Journal of Science Education and Technology, Vol. 7, No. 1, 1998

Facing Facts in U.S. Science and Mathematics Education: Where We Stand, Where We Want to Go

Curtis C. McKnight[1,3] and William H. Schmidt[2]

The Third International Mathematics and Science Study (TIMSS) provides data that seems clearly important to science and mathematics education in the U.S. TIMSS gathered extensive data on curriculum, textbooks, teachers, and instructional practices in science and mathematics education and some of these data are presented and discussed. Eighth grade achievement data show the U.S. to be somewhat above average in science achievement but consistently average or below in mathematics. U.S. official curricula cover comparatively many topics and are relatively unfocused. U.S. science and mathematics textbooks typically take a cautious, inclusive approach keeping traditional content while adding new reform topics. They thus lack. Teachers, without guidance to help them focus, typically divide their attention among many topics. Empirically, there is little agreement in the U.S. on what is truly "basic" judging by common topics among curricula and textbooks. U.S. teaching, at least in mathematics, is teacher and moves among many different activities, failing to tell a coherent story. We must face these as we seek to find ways to become what we want to be in providing science and mathematics education.

KEY WORDS: Science education; mathematics education; international comparisons.

INTRODUCTION

An old maxim about the boxing ring says, "You can run but you can't hide". That saying is true of science and mathematics education in U.S. schools today. We must face the facts of our current state in science and mathematics education, of where we stand and how far we are from where we want to go. The Third International Mathematics and Science Study (TIMSS) was designed to reveal important facts about our current efforts to provide pre-college students with effective education in the sciences and mathematics.

So far, TIMSS has revealed what it was expected to reveal and more. We who would see science and mathematics education improve significantly now must face those facts. We must look honestly at where we stand in comparison to other nations with which we share the world's economic arena. TIMSS goes beyond facts about where we stand to reveal deeper truths than how our students' science and mathematics achievements compare with other countries' students. We must also face some hard facts about how we got to where we are if we hope to move beyond our current status. After facing these facts, we must take a new look at where we want to go—our visions, goals, and hopes for educating our young people in science and mathematics. Our hope is that in facing facts together we will together pursue renewed, realistic educational visions.

This article is not new material. In Fall 1996, TIMSS moved from the first steps of its analyses to the first phases of its reporting. TIMSS reports will eventually consider science and mathematics outcomes for fourth graders, eighth graders, and those finishing high school (although the actual student

---

[1] Mathematics Department, PHSC 423, University of Oklahoma, 601 Elm Ave., Norman, Oklahoma 73019.

[2] CEPSE, Michigan State University, East Lansing, Michigan.

[3] Correspondence should be directed to Curtis C. McKnight, Mathematics Department, PHSC 423, University of Oklahoma, 601 Elm Ave., Norman, Oklahoma 73019.

1059-0145/98/0300-0057$15.00/0

populations studied by TIMSS are defined somewhat more precisely). So far, achievement results have only been released for U.S. seventh and eighth grade science and mathematics and for the corresponding grades in other TIMSS countries. TIMSS has released more extensive information on curricula and textbooks. Most of what is discussed here summarizes material in two recent reports (NCES, 1996; Schmidt, McKnight and Raizen, 1997). These reports examine closely the pivotal data for U.S. eighth grade and that is the focus here.

A WORD ON METHODS

TIMSS collected data related to what has been called the *intended* and *implemented* curriculum of participating nations as well as achievement outcomes (Schmidt and McKnight, 1995). The *intended* curriculum includes national systems' educational goals as laid out in their curricular documents and other documents articulating national visions and plans. Curricular intentions are also reflected in the content of textbooks and other instructional materials. These were analyzed through carefully segmenting, classifying, and characterizing the full text of curriculum guides and materials in the TIMSS countries.

The *implemented* curriculum is what teachers actually deliver in the classroom. These data were collected using a series of survey instruments administered to the teachers of the students sampled in TIMSS' achievement testing. Surveys were also used to collect contextual data that help to clarify differences and similarities among educational systems.

Student achievements were measured through tests of student performance. One of TIMSS' primary goals was to relate differences in student achievement to differences in the intended and implemented curriculum as documented in the other parts of TIMSS.

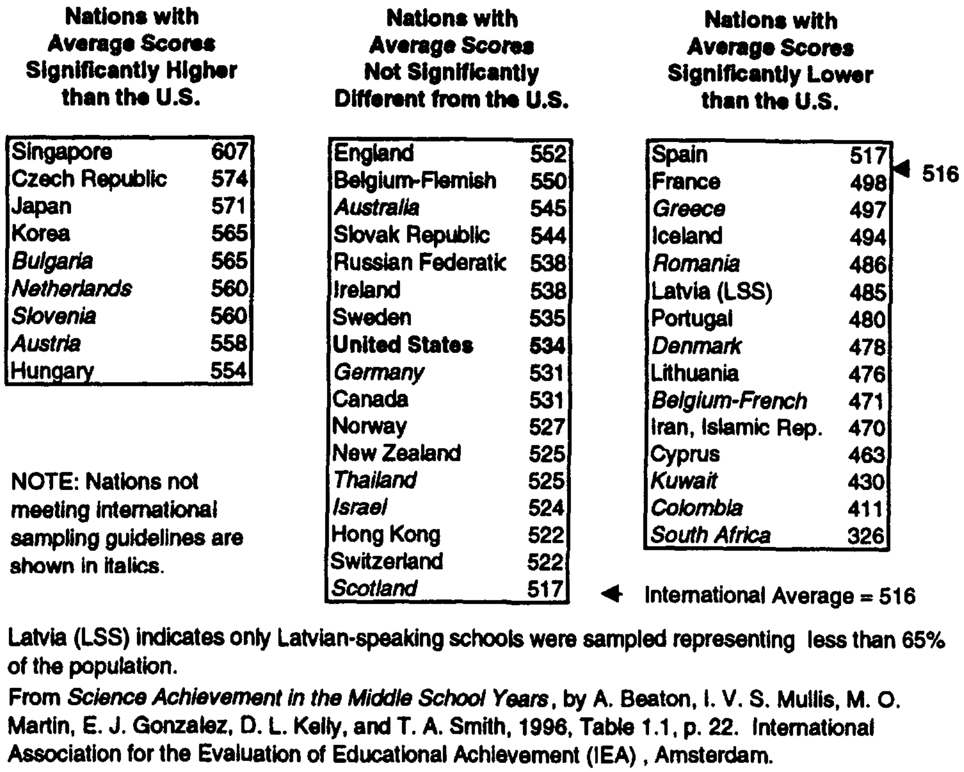
Developing valid, sensitive measures of student achievement as curricular attainments is not easy. The measures must reflect essential rather than accidental attainments of the education systems involved. They must be sensitive to differences across educational systems. The diversity of relevant educational systems, curricula and goals increases with the number of participating nation. This increases the difficulty of writing achievement tests that match those goals and curricula. There is an inherent need to increase the range of curricular goals sampled by test items. This is reflected in demands to sample more domains and sub-domains even within common broad areas such as mathematics or science. Developing appropriate achievement tests is far from a simple exercise in domain-referenced testing.

This article focuses almost entirely on TIMSS Population 2, that is, the two adjacent grades in each participating country that contain the majority of thirteen-year-old students. Students tested were selected by careful sampling plans designed and implemented by each country. The plans and their implementation were evaluated by sampling experts acting as referees. The samples in each country were comparable. They were PPS (probability proportional to size) stratified random samples requiring equal inclusiveness among the student populations in the participating countries. Careful attention was paid to make sure that data did not reflect inappropriate comparisons (for example, average students in one country and students in specialized tracks, streams, school types, or regions in another country).

The achievement test designed for the TIMSS thirteen-year-old students included eight test booklets. Each booklet contained 40 mathematics and 40 science items sampled from a larger pool of 135 mathematics items and 151 science items. Most items were multiple choice. Some "open" short-answer and extended-response items were also used. Test administration was designed so that all eight test booklets would be used in each sampled class, although this goal was not always implemented in all countries and deviations are noted in official reports as is substandard sampling.

All TIMSS test items were coded according to mathematics and science frameworks developed for TIMSS. These frameworks underwent detailed development and multi-national review. They were reported extensively in technical reports, a monograph, and appendices in more recent TIMSS (for example Schmidt *et al.*, 1996 and Schmidt, McKnight *et al.*, 1997). The frameworks specify a hierarchical-coding scheme relating to three "aspects" of curriculum: content (topic area), performance expectations (what students are expected to be able to do with particular content), and perspectives (attitudes or values).

For the population discussed here, the TIMSS mathematics test measured performance on 25 topics, and the science test on 49 topics. However, because of student testing time limitations, items were sampled and booklets put together to allow reliable scaling. Global scales ("science", "mathematics")



Nations with Average Scores Significantly Higher than the U.S.

Singapore	607
Czech Republic	574
Japan	571
Korea	565
Bulgaria	565
Netherlands	560
Slovenia	560
Austria	558
Hungary	554

Nations with Average Scores Not Significantly Different from the U.S.

England	552
Belgium-Flemish	550
Australia	545
Slovak Republic	544
Russian Federatic	538
Ireland	538
Sweden	535
United States	**534**
Germany	531
Canada	531
Norway	527
New Zealand	525
Thailand	525
Israel	524
Hong Kong	522
Switzerland	522
Scotland	517

◄ International Average = 516

Nations with Average Scores Significantly Lower than the U.S.

Spain	517
France	498
Greece	497
Iceland	494
Romania	486
Latvia (LSS)	485
Portugal	480
Denmark	478
Lithuania	476
Belgium-French	471
Iran, Islamic Rep.	470
Cyprus	463
Kuwait	430
Colombia	411
South Africa	326

◄ 516

NOTE: Nations not meeting international sampling guidelines are shown in italics.

Latvia (LSS) indicates only Latvian-speaking schools were sampled representing less than 65% of the population.

From *Science Achievement in the Middle School Years*, by A. Beaton, I. V. S. Mullis, M. O. Martin, E. J. Gonzalez, D. L. Kelly, and T. A. Smith, 1996, Table 1.1, p. 22. International Association for the Evaluation of Educational Achievement (IEA), Amsterdam.

Fig. 1. Nations' (eighth grade) average science performance compared to the U.S. (scale scores).

were constructed using a single-parameter IRT (item response theory) model. Six mathematics and five science sub-scale scores were also computed. The global scores were in an arbitrary metric with numbers (543 in Fig. 1) which are meaningless for any purpose other than comparing outcomes.

SELECTED RESULTS

Comparing U.S. Science and Mathematics Education Cross-Nationally

One important question about U.S. science and mathematics education is: "Where do we stand compared to other countries?" That is, "How do the students' science and mathematics achievements compare to those of other countries' students?" This is not the only important question, but it is, nevertheless, an important one. Here we present data on achievements for the eighth grade. Data on other grades will be released later this year.

Science Achievement. The TIMSS results reveal the U.S. as somewhat above average among the TIMSS countries testing students for the thirteen-year-old population. Figure 1 (adapted from an official TIMSS report) presents an overall comparison of science achievement (several areas from the sciences combined) for the U.S. and other participating countries. The scores represent scaled values (using a one parameter IRT model to achieve numerical values permitting comparisons of differences. The numbers shown (543, etc.) allow comparisons but their absolute magnitudes have no intrinsic meanings and are wholly artifacts of the scaling procedure. The differences are not. The categories of significantly higher, significantly lower, and not significantly different were used comparing these scores to the cross-national mean using standard errors computed for the scale.

U.S. students performed better than the cross-national mean but mean student scaled scores in several countries were significantly higher than U.S. students' mean scale score. those in the U.S. Many countries had scores that did not differ significantly from that for the U.S. and some had scores significantly lower. These data may seem at first not to be particularly good news since we profess a desire for a higher standing in science achievement among the community of nations. However, compared to mathematics achievement, these data indicate a degree of success and a good foundation for improvement.

The overall rankings are not particularly revealing. More can be seen by examining the scores (shown in Fig. 2 as national mean percentages of correct responses to items constituting the sub-test). Five different areas of school science are shown. These scores were obtained by grouping items from the TIMSS thirteen-year-old science tests into categories representing important areas within science education (as indicated by the category names).

The science education category "environmental issues and the nature of science" consisted of issue-oriented items not primarily focused on more specific disciplines (physics, chemistry, life science, earth science). Here the U.S. performed significantly above the international mean and only Singapore's students in clearly outperformed U.S. students. The environment has been a focus in U.S. science education and that focus has clearly resulted in "world class" achievement.

In the other four science categories in Fig. 2, the U.S. scored above the international average but not significantly so. In earth science, life science, and chemistry, there were only four to seven countries among those participating that had achievement results significantly better than the U.S. Physics at eighth grade represented our weakest comparative performance but even here the U.S. was essentially at the international average. However, more countries performed significantly better than the U.S. in physics than in other areas. These modest successes for science education are good news and a quite different story than the mathematics education results.

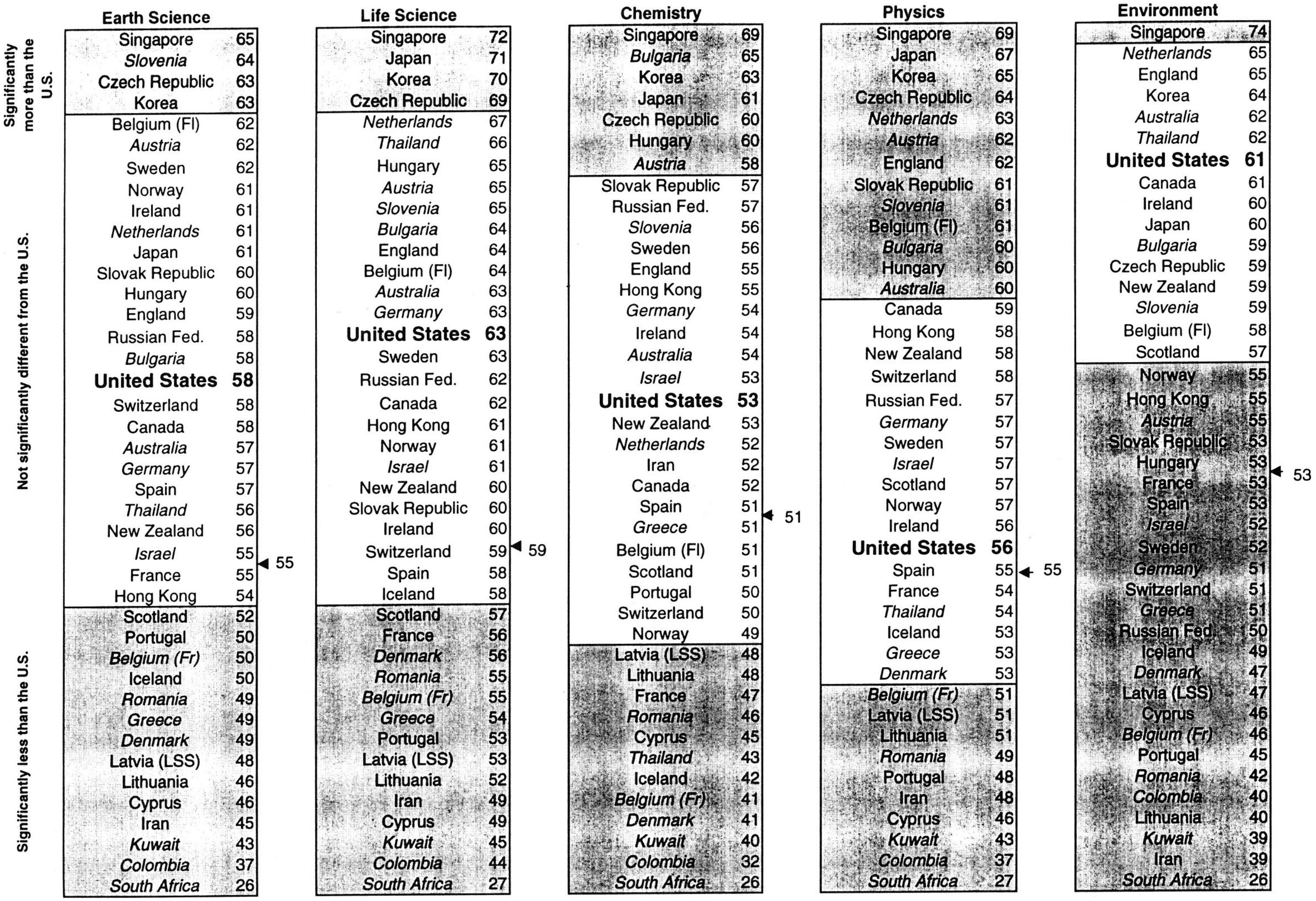
Mathematics Achievement. The U.S. scores on the thirteen-year-old mathematics test were below the international mean overall and in almost every area. For the mathematics "total test" score, U.S. students had a mean performance significantly better than that of only seven countries—Colombia, Kuwait, South Africa, Iran, Portugal, Cyprus, and Lithuania (Fig. 3). Again, the scores represent one parameter IRT scaled values useful only for comparisons. Differences may be only a few items more or less, but given large and representative national samples, these few items are sufficient to indicate consistent, statistically significant differences.

The achievement picture is somewhat more revealing if we break the TIMSS eighth grade mathematics test into different mathematical areas for reporting. Most TIMSS eighth grade mathematics test items can be assigned to one of six categories representing the primary mathematical emphasis of each item. A separate listing for each category is shown in Fig. 4. These again are the test results for thirteen-year-olds. As for science, these sub-test scores are reported as mean percentage of items answered correctly rather than as scale scores.

U.S. students performed comparatively better in "fractions and number sense" and in "data representation, analysis and probability". In both cases, the U.S. average was above the international mean and in both cases comparatively fewer countries scored significantly higher than the U.S. The reasons for these two "successes" are likely quite different. One major focus of U.S. mathematics reform efforts throughout the 1990's has been on representing and analyzing data (especially with graphs and simple statistics) and on probability. The comparative success here suggests that this attention has borne fruit in higher student achievements. This may well be because of the use of such content in studying science but, in any case, is certainly good news for those concerned about the tools our students have for learning science.

While "number sense" has also been an emphasis in reform, this category of questions includes many items on arithmetic operations with common and decimal fractions, and on comparing and representing these fractions. This has been a consistent emphasis in United States mathematics teaching up to and including eighth grade because these topics were typically introduced early and persisted far longer in United States curricula and textbooks than in those of most other countries. We perform better in this area because we continue to cover and "rehearse our performance" in it again and again.

U.S. students performed comparatively worse in "geometry" and in "measurement". In both of these areas, the U.S. average percentages of items correct were below the international mean and significantly below the scores of many countries. In both areas only four countries had scores that were significantly below the U.S. score. Measurement included not only questions about using measurement instruments, but also many more geometrical items in finding areas and volumes of common shapes and solids. Little of the measurement content depended on knowledge of the metric system. Geometry is a broad topic and the TIMSS eighth grade mathematics test



Earth Science		Life Science		Chemistry		Physics		Environment	
Singapore	65	Singapore	72	Singapore	69	Singapore	69	Singapore	74
Slovenia	64	Japan	71	*Bulgaria*	65	Japan	67	*Netherlands*	65
Czech Republic	63	Korea	70	Korea	63	Korea	65	England	65
Korea	63	Czech Republic	69	Japan	61	Czech Republic	64	Korea	64
Belgium (Fl)	62	*Netherlands*	67	Czech Republic	60	*Netherlands*	63	*Australia*	62
Austria	62	*Thailand*	66	Hungary	60	*Austria*	62	*Thailand*	62
Sweden	62	Hungary	65	*Austria*	58	England	62	**United States**	**61**
Norway	61	*Austria*	65	Slovak Republic	57	Slovak Republic	61	Canada	61
Ireland	61	*Slovenia*	65	Russian Fed.	57	*Slovenia*	61	Ireland	60
Netherlands	61	*Bulgaria*	64	*Slovenia*	56	Belgium (Fl)	61	Japan	60
Japan	61	England	64	Sweden	56	*Bulgaria*	60	*Bulgaria*	59
Slovak Republic	60	Belgium (Fl)	64	England	55	Hungary	60	Czech Republic	59
Hungary	60	*Australia*	63	Hong Kong	55	*Australia*	60	New Zealand	59
England	59	*Germany*	63	*Germany*	54	Canada	59	*Slovenia*	59
Russian Fed.	58	**United States**	**63**	Ireland	54	Hong Kong	58	Belgium (Fl)	58
Bulgaria	58	Sweden	63	*Australia*	54	New Zealand	58	Scotland	57
United States	**58**	Russian Fed.	62	*Israel*	53	Switzerland	58	Norway	55
Switzerland	58	Canada	62	**United States**	**53**	Russian Fed.	57	Hong Kong	55
Canada	58	Hong Kong	61	New Zealand	53	*Germany*	57	*Austria*	55
Australia	57	Norway	61	*Netherlands*	52	Sweden	57	Slovak Republic	53
Germany	57	*Israel*	61	Iran	52	*Israel*	57	Hungary	53 ◄ 53
Spain	57	New Zealand	60	Canada	52	Scotland	57	France	53
Thailand	56	Slovak Republic	60	Spain	51 ◄ 51	Norway	57	Spain	53
New Zealand	56	Ireland	60	*Greece*	51	Ireland	56	*Israel*	52
Israel	55 ◄ 55	Switzerland	59 ◄ 59	Belgium (Fl)	51	**United States**	**56**	Sweden	52
France	55	Spain	58	Scotland	51	Spain	55 ◄ 55	*Germany*	51
Hong Kong	54	Iceland	58	Portugal	50	France	54	Switzerland	51
Scotland	52	Scotland	57	Switzerland	50	*Thailand*	54	*Greece*	51
Portugal	50	France	56	Norway	49	Iceland	53	Russian Fed.	50
Belgium (Fr)	50	*Denmark*	56	Latvia (LSS)	48	*Greece*	53	Iceland	49
Iceland	50	*Romania*	55	Lithuania	48	*Denmark*	53	*Denmark*	47
Romania	49	*Belgium (Fr)*	55	France	47	*Belgium (Fr)*	51	Latvia (LSS)	47
Greece	49	*Greece*	54	*Romania*	46	Latvia (LSS)	51	Cyprus	46
Denmark	49	Portugal	53	Cyprus	45	Lithuania	51	*Belgium (Fr)*	46
Latvia (LSS)	48	Latvia (LSS)	53	*Thailand*	43	*Romania*	49	Portugal	45
Lithuania	46	Lithuania	52	Iceland	42	Portugal	48	*Romania*	42
Cyprus	46	Iran	49	*Belgium (Fr)*	41	Iran	48	*Colombia*	40
Iran	45	Cyprus	49	*Denmark*	41	Cyprus	46	Lithuania	40
Kuwait	43	*Kuwait*	45	*Kuwait*	40	*Kuwait*	43	*Kuwait*	39
Colombia	37	*Colombia*	44	*Colombia*	32	*Colombia*	37	Iran	39
South Africa	26	*South Africa*	27	*South Africa*	26	*South Africa*	27	*South Africa*	26

◄ International Average Percent Correct

From *Science Achievement in the Middle School Years*, by A. Beaton, I. V. S. Mullis, M. O. Martin, E. J. Gonzalez, D. L. Kelly, and T. A. Smith, 1996, International Association for the Evaluation of Educational Achievement (IEA), Amsterdam.

Fig. 2. National (eighth grade) averages in science content areas (mean percent of items correct).

Nations with Average Scores Significantly Higher than the U.S.	
Singapore	643
Korea	607
Japan	605
Hong Kong	588
Belgium-Flemish	565
Czech Republic	564
Slovak Republic	547
Switzerland	545
Netherlands	541
Slovenia	541
Bulgaria	522
Austria	539
France	538
Hungary	537
Russian Federatic	535
Australia	530
Ireland	527
Canada	527
Belgium-French	526
Sweden	519

Nations with Average Scores Not Significantly Different from the U.S.	
Thailand	522
Israel	522
Germany	509
New Zealand	508
England	506
Norway	503
Denmark	502
United States	**500**
Scotland	498
Latvia (LSS)	493
Spain	487
Iceland	487
Greece	484
Romania	482

◄ 513

Nations with Average Scores Significantly Lower than the U.S.	
Lithuania	477
Cyprus	474
Portugal	454
Iran, Islamic Rep.	428
Kuwait	392
Colombia	385
South Africa	354

◄ International Average = 513

NOTE: Nations not meeting international sampling guidelines are shown in italics.

Latvia (LSS) indicates only Latvian-speaking schools were sampled representing less than 65% of the population.

From *Mathematics Achievement in the Middle School Years*, by A. Beaton, I. V. S. Mullis, M. O. Martin, E. J. Gonzalez, D. L. Kelly, and T. A. Smith, 1996, Table 1.1, p. 22. International Association for the Evaluation of Educational Achievement (IEA), Amsterdam.

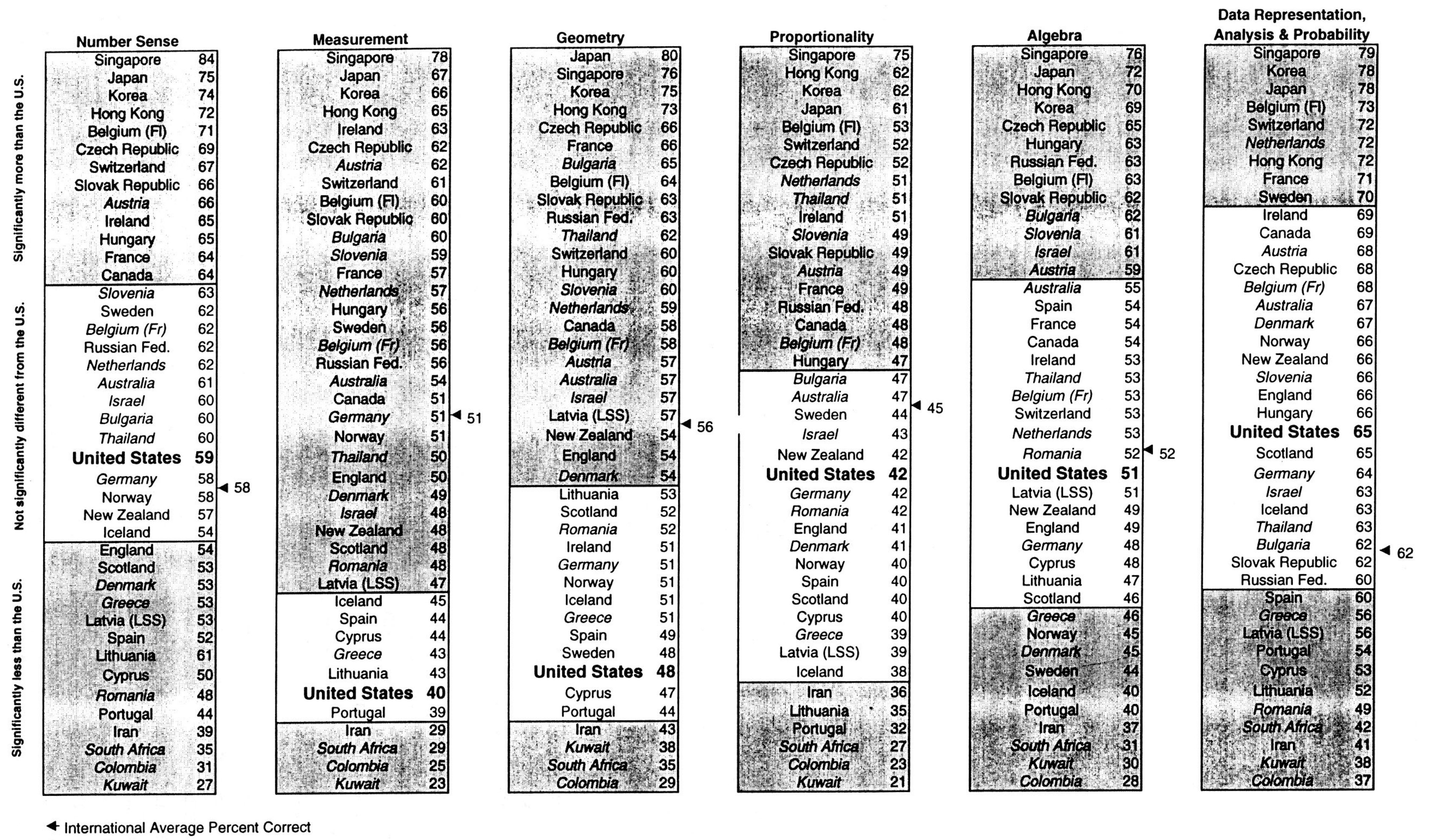
Fig. 3. Nations' (eighth grade) average mathematics performance compared to the U.S. (scale scores).

reflected this. However, while the U.S. may not have devoted extensive time to some of aspects of geometry, the same was true for most other countries. The geometry items were essentially "equally unfair" to most participating countries. The comparatively low achievements here thus are disturbing even if we regard the U.S. as not focusing extensively on this content prior to or during eighth grade. Of course, the release of the "end of high school" results in February, 1998, may show a difference pattern of geometry achievement.

DISCUSSION AND RELATED DATA

The results for both science and mathematics performances are disappointing for a nation that strives to be among the leaders in science and mathematics education and for whom the ability to compete effectively in the global economy is essential. The results for mathematics, weaker than those for science, might best be characterized as disastrous since they suggest that our students are not attaining the basic intellectual tools needed for successful pursuit of future careers in science or technological areas or even to behave literately in an increasingly technology-intensive society. How long can we maintain even somewhat above average science achievements if our students attain below average capacities in mathematics? At present our students have been comparatively, although certainly not outstandingly, successful in science achievement. Unfortunately, those students and the students who follow them may well be without the mathematical foundations that will allow them to go beyond school science to participate effectively in further work with science or technology.

These achievement results, however, are only a part of the story of U.S. science and mathematics education. They are useful benchmarks that provide a context of our current comparative status. They show our accomplishments to be at best modest and our children to be at risk, especially in a global society. Certainly the signals sent by these results make it im-



Number Sense		
Singapore	84	
Japan	75	
Korea	74	
Hong Kong	72	
Belgium (Fl)	71	
Czech Republic	69	
Switzerland	67	
Slovak Republic	66	
Austria	66	
Ireland	65	
Hungary	65	
France	64	
Canada	64	
Slovenia	63	
Sweden	62	
Belgium (Fr)	62	
Russian Fed.	62	
Netherlands	62	
Australia	61	
Israel	60	
Bulgaria	60	
Thailand	60	
United States	**59**	
Germany	58	◄ 58
Norway	58	
New Zealand	57	
Iceland	54	
England	54	
Scotland	53	
Denmark	53	
Greece	53	
Latvia (LSS)	53	
Spain	52	
Lithuania	61	
Cyprus	50	
Romania	48	
Portugal	44	
Iran	39	
South Africa	35	
Colombia	31	
Kuwait	27	

Measurement		
Singapore	78	
Japan	67	
Korea	66	
Hong Kong	65	
Ireland	63	
Czech Republic	62	
Austria	62	
Switzerland	61	
Belgium (Fl)	60	
Slovak Republic	60	
Bulgaria	60	
Slovenia	59	
France	57	
Netherlands	57	
Hungary	56	
Sweden	56	
Belgium (Fr)	56	
Russian Fed.	56	
Australia	54	
Canada	51	
Germany	51	◄ 51
Norway	51	
Thailand	50	
England	50	
Denmark	49	
Israel	48	
New Zealand	48	
Scotland	48	
Romania	48	
Latvia (LSS)	47	
Iceland	45	
Spain	44	
Cyprus	44	
Greece	43	
Lithuania	43	
United States	**40**	
Portugal	39	
Iran	29	
South Africa	29	
Colombia	25	
Kuwait	23	

Geometry		
Japan	80	
Singapore	76	
Korea	75	
Hong Kong	73	
Czech Republic	66	
France	66	
Bulgaria	65	
Belgium (Fl)	64	
Slovak Republic	63	
Russian Fed.	63	
Thailand	62	
Switzerland	60	
Hungary	60	
Slovenia	60	
Netherlands	59	
Canada	58	
Belgium (Fr)	58	
Austria	57	
Australia	57	
Israel	57	
Latvia (LSS)	57	◄ 56
New Zealand	54	
England	54	
Denmark	54	
Lithuania	53	
Scotland	52	
Romania	52	
Ireland	51	
Germany	51	
Norway	51	
Iceland	51	
Greece	51	
Spain	49	
Sweden	48	
United States	**48**	
Cyprus	47	
Portugal	44	
Iran	43	
Kuwait	38	
South Africa	35	
Colombia	29	

Proportionality		
Singapore	75	
Hong Kong	62	
Korea	62	
Japan	61	
Belgium (Fl)	53	
Switzerland	52	
Czech Republic	52	
Netherlands	51	
Thailand	51	
Ireland	51	
Slovenia	49	
Slovak Republic	49	
Austria	49	
France	49	
Russian Fed.	48	
Canada	48	
Belgium (Fr)	48	
Hungary	47	
Bulgaria	47	
Australia	47	◄ 45
Sweden	44	
Israel	43	
New Zealand	42	
United States	**42**	
Germany	42	
Romania	42	
England	41	
Denmark	41	
Norway	40	
Spain	40	
Scotland	40	
Cyprus	40	
Greece	39	
Latvia (LSS)	39	
Iceland	38	
Iran	36	
Lithuania	35	
Portugal	32	
South Africa	27	
Colombia	23	
Kuwait	21	

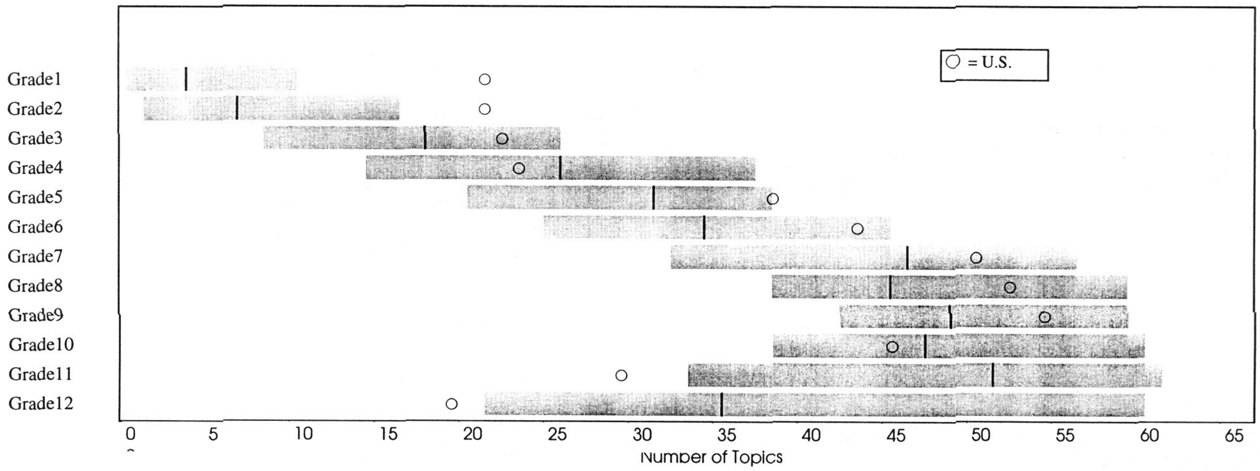
Algebra		
Singapore	76	
Japan	72	
Hong Kong	70	
Korea	69	
Czech Republic	65	
Hungary	63	
Russian Fed.	63	
Belgium (Fl)	63	
Slovak Republic	62	
Bulgaria	62	
Slovenia	61	
Israel	61	
Austria	59	
Australia	55	
Spain	54	
France	54	
Canada	54	
Ireland	53	
Thailand	53	
Belgium (Fr)	53	
Switzerland	53	
Netherlands	53	
Romania	52	◄ 52
United States	**51**	
Latvia (LSS)	51	
New Zealand	49	
England	49	
Germany	48	
Cyprus	48	
Lithuania	47	
Scotland	46	
Greece	46	
Norway	45	
Denmark	45	
Sweden	44	
Iceland	40	
Portugal	40	
Iran	37	
South Africa	31	
Kuwait	30	
Colombia	28	

Data Representation, Analysis & Probability		
Singapore	79	
Korea	78	
Japan	78	
Belgium (Fl)	73	
Switzerland	72	
Netherlands	72	
Hong Kong	72	
France	71	
Sweden	70	
Ireland	69	
Canada	69	
Austria	68	
Czech Republic	68	
Belgium (Fr)	68	
Australia	67	
Denmark	67	
Norway	66	
New Zealand	66	
Slovenia	66	
England	66	
Hungary	66	
United States	**65**	
Scotland	65	
Germany	64	
Israel	63	
Iceland	63	
Thailand	63	
Bulgaria	62	◄ 62
Slovak Republic	62	
Russian Fed.	60	
Spain	60	
Greece	56	
Latvia (LSS)	56	
Portugal	54	
Cyprus	53	
Lithuania	52	
Romania	49	
South Africa	42	
Iran	41	
Kuwait	38	
Colombia	37	

◄ International Average Percent Correct

From *Science Achievement in the Middle School Years*, by A. Beaton, I. V. S. Mullis, M. O. Martin, E. J. Gonzalez, D. L. Kelly, and T. A. Smith, 1996. International Association for the Evaluation of Educational Achievement (IEA), Amsterdam.

Fig. 4. National (eighth grade) averages in mathematics content areas (mean percent of items correct).



* Bars indicate the intermnational 25th and 75th percentiles of number of topics; lines indicate the international median number of topics.

Fig. 5. Number of topics covered in typical U.S. science curricula at each grade.

portant to discover how the U.S. came to this comparative position and how they can move beyond it.

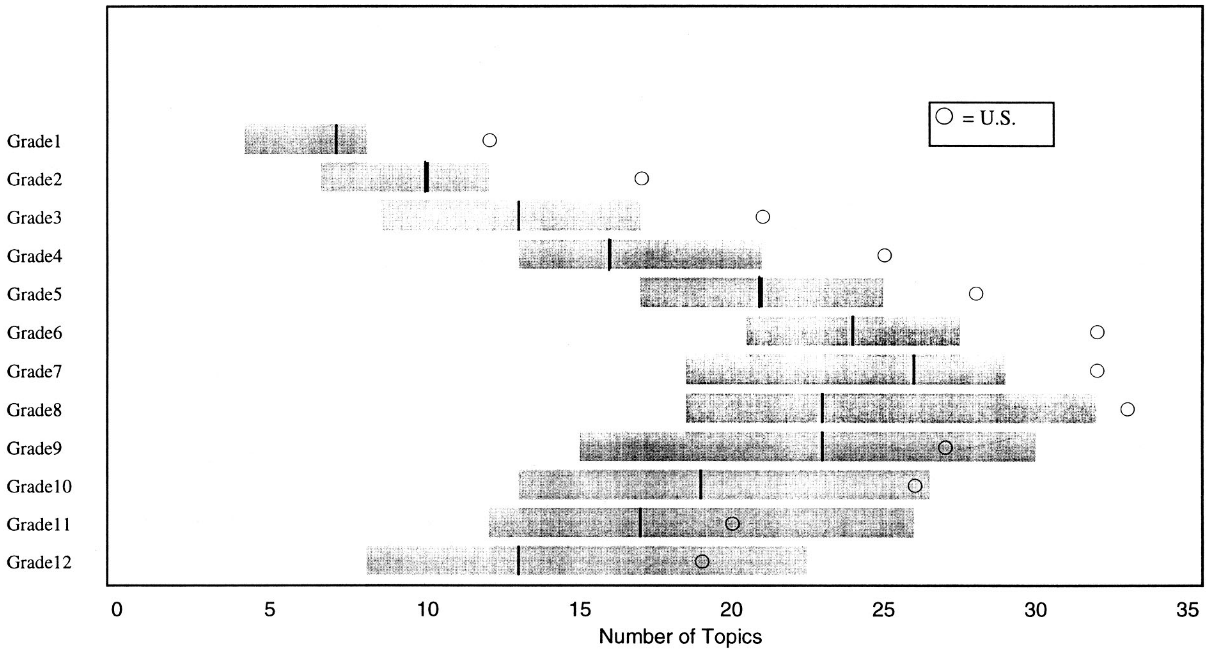
Fortunately, TIMSS is more than a cross-national comparison of science and mathematics achievement. From its initial conception, TIMSS was designed to provide insight into the "why's" of the outcomes. TIMSS data include detailed analyses in the U.S. and other participating countries of official curricula in the sciences and mathematics, of the textbooks that support implementation of those curricula, and of the activities of teachers as they create learning opportunities in the nations' classrooms. From these data, other truths emerge that also must be faced and taken into consideration as we devise strategies to improve science and mathematics education in the future.

Schools Matter. The U.S. national debate over the years has often questioned whether schooling really makes a difference. It has been deemed possible that social factors and socio-economic status determined student opportunities so fully that schooling merely reflected and transmitted these broader differences. The good news is that the TIMSS results provide evidence that schools do matter. Less good is the fact that this difference became clear through data revealing limitations created by weaknesses in our educational system and their impacts on our schools. What we teach and how we teach it is important. When we fail to share clear aims and effective means to attain them, the effects are seen in our children's limited accomplishments. We need to examine what we know about how "clear aims and effective means" are linked to science and mathematics student achievement.

What's the Matter with Schools? American education does not suffer from a lack of hard work. Our teachers work hard. Most often our students work hard. U.S. educational professionals responsible for the training of teachers and the creation of curricula in the science and mathematics work hard. Unfortunately, the structure and pressures of U.S. mass education have created systemic factors that severely limit teacher success and student accomplishment.

If our students stand on shifting sand rather than a firm foundation in their pursuit of competence in mathematics and the sciences, this is in part due the curricula, conditions, and instructional situations typically provided to students and teachers. The TIMSS data have clearly shown that our official curricular visions—our educational intentions, aims, and plans—are splintered, even in science and mathematics education (Schmidt, McKnight and Raizen, 1997). There seems to be no intellectually coherent vision for either science education or mathematics education that dominates U.S. practice.

This results, in part, from the nature of the U.S. educational system. Responsibility and decision making authority is shared by more than 15,000 school districts, 50 states, and some national efforts at setting goals. The sheer number of independent actors creates a "babel" of voices in which it is hard to hear any one clear voice pointing the way. U.S. science curricula at every grade contain somewhat more topics than do curricula in most other countries, as Fig. 5 shows. In mathematics education, this splintering



* Bars indicate the intermnational 25th and 75th percentiles of number of topics; lines indicate the international median number of topics.

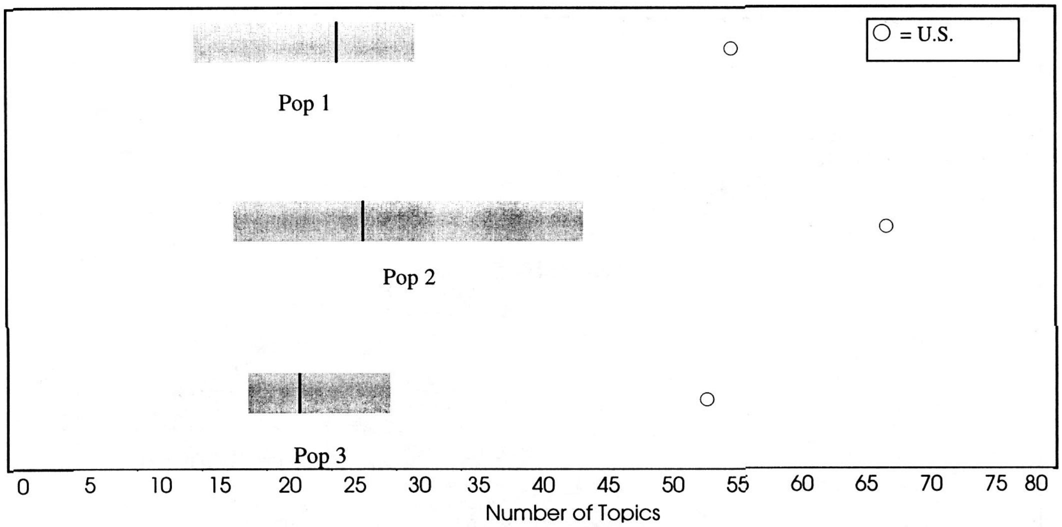
Fig. 6. Number of topics covered in U.S. mathemtics curricula at each grade.

of content into many small topics is even more pronounced, as Fig. 6 makes clear. Figs. 5 and 6 represent (the gray bars) the interquartile range of the numbers of topics over all participating countries for school grade levels (adjusted to comparable grades and labeled with the common U.S. label for those grades). The black line within each shaded bar in the figures represents the median number of topics. The circle in each bar represents where the U.S. falls in this picture of the cross-national distribution of the number of topics covered in each grade.

U.S. mathematics and science textbooks echo this splintering. If our official curricula are in effect a desert that at best provides sand as a foundation for desired national achievement in the sciences and mathematics, our textbooks are deceptive "oases" in that desert. Our textbooks include almost any topic for which one could wish. They maintain traditional contents but still include the new contents set out in reform efforts in science and mathematics education. In fact they have been recently been widely characterized in press conferences and other discussions as being "a mile wide and an inch deep."

Figures 7 and 8 show the how little our science and mathematics textbooks are dominated by a few more extensively taught topics. The gray bars in these two figures represent the interquartile range of the number of TIMSS framework topics presented in textbooks (comparable to the data reported for common topic coverage in curricula shown in Figs. 5 and 6). The black lines are again the median and the circle the number of textbook topics across a representative sample of U.S. textbooks. Rather than showing these data by grades, more precise information based on line by line analyses of textbooks is used here. Textbooks were examined at this level of detail only for the three TIMSS student populations to be tested. Population 1 is the two adjacent grades in each country containing the majority of nine-year-olds (third and fourth grade in the U.S.). As before, Population 2 is the two adjacent grades containing the majority of thirteen-year-olds (seventh and eighth grade in the U.S.). Population 3 consists of all students completing the last year of secondary school offered in a country (twelfth grade in the U.S.). Population 3 includes both a representative sample of students generally and "over sampled" sub-populations of "advanced" students (defined by international consensus to be those taking a full year of calculus in mathematics and as those taking a full year of physics in science).

In a context of diverse aims for mathematics and science education, it is not surprising that textbook publishers, driven by market forces, take a cautious,

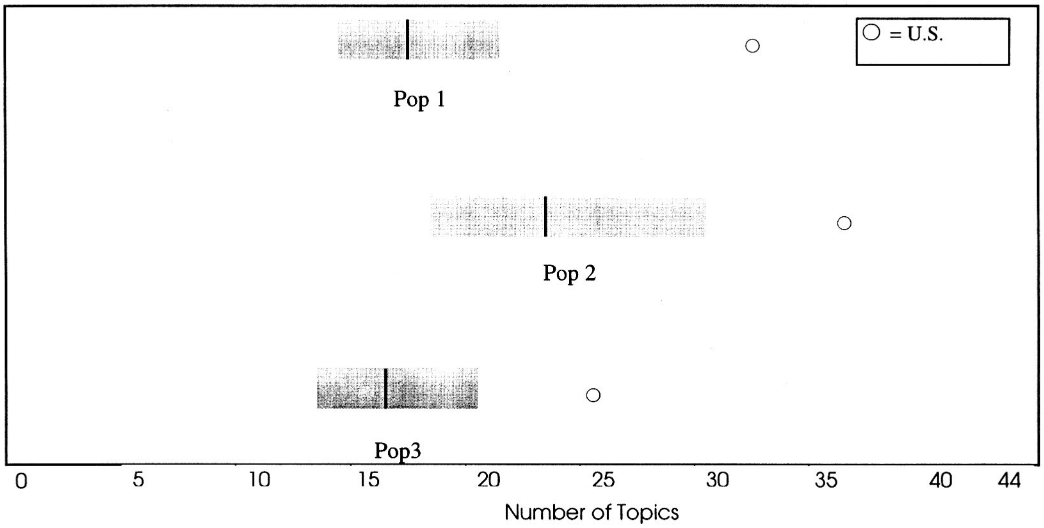


* Bars indicate the intermnational 25th and 75th percentiles of number of topics; lines indicate the international median number of

Fig. 7. Number of topics in U.S. science textbooks at each testing population.

inclusive approach to the topics to which attention is devoted in the books they publish. The overall result, however, as these aggregate data show, is that, unless we are dealing with content-specific textbooks (earth science, algebra, etc.), textbook space is partitioned among so many topics that those textbooks provide comparatively less focused attention on key topics that form the main aims of instruction at the eighth (or any other) grade level than do other countries' books.

Given this splintering in science and mathematics textbooks and official curricula, implementing real reform is extremely difficult and, at best, a never ending struggle. The reform ideas set out by the National Council of Teachers of Mathematics (NCTM, 1989) had been in place before the TIMSS textbook data were collected—unlike more recent efforts at science standards. The vision of mathematics education presented by the NCTM is somewhat reflected in the textbooks analyzed. Unfortunately, it is present



* Bars indicate the intermnational 25th and 75th percentiles of number of topics; lines indicate the international median number of topics.

Fig. 8. Number of topics in U.S. mathematics textbooks at each testing population..

in an inclusive, fragmented context of many topics, movement from topic to topic, and little effort to highlight more important content. Whether a similar situation will continue to prevail after some time in science textbooks remains to be seen. The presence of more area-specific textbooks for science gives some cause for optimism.

Clearly this context of fragmented curricula and textbooks has an impact on the possibilities of reform. Few would say that reform documents in either science or mathematics education do not present a clear, coherent vision of what is desirable. However, those visions are presented in a context of fragmented, inclusive, and competing curricula and textbooks in science and mathematics. In such a context, these calls for reform risk almost inevitably becoming one voice among many. The result may well make pursuing reform seem impossible given current mathematics and science curricula. Candidates for clear coherent visions of science and mathematics education exist. The problem is that no one voice can overcome the babble created by our splintered curricular visions and thus no one clear, coherent vision dominates our science and mathematics education practice.

What do U.S. teachers do in this context of splintered visions and inclusive textbooks? Our teachers appear to try to cover something of all the topics included in our textbooks. Figures 9 and 10 show that the picture of instructional emphases among topics by eighth grade science and mathematics teachers reflect the fragmentation of official curricula and textbooks.

Figure 9 portrays whether individual teachers in the TIMSS sample cover specific topics that are covered by some but not all of the teachers in their country. Japan and Germany are portrayed because a special, more detailed sub-study within the U.S. component of TIMSS was funded to allow more detailed comparisons among the three countries. Each column in one of the three diagrams in Fig. 9 represents a topic. Each row represents a teacher in the sample. A dash in a particular cell indicates that the teacher represented by that cell's row covered the topic represented by that cell's column. A blank indicates no coverage. Topics are arranged so that the most commonly covered topics are to the left in each diagram. Teachers are arranged so that teachers covering the most topics are at the top of each diagram. The line cutting across each diagram represents the total number of topics covered by each teacher (that is, in each row). Thus, how "gray" each box appears gives an impression of how many topics teachers cover—more gray indicating typical coverage of more topics. How quickly the line moves to the left as it goes from top to bottom also gives an impression of how many topics teachers typically covered in one of the three countries. By both criteria, U.S. eighth grade science teachers are seen clearly to cover more different topics typically than teachers in the other two countries. Figure 10 presents the comparable data for mathematics.

As before, these effects are not as pronounced in science as in mathematics which may account, in part, for U.S. students' comparatively stronger performance on the TIMSS science tests. Overall, our teachers teach many topics but few in depth. As a result, their professional training generally may be geared more towards a surface knowledge of many aspects of their discipline rather than an in-depth understanding of a few topics that will form the core of their continuing teaching mission.

Our True Basics. We have sketched some of the insights TIMSS data provide about U.S. science and mathematics curricula, textbooks, and teachers. There are others. For instance, public educational discussion for some years has periodically discussed "the basics" and going "back to the basics" in mathematics and science learning. What is considered "basic" is, unfortunately, inconsistently and ambiguously defined. The term's use gives a misleading impression of specificity. It also raises the issue of whether what is "basic" should be defined by an ideological position or by the common practice within a country, that is, whether basics are empirical or philosophical matters. If "basics" are taken to be those things commonly or traditionally taught, it is an empirical question what are U.S. basics or even international basics. That question addresses the content of what we teach. There are also insights needed on how we teach that content.

One type of TIMSS analysis approached empirically the question of what was commonly taught, what was truly "basic." Cores of science and mathematics content were identified to characterize what was commonly taught. Internationally, a topic at one of the target grades was included in the core if it was taught to some extent in at least 70 percent of the participating TIMSS countries. Since the TIMSS data included information both on official curriculum documents and on textbooks, core topics could be separated into those that were in official curricula

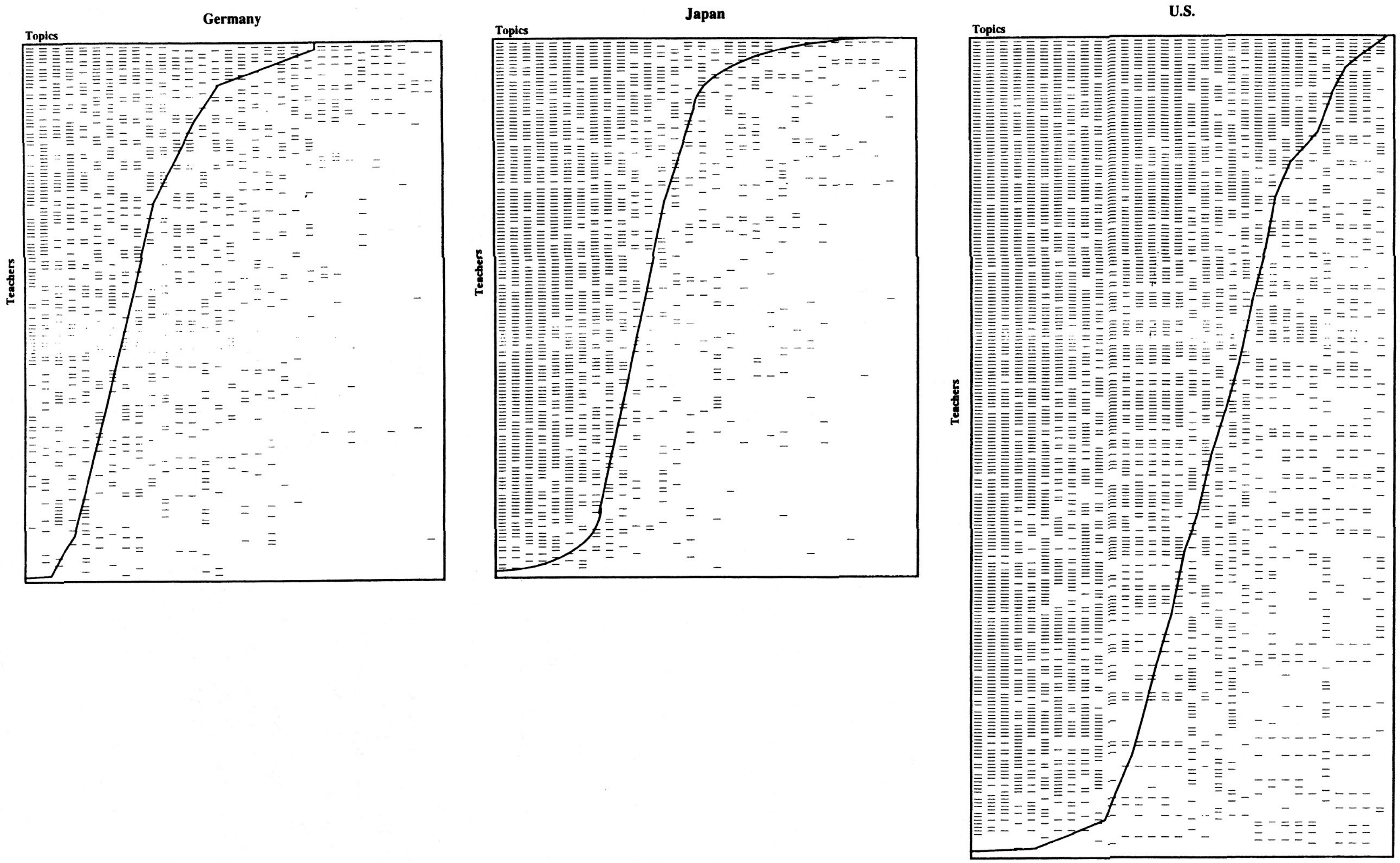


Fig. 9. Number of topics covered by eighth grade science teachers in three countries.

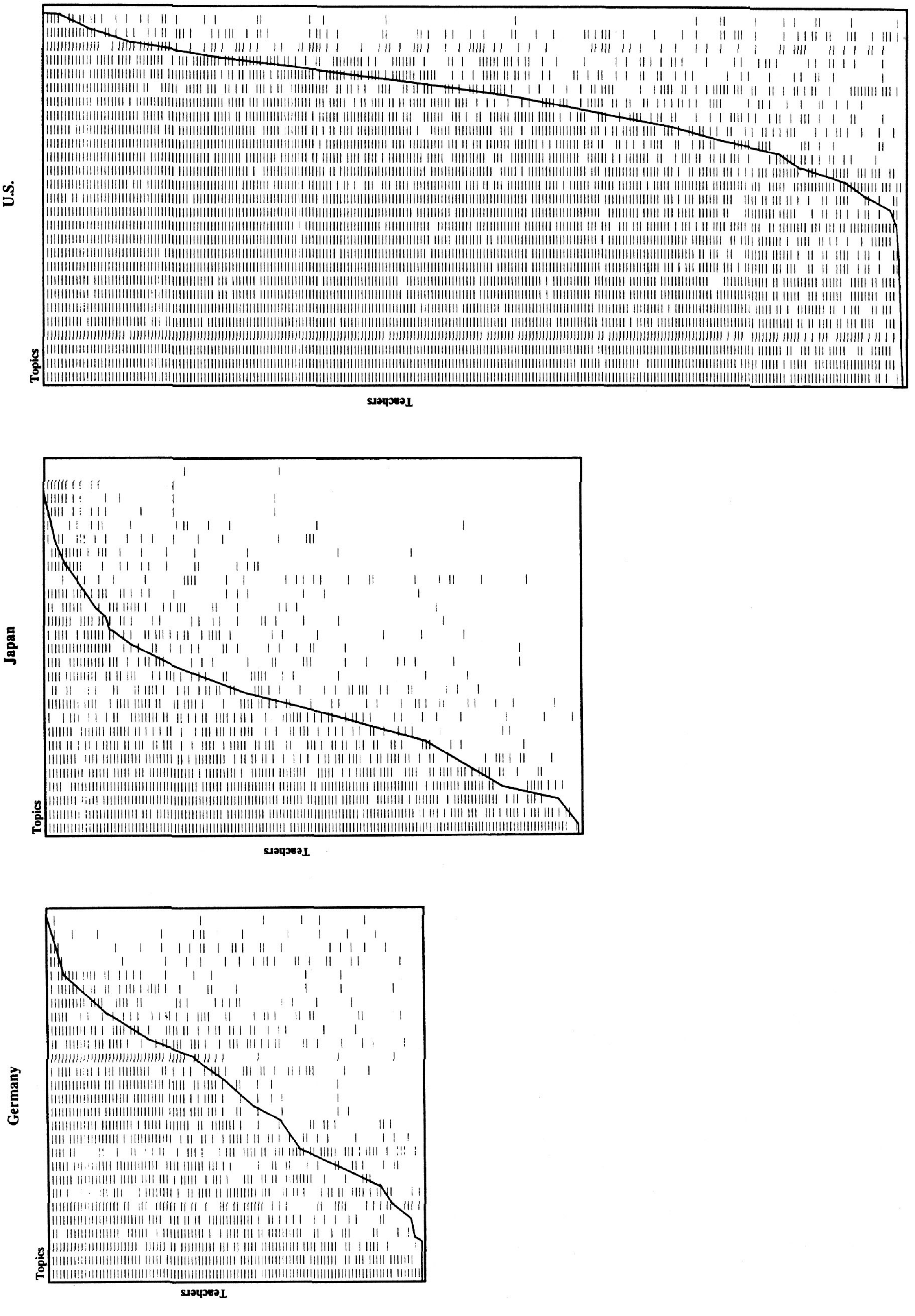


Fig. 10. Number of topics covered by eighth grade mathematics teachers in three countries.

but not textbooks, those that were in textbooks but not official curricula, and those that were in both. Textbook data allowed us to go further and identify topics that received more emphasis in the form of textbook space (with six percent of textbook space devoted to a topic qualifying it as "emphasized" here).

These data for the international common core in fourth and eighth grade mathematics are presented in Fig. 11. As discussed earlier, Population 1 in TIMSS was defined as the two adjacent grades in each country that contained the most nine-year-olds. Thus the "upper grade of Population 1" was the fourth grade in the U.S. and most other countries. Similarly "upper grade of Population 2" was the eighth grade in the U.S. and most other countries.

The topics listed in Fig. 11 are topics found in the TIMSS mathematics framework which included an organized list of topics to provide standardized categories that could link analyses of curricula, textbooks, questionnaires, test items, and other data gathering instruments. The data in the figure provide a clear characterization of what was commonly intended to be taught at these two grades in at least 70 percent of the countries. The core is quite small at fourth grade focusing mainly on numbers, geometry and measurement. Decimal fractions, coordinate geometry, and geometric transformations were in official curricula but not commonly supported in the textbooks of 70 percent of the countries. By contrast, data representation and analysis (simple graphing, means, etc.) were widely covered in textbooks but not as commonly found in official curricula. Three topics were emphasized (indicated by asterisks)—whole number meanings and operations and measurement units. This is a characterization of what is common to fourth grade mathematics in a broad sample of countries, not just in the U.S.

The eighth grade core is more varied, including integers, rational numbers, exponents, considerable two and three dimensional geometry, proportionality problems, equation-based algebra, and data representation and analysis. The topics in bold-faced type are more general categories that subsume the more specific categories listed below them in plain type. Again there are topics common in official curricula (for example, real numbers and "congruence and similarity") that are not commonly in textbook. In eighth grade textbooks there is a longer list of content—whole number operation properties, common and decimal fractions, percentages, measurement units, etc.—that are common in textbooks but not official curricula. These latter topics seem to represent a conservative, inclusive element common to textbooks around the world. Most are topics that were covered extensively in earlier grades but for which space continues to be devoted in textbooks as late as the eighth grade. Many might think such "lingering" on previously covered topics to be typical only of the U.S. but these data indicate, at least for textbook publishers (some of whom are official national agencies), this is true in many countries (Schmidt, McKnight, *et al.*, 1997).

The core of mathematics topics common to 70 percent of the U.S. curriculum guides and textbooks analyzed differs from this international core in several ways. The U.S. fourth grade "basics" include all of the international core topics and several more. "Data representation and analysis" was in the international textbook core but not in official curricula. In the U.S. both textbooks and state curriculum guides widely include this topic. Although U.S. state curriculum guides include more fourth grade mathematics topics than are included in the international core, U.S. fourth grade mathematics textbooks include still more topics.

The picture is much the same for U.S. eighth grade mathematics, but there are some important differences. Some arithmetic and measurement content which was not "basic" internationally continues to persist in the U.S. "basics", its core of commonly intended topics both in state curriculum guides and in textbooks. This includes—at eighth grade—wide inclusion of whole number operations, common fractions, percentages, and measurement units. On the positive side, some topics prominent in U.S. mathematics reform proposals receive coverage both in state curriculum guides and in both algebra, general mathematics, and pre-algebra eighth grade textbooks. These topics, among others, include proportionality concepts, estimation and number sense, and probability.

In the U.S., well over a third of eighth grade students take "Algebra One", a course taught with a textbook aimed at a first full year's study of algebra. Even these courses and textbooks, however, turn out to be more inclusive than their international counterparts. Although the majority of attention is devoted to algebraic topics, many other topics are commonly included and the pattern remains somewhat like the U.S. "basics" outlined above.

Upper Grade of Population 1	Upper Grade of Population 2
CURRICULUM GUIDES (Not in Textbooks)	
Numbers Decimal Fractions Geometry Coordinate Geometry Transformations	Numbers Real Numbers Geometry Const. using Straightedge and Compass Congruence and Similarity Proportionality Concepts Other Content
CURRICULUM GUIDES (Included in Textbooks)	
Numbers **Whole Numbers-Meanings*** **Whole Numbers-Operations*** Whole Numbers-Properties of Operations *Common Fractions* Measurement **Units*** Perimeter, Area & Volume Geometry Basic 2-D Geometry Polygons & Circles	Numbers Integers Rational Numbers Exponents, Roots & Radicals Measurement Perimeter, Area & Volume Geometry Coordinate Geometry Basic 2-D Geometry Polygons & Circles 3-D Geometry Transformations Proportionality Problems *Algebra* Patterns, Relations & Functions **Equations and Formulas*** Data Rep., Probablility and Statistics Data Representation & Analysis
EXCLUSIVELY IN TEXTBOOKS	
Data Representation, Probablility and Statistics Data Representation & Analysis	Numbers Whole Number: Properties of Operations Common Fractions Decimal Fractions Relation of Common & Decimal Fractions Percentages Measurement Units

Fig. 11. Commonly intended mathematics topics. *Note. Topic emphasized in textbooks.

These commonly intended topics are the basis for instruction in one grade in each country (and thus in roughly the same amount of mathematics instructional time). Thus, the U.S. seems comparatively unfocused in this empirically based concept of what is "basic." It includes the common cross-national core and more. This difference seems so extensive that it represents not just a difference in quantity but likely represents a difference in quality. U.S. instructional attention seems spread very thinly and to be so because there is little consensus on a focused, strategic concept of more important content. Other than specialized classes (e.g., algebra), this is more true at eighth grade than fourth. The U.S. seems clearly to follow a more fragmented, "breadth rather than depth" approach. What is truly basic needs more thought.

The data for the international common core in fourth and eighth grade science are presented in Fig. 12. This core contains a large number of topics from life sciences, earth sciences, physical sciences (physics and chemistry), and other topics in science. There are some topics that appear widely only in curriculum guides but virtually none that appear widely only in textbooks. The only topic that appears in both official curriculum documents, science textbooks, and is emphasized (given six percent or more of textbooks' space) at the eighth grade is "organ and tissues." Thus, the international "core" is somewhat less focused, especially for the eighth grade, than was true for mathematics.

In contrast, the U.S. has comparatively fewer common topics. The internationally emphasized topic, "organs and tissues", is not emphasized in the U.S. eighth grade science. The US, however, has far more topics that appear widely only in textbooks. At first glance, science content in U.S. official curricula and textbooks seems more focused than that content internationally. Unfortunately, while this is somewhat true compared to mathematics, other data indicate that typical U.S. eighth grade science curricula and textbooks cover many topics and, in fact, somewhat more than is typical internationally. The TIMSS data indicate that U.S. science curricula intend the coverage of about 20 to 30 topics in at least some official state curricula.

Why, then, is the list of widely intended topics so small in the U.S.? Most states in their science curricula planned to cover 20 to 30 topics but few of the topics were the same among the states. Unlike school mathematics, U.S. school science did not seem to be organized to gradually accumulate mastery of content over several grades. There may be commonalties that lie beneath the level of topics. For example, school science may be organized around common processes which can be applied with different contents. This would not require widely shared specific topics. Whether there are underlying commonalties of science processes, the content topics vary among states by states' preferences. This may reflect less national consensus about what should be taught in science or, on a more positive note, may indicate states basing their science curricula on perceived relevance to local situations. That is, geographical, ecological, and other aspects of local conditions can makes certain topics more interesting in one locale than another. Physical science (physical properties of matter, electricity, light, etc.) seems to show more commonalties and to be organized for longer lasting, more incremental coverage across the grades — in short, to show a pattern more like that of mathematics.

At both the fourth and eighth grades, science textbooks commonly included many topics not also in the corresponding state curriculum guides. This is in sharp contrast to the "core" internationally. The conservative, inclusive strategy seen in mathematics textbooks also seems to help shape content in U.S. science textbooks. The lack of topics in official curricula but not in textbooks may well reflect the fact that these documents were analyzed before the wide dissemination of proposed science standards and reforms. If so, the portrait of topics in official curricula but not textbooks may now be more like mathematics than it was at the time these data were collected.

It appears that for science, in contrast to mathematics, there was, at the time these data were collected, little agreement across states on what was "basic" in science education at fourth and eighth grade other than some physical science. If consensus existed within states, it did not appear to exist among states. This contrasts with the common core of "basic" science content seen internationally. Again, U.S. science curricula may be focused at local levels although data on the number of topics proposed for instruction rather than the specific topics suggests this is not so. These state curricula did not aggregate to any sort of national consensus on what was basic in science education, at least at the time these data were collected. When the TIMSS tests measured student achievements for the U.S., these achievements had been generated by a diverse range of relatively

Upper Grade of Population 1	Upper Grade of Population 2	
CURRICULUM GUIDES (Not In Textbooks)		
Earth Sciences Earth Features Bodies of water Life Sciences Human Biology & Health Environmental and Resource Issues Pollution Material & energy resources conservation World population Food production, storage	Life Sciences Diversity, Organization, Structure of Living Things Microorganism types Cells Life Spirals, Genetic Continuity, Diversity Evolution, speciation,diversity Interactions of Living Things Biomes, ecosystems Habitats & niches Animal and plant behavior Human Biology & Health	Physical Sciences Structure of Matter Subatomic particles Energy and Physical Processes Magnetism Environmental and Recourse Issues World Human Population Food Production, Storage Effects of Natural Disasters Nature of Science Nature of Scientific Knowledge, Methods
CURRICULUM GUIDES (Included in Textbooks)		
Earth Sciences Earth Processes Weather & climate Earth in the Universe Earth in the solar system Life Sciences Div., Organization, Structure of Living Things ***Plant, fungi types** ***Animal types** Organs, tissues Interactions of Living Things Interdependence of life Physical Sciences Matter Physical properties of matter Energy and Physical Processes Energy types, sources, conservation Environmental and Resource Issues Land, water, sea, resource conservation	Earth Sciences Earth Features Earth Processes Weather & climate Life Sciences Diversity, Organization, Structure of Living Things Plant, fungi types Animal types ***Organs, tissues** Life Processes and Systems Enabling Life Functions Organism energy handing Organism sensing, responding Life Spirals, Genetic Continuity, Diversity Life cycles of organisms Reproduction of organisms Interactions of Living Things Interdependence of living things Human Biology and Health Human diseases	Physical Sciences Matter Classification of matter Physical properties of matter Chemical properties of matter Structure of Matter Atoms, molecules, ions Energy and Physical Processes Energy types, sources, conversions Heat & temperature Light Electricity Chemical Transformations Describe chemical changes of matter Forces and Motion Types of forces Science, Technology, and Mathematics Interactions of Science, Mathematics and Tech. Science applications in math, technol. Interactions of Science, Technology and Society Influence of sci, technol. on society Environmental and Resource Issues Pollution Land, Water, Sea Resource Conservation Material & Energy Resource Conservation
EXCLUSIVELY IN TEXTBOOKS		
	Physical Sciences Physical Transformations Describe physical changes of matter Forces and Motion Time, space, motion History of Sci. & Technol.	

Fig. 12. Commonly intended science topics. *Note. Topic emphasized in textbooks.

unfocused state curricula, supported by inclusive textbooks, and not by a broad national consensus of what science was "basic" at these grades.

Our Instructional Approaches. The U.S. seemed to have less demanding and less focused conceptions of what was basic to science and mathematics education than did many other countries. This finding deals with what is studied in our classrooms. We also need to consider how this content is presented in U.S. science and mathematics classrooms. Several parts of the TIMSS investigations document features of U.S. instruction.

A related project, the Survey of Science and Mathematics Opportunity, was responsible for much of the instrument development and analysis planning for TIMSS. A part of this work involved detailed classroom observations in the U.S. and five other countries. Certain characteristic features of U.S. instructional approaches stand out (see Schmidt *et al.*, 1996). Much of the main TIMSS data on instructional approaches and classroom activities is the subject of on-going analyses.

Teachers played a central role in U.S. science and mathematics pedagogy as investigated by TIMSS. They both transmitted information and directed the flow of classroom activities. The teachers observed were more involved with the subject matter content than were the students, although in many lessons little subject matter content could be observed. On the other hand, U.S. teachers at fourth and eighth grades did not function as autonomous subject matter experts as did, for example, French teachers. They seemed more consistently dependent on mandated materials and student textbooks.

Lessons were structured and led by teachers, often with little influence from students, especially in mathematics. Some lessons focused on a central activity pursued throughout the instructional period, but this activity was selected and directed by the teacher although students worked actively, often in small groups. Other lessons consisted of teacher-led sequences of activities including correction of previous written homework, introduction and explanation of new content, and individual work on the new material followed often by beginning written homework. This kind of written homework played a larger role than it did in many other countries, although it was frequently merely checked for accuracy or recorded and did not form the basis for class discussions. Written homework's function appeared in the U.S. to be to provide closure to previous lessons work and to secure addition out-of-class study from students. Homework in other countries was more often substantively made an integral part of lesson development.

Compared to the other countries observed, U.S. teachers presented content in a more theoretical, abstract form. For example, the language used in some U.S. fourth grade science lessons (use of terms such as "energy", "proton", "neutron", "electron," and "atom") prompted discussants from other countries to question how appropriate it was to use such terminology and such formal approaches. Content seemed to be little more than a vocabulary lesson, in some cases with abstract models and ideas, perhaps inappropriate for the developmental level of the children, holding the various concepts and terms together.

Another part of the U.S. component of TIMSS involved videotaping a sample of class periods in the classrooms of students who would take part in the TIMSS mathematics achievement testing. This was done for U.S. classrooms and for their counterparts in Japan and Germany. Unfortunately, fiscal limitations resulted in this being done only for mathematics and not for science. The videotapes were provided with written transcriptions and, if necessary, translations. A cross-referencing and indexing system allowed specific contents or other aspects to be queried with computer-guided cueing of the appropriate videotaped segments.

These videotapes provided classroom artifacts that could be systematically analyzed in greater detail than notes on classroom observations. They were "blindly" coded for content, for structure, and for coherence in presenting mathematical content, the latter by professional mathematicians. These mathematicians could also rate the efficiency and mathematical quality of the lessons taped. Of the lessons examined, about 90 percent of U.S. lessons were rated as of low quality. No U.S. lessons were rated as of high quality while 25 to 30 percent of Japanese and German lessons were rated highly. Figure 13 presents a summary of these data. "Quality" for the mathematicians providing these ratings was articulated as the degree to which topics were connected within a lesson, rather than skipping among topics and activities, and the degree to which these connected topics held together to tell a "mathematical story"—that is, to engage students in a connected exposition of mathematical content through discussions and activities. By these criteria, most U.S. mathematics lesson fell short.

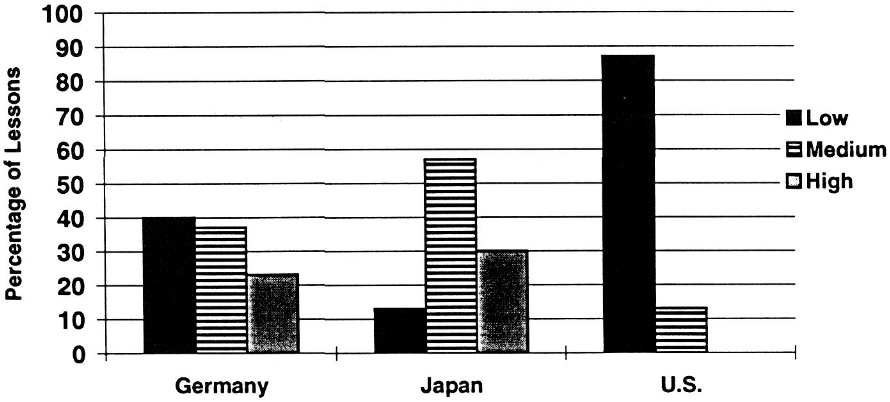


Fig. 13. Ratings of videotaped lesson quality in the U.S., Japan, and Germany

This is not a different story from that of official curricula, student textbooks, and teacher instructional time allocations. It is simply another aspect of the splintering and lack of focus that seems to characterize U.S. mathematics and science education as portrayed in the TIMSS data. Teachers can hardly be expected to provide coherent lessons when the visions guiding there efforts are splintered, and the textbooks and materials which support their efforts are fragmented, unfocused, and so inclusive as not to provide strategic guidance to teachers using them.

CONCLUSIONS: WHERE WE WANT TO GO

The discussion above has focused on facing facts about where we are. The results may not be surprising but they are clearly disappointing. U.S. mathematics and science education is splintered and unfocused. It tries typically to do too much but does too little with each of the many topics on which it focuses attention. Effective, coherent, selective vision focused on clear, shared goals is lacking at almost every level of these educational efforts. The resulting achievements could hardly be a surprise in light of the instruction and educational opportunities provided in U.S. mathematics and science education to shape the student outcomes measured. We simply are not where we want to be and we must change.

If we change mathematics and science education, where do we want to go with our changes? The TIMSS results clearly show that schools matter. Educational opportunities and their quality as provided through schooling make a difference. The problems which must be overcome are created systemically and must be solved systemically. Individual teachers cannot overcome the lack of clear curricular focus or bulky, inclusive textbooks. It is not hard work by teachers that is needed, for the U.S. already has that. What is needed is smart work by curriculum planners, textbook and material developers and publishers, policy setters, and by teachers.

The core issue seems to be whether the U.S. can develop dominant coherent and focused visions of mathematics and science education, their goals and means. Suggesting that shared vision is a core issue is not attacking U.S. traditions of local educational autonomy and responsibility. Clearly, systemic issues, especially in an educational system as complex as the U.S. aggregate educational system, provide many manifestations of fragmentation and lack of clear goals. Equally clearly, they provide many opportunities for changes that contribute to the solution of the deeper, underlying problems.

By means appropriate to U.S. educational traditions of shared responsibility, we must come to share coherent, focused visions of what science and mathematics education in our schools is to accomplish. As these visions emerge, we must find the ways to introduce them thoroughly and consistently into our educational efforts, by building consensus, providing discussion and clearer insights, by providing more appropriate textbooks and materials, and by training teachers in more focused, selective, and effective ways. Most of all, we must face the fact that the quality of U.S. mathematics and science education is unacceptable when compared to other countries, and continue to monitor and face that fact until we find ourselves moving together toward where we want to be for future generations of U.S. citizens to be more appropriately and thoroughly educated in mathematics and the sciences.

The theme of this special issue of the Journal is *Student Science Partnerships (SSPs)*. This article has not directly been about that theme. However, having stated the conclusions above, some of the potential of SSPs seems very clear. SSPs have the possibilities to

- add focus and continuity to science instruction,
- concentrate instructional time on a limited number of real issue and topics, and
- use a multi-disciplinary approach to science instruction.

Perhaps these TIMSS results and the needed improvements they suggest can be one context to be kept in mind as one reflects on the remainder of this issue's articles.

REFERENCES

National Center for Education Statistics (NCES) (1996). *Pursuing excellence: A study of U.S. eighth-grade mathematics and science teaching, learning, curriculum, and achievement in international context.* U.S. Department of Education, Washington, D.C.: U.S. Government Printing Office.

National Council for Teachers of Mathematics (NCTM) (1989). *Curriculum and evaluation standards for school mathematics.* Reston, Virginia: National Council of Teachers of Mathematics.

Schmidt, W. H., and McKnight, C. C. (1995). Surveying educational opportunity in mathematics and science: An international perspective. *Educational Evaluation and Policy Analysis*, 17(3), 337–353.

Schmidt, W. H., McKnight, C. C., & Raizen, S. (1997). *A splintered vision: An investigation of US science and mathematics education.* Dordrecht, Boston, London: Kluwer Academic Publishers.

Schmidt, W. H., McKnight, C. C., Valverde, G. A., Houang, R. T., & Wiley, D. E. (1997). *Many visions, many aims: A cross-national investigation of curricular intentions in school mathematics.* Dordrecht, Boston, London: Kluwer Academic Publishers.

Schmidt, W. H., Raizen, S., Britton, E. D., Bianchi, L., & Wolfe, R. (1997) *Many visions, many aims: A cross-national investigation of curricular intentions in school science.* Dordrecht, Boston, London: Kluwer Academic Publishers.

Schmidt, W. H., *et al.* (1996). *Characterizing pedagogical flow: An investigation of mathematics and science teaching in six countries.* Dordrecht, Boston, London: Kluwer Academic Publishers.