual student work. On the other hand, it is apparent that in Ohio's math classrooms all of these six choices can be found, and with considerable frequency. This suggests that teachers are comfortable mixing and matching classroom organization patterns as needed.

Table 7. **Ohio Teachers' Reports of Class Organization for Mathematics Instruction**[30]

	Grades 3 & 4			**Grades 7 & 8**			**Grade 12**		
(in percent)	Rare	Some	Most	Rare	Some	Most	Rare	Some	Most
Whole class, teacher led	0	42	58	2	53	46	0	40	60
Whole class, students responding to each other	3	64	33	10	68	21	7	61	32
Individual work, teacher assisted	0	54	45	2	48	50	2	41	57
Individual work, independent	10	56	33	17	59	24	13	59	29
Small groups, teacher assisted	2	80	18	4	74	23	5	67	29
Small groups, independent	12	78	10	20	72	9	15	75	10

There appear to be no sharp differences in this table between primary, middle, and secondary school. The twelfth grade teachers are somewhat more likely to use teacher assisted individual work. The middle school teachers do teacher-led whole class instruction a little less often. On the whole, it is tempting to read Figure 6 as supporting instructional organization of the typical pattern commonly expected: teacher-led portions occurring most days, giving way most days to some individual, teacher supervised practice, with occasional group work when appropriate.

How does this compare to organizational patterns elsewhere? In Table 8 we compare Ohio to the U.S. overall, to Japan, and to the First in the World Consortium, the high performing Chicago suburbs which participated in TIMSS as a "mini-nation" of its own. The similarity between Ohio and the U.S. is striking. The largest exception occurs in independent individual work. Ohio's teachers, particularly in the primary years, are more apt to make use of this mode than is true for the rest of the U.S. In the primary grades they are also somewhat less likely to turn to teacher supervised individual work. What this means is not clear, although, as with textbooks, it lends some support to the wider range of approaches in use in Ohio.

Table 8. **Teachers' Reports of Class Organization for Mathematics Instruction**[31]

	Grades 3 & 4				**Grades 7 & 8**			
(Percent responding "most lessons" or "all lessons")	Ohio	US	FiW	Japan	Ohio	US	FiW	Japan
Whole class, teacher led	58	54	48	78	46	49	75	78
Whole class, students responding to each other	33	32	37	50	21	22	42	22
Individual work, teacher assisted	45	55	24	34	50	50	35	27
Individual work, independent	33	15	26	25	24	19	22	15
Small groups, teacher assisted	18	20	36	7	23	26	20	7
Small groups, independent	10	11	23	2	9	12	16	1

NOTE: Each cell of this table presents the combined percentages for two response categories—"most lessons" and "all lessons"—of the four available for the question asked each population. The percentages across the cells within the table should therefore not be expected to sum to 100 by row or by column.

But this variety is not in evidence in Japan. There, over three-quarters of all instruction is teacher-led whole class instruction. At the elementary level, whole class with student interaction is also common, although much less so in the middle school years. Teacher-supervised individual work occurs far less often than in the U.S. or Ohio. Independent work is also not very common, nor is group work. Still, the TIMSS video study makes clear that in Japan this uniformity does not necessarily stifle student engagement (Stigler & Hiebert, 1999). In fact, Japanese instruction is often held up as an example of the instructional innovations that U.S. math education reformers want to see (Peak, 1996).

Compare also the patterns observed in the First in the World Consortium. There, unlike in Japan or Ohio, primary math teachers do considerable classroom group work, although whole class work remains the most common mode. Primary classes also appear not to be as dominated by the teachers. However, the pattern is markedly different in middle school. Here most teachers work most of the time in teacher-led whole class instruction. Independent work is also teacher driven. The pattern looks remarkably similar to the Japanese.

Recall for a moment that U.S. schools' performance in TIMSS was above average internationally at grades three and four. It fell sharply in middle school. Is it possible that the organizational and instructional patterns that work best for children and for learning are different at these grade levels? A strong emphasis on whole class instruction was reported in most other countries with high achievement in TIMSS at the middle school level (Beaton, 1996). Is that pattern conducive at this level to a more focused, and possibly more rigorous approach to mathematics instruction? Certainly that is the implication of the data from the First in the World schools (Kimmelman, 1999, p.43).

What Students Do during Mathematics Instruction

However, it is also necessary to understand what students are asked to do within these classrooms. The organizational pattern, after all, is only a vessel: what students learn is a function of the opportunities they receive during instruction and what they are enable to do with those opportunities. Table 9 presents a variety of evidence.

Table 9. **Ohio Teachers' Reports of How Frequently Students Are Asked to Do Certain Tasks During Mathematics Instruction**[32]

	Grades 3 & 4			Grades 7 & 8			Grade 12		
(in percent)	Rare	Some	Most	Rare	Some	Most	Rare	Some	Most
Explain reasoning behind ideas	0	27	73	1	30	69	0	27	73
Represent and analyze relationships using tables, charts, or graphs	3	85	12	7	77	16	8	59	33
Work on problems which have no immediate solution	26	67	7	17	67	15	15	58	27
Use computers to solve exercises	50	46	4	60	36	4	60	32	8
Write equations to represent relationships	13	55	32	12	54	34	1	36	63
Practice computational skills	1	17	82	4	21	75	18	24	58

Two of these tasks occur in almost all mathematics classrooms in Ohio, occurring most days and at all grade levels. These are explaining the reasoning behind mathematical ideas and practicing computation skills, although this latter task declines somewhat in high school. That these occur frequently is encouraging: students need to understand mathematics conceptually and to drill its mechanics. How much each should be present is harder to answer.

Ohio's expectations call for an increased presence of algebra in junior high school. If it is there, we would expect to find considerable time spent on the second and fifth tasks in the Table 9, representing and analyzing relationships and writing equations. While these occur often in some lessons, only equation writing appears in about a third of most lessons. That seems low if algebra is being stressed. By high school equation writing is common and graphical representation is seen with considerable regularity. However, one could wish for these skills to be acquired and extended earlier than twelfth grade.

Allowing students to develop their mathematical and problem-solving skills in situations where the solution is not obvious, but requires some ingenuity and bringing together and applying a variety of knowledge and skill is a strategy many reformers recommend.[33] The recommendation has sound basis in research (Lemaire & Siegler, 1995). However, this activity hardly occurs in a quarter of Ohio's primary level math classrooms. Yet, this is where much of the early learning of what mathematics is and can be should occur.[34]

While the availability of computers in mathematics classrooms is often more related to district wealth than any substantive pedagogical reason, where they are present, they can offer a variety of alternative mathematical exposures to students. However, they appear little used in Ohio's mathematics classrooms, regardless of grade level. In over half the classrooms they are never or rarely used in mathematics. In middle and high school they are used for some lessons in only about a third of the classrooms. Yet, this is precisely where computers in mathematics have available a relatively rich territory of materials and resources, with many software programs, applications, and emulations available.

We turn now to some comparative data, again using TIMSS, to provide a sense of whether the Ohio experience is unique. In Table 10, we compare the tasks Ohio's third and fourth grade students are asked to do to those in the U.S. and in the First in the World Consortium. Overall, what Ohio's primary school pupils are asked to

Table 10. **Teachers' Reports of How Frequently Third and Fourth Grade Students Are Asked to Do Certain Tasks During Mathematics Instruction**[35]

	Ohio			**U.S.**			**FiW Consortium**		
(in percent)	Rare	Some	Most	Rare	Some	Most	Rare	Some	Most
Explain reasoning behind ideas	0	27	73	1	28	71	0	14	86
Represent and analyze relationships using tables, charts, or graphs	3	85	12	10	81	9	9	86	5
Work on problems which have no immediate solution	26	67	7	35	59	7	22	64	14
Use computers to solve exercises	50	46	4	60	39	1	36	64	1
Write equations to represent relationships	13	55	32	18	55	28	5	65	30
Practice computational skills	1	17	82	1	29	70	2	40	58

in math class appears fairly similar to the U.S. average. Somewhat more of Ohio's students at this age group are exposed to using equations to show relationships, or, more accurately put, fewer classrooms receive no exposure to this. This lower likelihood of no exposure also applies to table and graph use, problems without obvious solutions, and computer use. However, at this level Ohio's students typically are considerably more likely to practice computation than elsewhere in the U.S.

A comparison to the First in the World Consortium brings out a few more differences. In these high performing schools, the emphasis on computational practice most lessons is reduced sharply. Instead, more time is spent there on working on the reasoning around mathematical ideas, and somewhat more on problems without immediate solutions. Table 11 extends the comparison to the middle school years.

Table 11. **Teachers' Reports of How Frequently Seventh and Eighth Grade Students Are Asked to Do Certain Tasks During Mathematics Instruction**[36]

	Ohio			**U.S.**			**FiW Consortium**		
(in percent)	Rare	Some	Most	Rare	Some	Most	Rare	Some	Most
Explain reasoning behind ideas	1	30	69	1	32	67	0	24	76
Represent and analyze relationships using tables, charts, or graphs	7	77	16	15	73	12	7	72	21
Work on problems which have no immediate solution	17	67	15	24	65	11	14	68	17
Use computers to solve exercises	60	36	4	76	21	3	44	56	0
Write equations to represent relationships	12	54	34	5	58	37	0	23	77
Practice computational skills	4	21	75	11	31	58	18	56	26

As in Table 10, Ohio's data are nearly identical to those for the U.S. overall. As in the primary classrooms, there are somewhat fewer middle grade classrooms in Ohio, relative to the U.S., where table and graph use, problems without obvious solutions, and computer use are instructional strategies not used by teachers. While these are positive signs for mathematics instruction, the indicator in this set for algebra—writing equations—in fact is slightly less common in Ohio's middle grade math classrooms than is typical for the U.S. as a whole. Striking at this level too is the fact that Ohio's middle school math teachers ask students to spend a lot more time practicing computation than is typical elsewhere.

A comparison to the Consortium here too sharpens distinctions observed at grades three and four (see Table 10). Over three-quarters of the math teachers in the middle schools there ask students to write equations in most or all lessons. In no teacher's class is this not a requirement, whereas that is so in one in eight Ohio middle grade math classes. Working with data relationships expressed in charts, graphs, or tables is also somewhat more frequent. On the other hand, in the

Consortium middle schools, computational skill practice drops even more than it did in the primary grades.

Coming to Terms with the Evidence on What Is Taught and How It Is Taught

These survey data by themselves cannot comprehensively nor conclusively describe and explain the state of Ohio's K-12 mathematics education system. They do, however, provide new evidence and new perspective on what gets taught and how it gets taught in Ohio's public schools mathematics classes. Factored in with other information they will support better decision making about the future directions of Ohio's math education.

The picture they paint is of an education system that shares many of the faults and credits that accrue to the U.S. education system, within which it exists. These data, taken altogether, also suggest the Ohio system is no more focused and no less variable than the U.S. system. Good teaching and learning do occur. Ohio's statewide mathematics SAT average runs about 30 points above the U.S. average (Snyder, 1999, p. 151).[37] Reports from skilled teachers confirm numerous instances of excellent and creative teaching, representing a large but untapped reservoir of talent (Otto, 2000).

On the other hand, even in Ohio schools that are working hard, teaching and learning are not always what they can be (Hewson & Kahle, 1999). The survey data suggest that most Ohio school districts expect, and most mathematics teachers try, to teach too many topics within curricular structures that are not well rationalized or articulated. Districts appear to lack a commitment to a consensus about what constitutes the core of mathematical knowledge and skills that students should acquire, instead adding topics throughout the curriculum. By doing so, they continue to deprive teachers of the opportunity to teach mathematics deeply and to mastery for all students.

Ohio's teachers are expected to convert the plethora of topics in the local curricula into coherent instruction. The resources they can turn to for support in this are relatively few: each other, local curriculum specialists, textbooks, possibly discussions about the impact and applicability of the national standards movement. The time they have available to work with these resources is minimal. Moreover, these resources are seen to be of limited assistance in focusing instruction, in setting priorities for what to teach, in supporting rigorous content, and selecting successful instructional strategy.

Of the available resources, only the Learning Outcomes for the Ohio Proficiency Tests are both authoritative in the state, and have begun to function to define the critical elements of the mathematics curriculum (LOEO, 2000). The publication this year of district and school report cards has increased their prominence in focusing instruction. Still, the Learning Outcomes do not possess the detail, the rigor, nor the clarity that teachers need to convert curriculum to instruction. Nor are these really the charge of what are essentially testing specifications. That should be the consequence of state academic standards and districts' efforts to support teachers.

Undergirding the current and potential effectiveness of Ohio's mathematics educational system, of course, is the quality of its teachers. Hiring the best teachers is one aspect. More critical is the support provided to keep them the best (National Research Council, 2000*a*). Here Ohio's districts often seem to fall short, despite some good efforts.[38] Certainly, in terms of classroom practice, the survey data suggest that Ohio's mathematics teaching and achievement is open to the same charges leveled recently against U.S. mathematics teaching and achievement.

In fact, we have uncovered lines of evidence that suggest Ohio may be doing less well than many other states. Mathematics curriculum appears to teach many topics later than elsewhere, topics are repeated over a wider range, teachers spend more time drilling basic computational skills, and classroom organization suggests strong dependence on traditional teaching patterns.

Changing schooling is surprisingly difficult (Tyack & Cuban, 1995), but not impossible (Fullan, 1991). What and how teachers teach is at the core of schooling. What we know about learning has changed (Bransford, 1999). This requires teaching change. But, in schooling, change cannot be uniform: "the search for answers to improving school performance and student achievement will never yield just one value—that is, solutions that will work for all schools and students in all times and places" (Ladd & Hansen, 1999).

But, the conditions and culture of schooling make this difficult. Teachers typically spend 35-40 hours per week alone in a classroom with 25 or so students. Add to this the routine work of reporting, planning, and paperwork, and there is very little time left for the kind of intense involvement in the intellectual enterprise of teaching and learning required to engender and maintain fundamental change.

Many teachers believe that the key to changing math education is *collaboration*. As one Ohio teacher told us (Otto, 2000), "The need for a cooperative venture in education—teachers to administrators to the state—is paramount." This theme permeates the relationships among teachers within the same school, districts, and subject areas. It extends to teachers across the state, as well as administrators, policymakers, business leaders, community members, and parents. No group alone will affect meaningful change in math and science education without cooperation, input, and collaboration from all others, Ohio's teachers claim.

Ohio's teachers convey an unsettling sense of isolation in their missions. Many feel alone, not simply when standing in front of their classrooms, but in their desire to do what needs to be done for the student. They feel little meaningful support from their administrations or communities. They feel at times ignored and discounted, even though they serve closest to the students themselves. And, as discussed elsewhere in this report, what tools and resources they do have available are often lacking.

Clearly, Ohio's mathematics teachers need to be better supported. This implies several opportunities:

- We need to learn more about the resources teachers currently use, with an eye to understanding their strengths and weaknesses, building on the first and remedying the latter. Despite their remarkable strengths, building a Model Curriculum and then expecting curriculum specialists to re-train teachers, for teachers to become familiar with it conceptually, and then to build suitably revised practice is somewhat naïve. Teachers work enmeshed in a web of local practice and belief and history and constraints. New concepts, new approaches may or may not fit that web. It will tend to shrug off what is different. Solutions that arise from within that web need to be identified and supported.
- We need to provide teachers with better knowledge of the consequences of the choices they make. This requires tools that measure student learning in relation to teaching initiatives, and in real time. Annual, standardized tests are potentially useful systemic accountability tools. They are not particularly useful to help teachers determine what works instructionally and what does not. What teachers need are measures that tell them whether this week's approach was more or less effective than last week's. Such measurement is not well supported in schools—and in fact is not likely unless schools and curricula become markedly more focused and rigorous.
- Tools to help teachers see what works for them in their daily lives are valuable. But, these will generate only occasional, haphazard improvements unless they exist in an organizational culture that values reflection and encourages the experimentation and risk-taking that improvement requires. Most schools today are not institutions that foster these attitudes.
- Schools must become more supportive of teacher initiative. Teachers need more time and more frequent opportunity to work together on instructional problems. Teachers need opportunity to see and hear about other ways of structuring teaching and learning. Opportunities for mentoring and sharing need to exist in the routine of work life in schools, not just in set aside moments.
- Teachers and administrators must learn to listen to students more. Learning often starts when perception contradicts belief. The opportunity to make

this happen will not occur unless teachers know what students believe about mathematics. Given better knowledge about students, it is easier to structure class work so that students can meaningfully explore and invent, rather than memorize. Teachers and organizations that listen better to students will also listen better to adult staff. Here too the opportunities for perception to come into conflict with belief should be sought, and the motivation to change, to improve strengthened by the contradictions.

- Districts, schools, and staff must devote time to thinking hard about what is to be taught, when, to whom, and how. This will be hard and protracted work, but it will result in more focused curricula and enhanced opportunity for all students to be exposed to deep mathematical thought. It is not wise to expect each district to do this independently. Neither is it wise for a state agency to do this work alone. Rather, multiple long-term collaborative efforts reaching across the customary boundaries give great promise of building curricula that are focused, rigorous, yet have sufficient scope and depth. Support for such work should come from a wide range of participants, including the state, business, advocacy groups, academia, and research institutes.
- As these solutions come on track, an opportunity structure must be built for teachers to continually engage in deep and meaningful professional dialog about the craft of teaching, content knowledge, and the science of learning. This will require several modifications in how we structure schooling. A key will be to find the time for teaching staff not spent supervising students. In addition, teachers will need support to learn how to work together since, unlike other professionals, this is not something they have been trained for or have experienced.

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NOTES

[1] This report focuses on mathematics. A companion report (van der Ploeg, 2000) focuses on science.

[2] These four questions are a rewording of the core of the conceptual model that underpins the TIMSS perspective on teaching and learning. It was elaborated and refined over a multi-year period in the early 1990s by a group of senior researchers from six countries working together to build an internationally consistent conceptual framework (Schmidt, Jorde, Cogan, et al., 1996). An overlapping group of international experts supplemented this work with the specification of a content model or curriculum framework for mathematics (Robitaille et al., 1993).

NCREL considers the TIMSS model and framework to be at the forefront of efforts to understand curriculum, instruction, and their consequences. We therefore adapted from these instruments for our study of Ohio's mathematics education system. However, NCREL fully accepts that survey instruments do not capture all the richness and variety that transpires in schools each day.

[3] In another report (van der Ploeg, 2000), we use extant sources to fill in some gaps in our discussion here of the first three questions, and we hazard some evidence on the fourth question.

[4] Because the survey questions are the same, the responses of Ohio's schools may be compared to those of the nations in the original TIMSS sample. In addition, other comparisons are becoming possible. Under the auspices of the National Center for Education Statistics (NCES), some of the TIMSS instruments have since 1996 been administered in a number of U.S. states and in the First in the World Consortium in Illinois (Kimmelman, Kroeze, Schmidt, et al., 1999). The IEA in 1999 sponsored TIMSS-R, re-administering TIMSS internationally; a larger number of U.S. states and consortia participated, including Project SMART in Ohio.

[5] These grades were chosen to coincide with the three TIMSS populations. The 1995 TIMSS did not employ a teacher survey for Population 3, end-of-secondary school. A survey form for teachers at this level was drafted in preparation for TIMSS (Schmidt, Jorde, Cogan, 1996). We administered an abbreviated version of this instrument.

[6] The number of Ohio public school districts is not fixed. For instance, in March 2000 a new district was formed, bringing the total to 612. Also, there are numerous schools in Ohio that are not public. About 50,000 high-school-age Ohio students, just less than 10 percent of all such students, attend them. Initially, we planned to include these in our sample. However, it became clear that we could not well identify the connections among these schools. That is to say, we could not expect to be able to talk about typical patterns of content exposure, because we could not tell from which school a student enrolled in a non-public high school came.

[7] Staff of the Ohio Department of Education was provided us a list of schools in summer 1999 that was the most current available at that time.

[8] Such identification tends to depress response rates. However, generalization to typical patterns of curriculum delivery and student exposure required we link schools at various levels.

[9] Some districts returned only one GTTM, with the district's curriculum leader responding for all grades and buildings. Elsewhere, school curriculum leaders completed the GTTM. In a few cases, we received multiple GTTMs from a building, one from each teacher teaching math. This variety makes it difficult to determine an exact, person-based response rate.

[10] Although we would prefer them to be higher, these return rates are, in fact, quite respectable. Compare the following. A recent survey on the value and utility of Ohio's Ninth Grade Proficiency Tests conducted by Ohio's Legislative Office of Education Oversight and distributed to some 900 eighth grade teachers obtained a 63 percent return rate (Lochtefeld, 2000). Compare also a national study recently published in a top refereed professional journal. This explored the relationships between school and staff characteristics and the fidelity with which school reform models are implemented. It was based on a sample of 184 schools, with a 68 percent teacher response rate (Berends, 2000).

[11] The TIMSS study used stratified random sampling of schools and classrooms. Several statistical weights are available to support analysis and appropriate generalization to students, teachers, or schools. Our Ohio sample had no explicit strata and we calculated no sampling weights. For consistency's sake, we therefore report only unweighted TIMSS survey results in this report.

[12] Although now approaching 10 years of age, these documents continue to receive strong support from a variety of independent perspectives (Finn & Petrilli, 2000; Finn, Petrilli, and Vanourek. 1998; Glidden, Masur & Snowden, 1999); Jerald 2000; Joftus and Berman, 1998).

[13] The Learning Outcomes that the Proficiency Tests measure have faced external review less often than the Model Curricula. A recent review conducted by Achieve, Inc. concluded the Outcomes were generally too "vague," although less so in science and mathematics than in other subjects.

[14] The "whiskers" at the end of each bar indicate how much Ohio's districts vary around the average. The further apart the top and bottom whiskers are, the more the districts differ. The whiskers also indicate when two averages may be said to be

meaningfully different. If the whiskers of two columns do not overlap, then the difference between the grades is unlikely to be caused by chance.

[15] We do not present the charts like Figure 3 for the U.S. and Japan. Suffice it to say, that the U.S. chart is very similar to the Ohio chart, although not always the range from first introduction to last use is usually not as broad. The Japanese chart is markedly different, as the commentary in the text makes clear.

[16] This does not mean that Japanese students did not do well on the TIMSS achievement tests. They did, both at the primary and the middle school level, markedly outperforming the U.S.

[17] Since TIMSS did not administer a teacher survey at the end-of-secondary level, these summary comparisons cannot extend to high school.

[18] However, we can be confident that Ohio's teachers' are quite similar in most basic respects to teachers nationally. The most recent data from the National Center for Education Statistics (2000) tells us that highest degree of 53 percent of Ohio's teachers a bachelor's, one percentage point above the national average; 42 percent attained a master's, the same as the national average. Ohio's teachers are experience with just over 31 percent having taught more than 20 years, compared to 30 percent nationally. The typical Ohio teacher was paid $38,977 in 1998, about $400 dollars less than the national average. These numbers, of course, cannot convey teachers, skills, motivation, or commitment (see Farkas et al., 2000).

[19] NCTM refers to the National Council of Teachers of Mathematics, which has been instrumental in developing standards for mathematics teaching.

[20] To comprehend the richness of knowledge and skill and capacity required to suport good teaching, it pays to review examples of good teaching. Chapter 7 of Bransford (1999) elucidates a number of cases. The sidebar to Gibbs (1999) provide others. The *Captured Wisdom* series of CD-ROMs provide numerous examples of rich and technologically sophisticated mathematics lessons (at www.ncrel.org/cw/index.html)

[21] These "math wars" are in some ways akin to the more familiar reading wars pitting phonics proponents against more wholistic approaches. In both cases, what is evidence, conjecture, and rhetoric can be hard to determine for the uninitiated. Nor are these experts themselves necessarily open and unbiased. The U.S. expert panel, for instance, included proponents of several of the programs being evaluated; the panel chose not to consider long-term evidence of success; the panel stipulated that programs must follow or support NCTM standards (Clayton, 2000)

[22] Mathematically Correct is a loose association of mathematicians and educators. Their positions and reviews are available on their website at www.mathematicallycorrect.com only.

[23] The full list of titles appears below here. No systematic reviews of textbooks have been competed at this level.

Mathematics Textbooks In Use in Grade 12 in Ohio

Publisher	Textbook	Percent of Teachers
McDougal Littell	Algebra & Trigonometry: Structure & Method, Book 2	9
Glencoe	(Merrill) Advanced Mathematical Concepts: Precalculus with Applications	6
McDougal Littell	Precalculus: A Graphing Approach	6
Scott Foresman/Addison Wesley	UCSMP Advanced Algebra	6
Houghton Mifflin	Advanced Mathematics: Precalculus ...	5
McDougal Littell	(Heath) Algebra 2: An Integrated Approach	5
McDougal Littell	Geometry for Challenge & Enjoyment	4
McDougal Littell	Integrated Math	4
Scott Foresman/Addison Wesley	Calculus: Graphical, Numerical, Algebraic	4
Scott Foresman/Addison Wesley	UCSMP Precalculus & Discrete Mathematics	4
Addison Wesley	Algebra & Trigonometry	2
Addison Wesley	Precalculus: A Graphing Approach	2
McDougal Littell	(Heath) Geometry: An Integrated Approach	2
McDougall Littell	(Heath) Precalculus with Limits: A Graphing Approach	2
Prentice Hall	Algebra 2 with Trigonometry	2
Saxon	Algebra 2: An Incremental Development	2
Scott Foresman/Addison Wesley	UCSMP Functions, Statistics & Trigonometry	2
Freeman	The Practice of Statistics	1
Glencoe	Algebra 2: Integration, Applications, Connections	1
Glencoe	Geometry	1
Glencoe	Mathematics Connections: Integrated & Applied	1

Harcourt Brace	Algebra 2 with Trigonometry	1
Harcourt Brace	Calculus with Analytic Geometry	1
Harcourt Brace	Calculus: One and Several Variables	1
Harcourt Brace	The Calculus: Graphical, Numerical & Symbolic ...	1
Holt Rinehart & Winston	Algebra II with Trigonometry	1
Houghton Mifflin	Algebra & Trigonometry: Structure & Method, Book 2	1
Houghton Mifflin	Geometry	1
Key Curriculum Press	Calculus: Concepts & Applications	1
Longman	Introductory Algebra	1
McDougal Littell	Algebra 1: An Integrated Approach	1
McGraw-Hill	Elementary Statistics: A Step by Step Approach	1
Merrill	Algebra 2	1
Prentice Hall	Advanced Algebra	1
Prentice Hall	Applied Calculus for Business, Economics, Life ...	1
Prentice Hall	Precalculus, Enhanced with Graphing Utilities	1
PWS Publishing	Precalculus Functions & Graphs	1
Saxon	Advanced Math: An Incremental Development	1
Scott Foresman	Calculus with Analytic Geometry	1
Scott Foresman/Addison Wesley	Calculus of a Single Variable	1
Scott Foresman/Addison Wesley	UCSMP Geometry	1
	Buckle Down! In Ohio Math	1

[24] In 1999, Ohio required high school credits equal to two Carnegie units in mathematics. This was to change to three units effective in 2001. In 1999, of those states with requirements, 18 called for three units, 24 for two units.

[25] The Proficiency Test that influences the middle school level is, of course, the Ninth-Grade Proficiency Test. This is the oldest of the Proficiency Tests, and the only one focused on *minimum* competencies, rather than higher levels of expectations. Its purpose is to assure that those receiving high school diplomas are competent in basic mathematical skills. A recent report suggests that this emphasis on minimum competencies has narrowed the middle school curriculum in numerous districts and that most teachers forego some instructional content to prepare students for the test (LOEO, 2000).

The Ninth-Grade Proficiency Test will soon be replaced by a more difficult, wider ranging test, the High School Graduation Qualifying Exam, to be given in tenth grade, beginning with the graduating class of 2005.

[26] Ohio's school districts are under mandate to review textbook adoptions every five years. In light of this, it is somewhat difficult to understand why some districts continue to rely on decade-old textbooks. Is cost an obstacle? That is, is it that some districts simply cannot afford new textbooks? Are newer editions simply not worth the cost? That is, is it that they find the differences between older and newer versions not instructionally consequential?

[27] Updating a text, assuring it doesn't omit a critical need in one of the larger markets (i.e. California, Texas, New York) is expensive, but doable. Designing and conducting large-scale controlled experiments to determine a textbook's effect is expensive and requires time. State requirements change frequently and sales points occur annually. More critically, experimentation is risky: what if the results fail to confirm effectiveness? One member of the U.S. expert panel insisted on such evidence of long-term impact on student achievement; the other panelists did not accept this as a criterion: the programs were "too new" to generate such data (Clayton, 2000). This lack of data is not uncommon in curricular decision making. The Obey-Porter legislation of 1997 encouraged schools nationally to adopt proven educational programs, and required program vendors to provide such proof. Even among the programs the legislation singled out, only one had solid long-term student achievement impact data; another one or two had amassed strongly supportive data (Herman, Aladjam & McMahon, 1999; Northwest Regional Educational Laboratory, 1998). Even for these three, there has been considerable debate among the specialists as to the reliability the data and methods and the veracity of the claims made (Pogrow, 1998).

[28] The sheer size of today's textbooks makes it difficult to evaluate one, let alone keep up with many. A graphic comparison appears in a recent *Scientific American* article which contains a picture of the core textbooks for four years of science from three high schools, one each in Sweden, Canada, and the U.S (Gibbs & Fox, 1999, p. 88). The Swedish stack is four thin paperbacks. The North American stacks are each four fat hardbacks, larger in all dimensions. And, this does not include the student workbooks and ancillary texts used in most U.S. high schools.

[29] We stress that the measure is indirect. Collaborative, interactive, engaging instruction is possible under many organizational regimes. Significant learning can occur in even very rigid structures, as any military recruit can attest after basic training. However, the purpose of schooling is at some remove from the purpose of the military.

[30] The responses reported in this table have been collapsed into three categories. Teachers were originally asked to respond to the choices “never or almost never,” “some lessons,” “most lessons,” or “every lesson.” For this table, the last two categories have been combined into “most.”

[31] The data sources for this table include Beaton (1996), Kimmelman (1999), and Mullis (1997).

[32] See endnote 30.

[33] This is not say that the research recommends simply throwing novel problems at students. Rather, good teaching provides opportunities for students to work out solutions that are at the edge of their knowledge, but not unreachable. Good teachers will assure also that students have available the resources they need to support their work.

[34] It may be argued that third or fourth grade is the point where many students “lose it” with respect to mathematics. They learn, laboriously, arithmetical procedures, procedures that to many seem arbitrary at best. They cannot easily recover to come to recognize the beauty of the patterns of mathematical abstraction. The human brain is naturally skilled at pattern recognition, a sort of *fuzzy* process. The precision of arithmetical calculation is not natural to the human brain. It requires a different kind of training. U.S. elementary school mathematics teaching rarely moves beyond the difficulties of procedural arithmetic. We cloud the beautiful with the difficult—because we have come to know the rules, but not the reasons. Cf. Bailey (1996) and Devlin (2000).

[35] See endnote 30. The data for this table come from Kimmelman (1999) and Mullis (1997).

[36] See endnote 30. The data for this table come from Beaton (1996) and Kimmelman (1999).

[37] Not all students take the SAT. Restricting the comparison to those states in which proportions of students roughly equal to Ohio’s 25 percent take this exam, Ohio performs just above the group average.

[38] For the past few years, in partnership with the National Commission on Teaching and America’s Future (NCTAF), Ohio has built an infrastructure to support new procedures for preparing, licensing, and promoting teacher professional development. Still, more is needed.