Research Series No. 191

A CURRICULUM OUT OF BALANCE: THE CASE OF ELEMENTARY SCHOOL MATHEMATICS

Andrew Porter

Published By

The Institute for Research on Teaching
College of Education
Michigan State University
East Lansing, Michigan 48824-1034

January 1988

This work is sponsored in part by the Institute for Research on Teaching, College of Education, Michigan State University. The Institute for Research on Teaching is funded from a variety of federal, state, and private sources including the United States Department of Education and Michigan State University. The opinions expressed in this publication do not necessarily reflect the position, policy, or endorsement of the funding agencies.

Institute for Research on Teaching

The **Institute for Research on Teaching** was founded at Michigan State University (MSU) in 1976 by the National Institute of Education. Following a nationwide competition in 1981, the NIE awarded a second five-year contract to MSU. Funding is currently received from the U.S. Department of Education, Michigan State University, and other agencies and foundations for individual research projects.

The IRT conducts major research projects aimed at improving classroom teaching, including studies of classroom management strategies, student socialization, the diagnosis and remediation of reading difficulties, and teacher education. IRT researchers are also examining the teaching of specific school subjects such as reading, writing, general mathematics, and science and are seeking to understand how factors outside the classroom affect teacher decision making.

Researchers from such diverse disciplines as educational psychology, anthropology, sociology, and philosophy cooperate in conducting IRT research. They join forces with public school teachers who work at the IRT as half-time collaborators in research, helping to design and plan studies, collect data, analyze and interpret results, and disseminate findings.

The IRT publishes research reports, occasional papers, conference proceedings, a newsletter for practitioners, and lists and catalogs of IRT publications. For more information, to receive a list or catalog, and/or to be placed on the IRT mailing list to receive the newsletter, please write to the IRT Editor, Institute for Research on Teaching, 252 Erickson Hall, Michigan State University, East Lansing, Michigan 48824-1034.

Abstract

When student achievement lags expectations, explanations are sought. One possibility is that the curriculum, as taught, is out of line with what is needed. Unfortunately, careful descriptions of the implemented curriculum are in short supply. Elementary school mathematics is used as a context for considering what can be learned from careful descriptions of classroom content and in what ways evaluating curricula and setting educational standards require exercising value judgments that extend beyond what is known empirically. Elementary school mathematics is characterized as instruction, where large numbers of mathematics topics are taught for exposure with no expectation of student mastery, where much of what is taught in one grade is taught again in the next, where skills typically receive 10 times the emphasis given to either conceptual understanding or application, and where, depending upon the accidents of school and teacher assignment, the amount of mathematics instruction a student receives may be doubled or halved. While generally consistent with current curriculum policies, these attributes of the curriculum are seen as highly problematic.

A CURRICULUM OUT OF BALANCE: THE CASE OF ELEMENTARY SCHOOL MATHEMATICS

Andrew Porter[1]

> Let the main ideas which are introduced into a child's education be few and important and let them be thrown into every combination possible. The child should make them his own and should understand their application. (Whitehead, 1929, p. 14)

This advice, written by philosopher and mathematician Alfred North Whitehead when addressing The Aims of Education, seems as sound today as it must have 50 years ago. I use it here as a standard for judging current day practice, and in particular, as a lens for making judgments about the appropriateness of what is taught in elementary school mathematics. I conclude that mathematics in United States elementary schools is uninspired and boring on the one hand and superficial on the other.

For the past 10 years, the Content Determinants research team[2] at the Institute for Research on Teaching (IRT) has been pursuing a program of studies to determine factors that influence teachers' content decisions in elementary school mathematics (e.g., Porter, Floden, Freeman, Schmidt, and Schwille, 1986). Originally motivated by an interest in how student achievement tests might drive the curriculum, interests quickly expanded to consider

---

[1] Andrew Porter was coordinator of the Content Determinants Project and is a professor in the Department of Counseling, Educational Psychology and Special Education at Michigan State University.

[2] Robert Floden, Donald Freeman, William Schmidt, and John Schwille were senior researchers with the project. Floden, Freeman, and Schwille are professors in the Department of Teacher Education at MSU and Schmidt is a professor in the Department of Counseling, Educational Psychology and Special Education. The contributions of those who were with the group for shorter periods of time are gratefully acknowledged: Linda Alford, Gabriella Belli, Zane Berge, Michael Gant, Susan Irwin, Frank Jenkins, Lucy Knappen, Therese Kuhs, and Janet Vredevoogd.

the full range of possible content determinants. At first our reasoning was that the influence of tests can only be understood when placed within a context of the influence of other factors (e.g., student interests and aptitudes, teacher subject matter knowledge, and other elements of the policy environment--including objectives, mandated textbooks, ability grouping, and the like). After some initial work, not surprisingly we discovered that tests are only one of several important influences upon what is taught and learned in schools.

Our interest in studying teachers' decisions about what to teach was motivated by a concern for student achievement. Collectively, teachers' decisions of how much time to allocate to math instruction, what topics to teach, to which students, when and in what order, and to what standards of achievement largely determine students' opportunities to learn (especially for subjects such as mathematics that are primarily learned in school). While opportunity to learn is but one of several factors that influences student achievement (e.g., Carroll, 1963), it is arguably the factor most easily manipulated. Student aptitude, perhaps the single most important determinant of student achievement, must be taken as a given. Improvements in pedagogical practices could greatly increase student achievement, but much of what we know about good pedagogy has been difficult to get teachers to practice. Further, a great deal of mystery remains about excellence in pedagogy (e.g., Porter & Brophy, in press).

Until now, content determinants work has carefully avoided making judgments about good and bad practice. We have sought to explain why it is that teachers teach the mathematics they teach. We have not asked whether or not the mathematics taught is worthwhile. Similarly, we have taken a neutral position on the desirability of teacher autonomy. Our research has sought to discover the extent to which teacher content practices are a function of teachers' professional beliefs and values or a function of school policies and other external influences (Floden et al., 1987). Here I depart from this conservative position, recognizing full well that distinguishing between good and bad is risky business, requiring judgments that extend well beyond data. Surely some will disagree with the conclusions I reach; this I understand and accept. It is hoped that for some, however, the following analysis will create a new and deeper understanding of the inadequacies of what is taught in elementary school mathematics and insights into how those inadequacies might be remedied.

You may ask, what is the point of careful descriptions of content and judgment of content worth; don't we already know what is taught in elementary school mathematics? Isn't fourth grade multiplication and fifth grade fractions and decimals? More particularly, don't teachers simply teach what is in the textbook? As for time, don't all teachers have a math period everyday? But these are stereotypes. Like most stereotypes, there is enough truth in them to keep them alive but too much that is incomplete and misleading for them to be used as the basis for sound decision making.

Nature of the Empirical Basis

The empirical basis for knowing what is taught in school is surprisingly weak. Few studies have been conducted and what studies are available have serious problems. There are, of course, numerous descriptions of student achievement, but descriptions of student achievement can serve as only the crudest proxy for descriptions of what is taught. As noted above, opportunity to learn is one of several important determinants of student achievement. Further, an achievement test is a sample of what might be taught.

Depending upon the test and the perspective used to judge its content, the sample may be seriously biased.

There are a few studies of the "intended curriculum": descriptions of the content called for by sets of objectives, content analyses of textbooks, and tests (e.g., Freeman et al., 1983). But ultimately teachers determine what is taught in school. Even if all teachers could be counted upon to provide instruction consistent with mandates of the educational hierarchy, they still would be forced to make important decisions of their own because the mandates are incomplete in specifying what should be taught.

One reason why so few studies of the "implemented curriculum" exist is that they are expensive and difficult to conduct. Classroom observation, the most direct approach, is clearly out of the question. Even the most serious classroom observation studies are limited to observations of teaching practices taken for a small sample of days (often only two days) spread across the school year (e.g., Shavelson & Dempsey, 1976). These observation studies may provide valid estimates of teacher pedagogical practices, but they certainly cannot provide a complete picture of what is taught. If one wants to know, for example, how much time a teacher spends teaching story problems, an estimate of time spent on story problems must be obtained that is a function of instruction provided each day.

When researchers have attempted to obtain descriptions of the implemented curriculum, they have relied on self-reports, occasionally reports from students, but more typically reports from teachers. For example, the second IEA (International Association for the Evaluation of Educational Achievement) study on mathematics asked teachers to report on whether or not they had taught each of several specific mathematics topics and whether they believed their students had been taught those topics prior to the year of their instruction (McKnight et al., 1987). Such retrospective data can provide only a crude sense for the implemented curriculum, one which fails to distinguish degrees of coverage.

The descriptions offered here of what is taught in elementary school mathematics are based upon two separate studies, each of which used daily teacher logs as the primary method of data collection. The first study described the content of mathematics instruction for seven teachers during the 1979-80 school year. This small sample involved third-, fourth-, and fifth-grade teachers located in six different schools, in three different Michigan school districts. Each teacher kept a daily record for each student of what was taught and for how long. These daily logs were collected on a weekly basis during an interview with the teacher. Ambiguities in the logs were clarified at the time of collection.

In the second study, 34 teachers in 17 schools selected from six Michigan school districts kept daily logs of the mathematics instruction they provided during the 1982-83 school year. Half of these teachers taught fourth grade and the other half taught fifth grade--one teacher at each grade level from each of the 17 schools. In this second study, the log-keeping procedure was slightly more structured. Teachers were asked to identify up to five topics each day representing the primary focus of their instruction for each of three target students (a student the teacher judged to be at the 80th percentile of mathematics aptitude of the class, one at the 50th percentile, and one at the 20th percentile).[3] Teachers were provided a catalog of 288 topics that might be taught and were asked to describe their instruction in

---

[3] Results reported in this paper are limited to data from the 50th percentile target students.

terms of those catalog topics, indicating content not found in the catalog when necessary. Again, logs were collected on a weekly basis, but in this study they were mailed to the researchers, not collected in person. Logs were still "edited" on a weekly basis by the researchers and, when ambiguities were identified, they were clarified by phone, mail, or during an interview.

Before turning to the results, a brief comment on the definition of mathematical topics is necessary. Early in our work we created a three-dimensional taxonomy to describe what might be taught in the middle elementary grades (Kuhs et al., 1979). The dimensions of the taxonomy are general intent (e.g., conceptual understanding or application), nature of the material (e.g., fractions, decimals, whole numbers), and the operations required to solve a problem (e.g., estimate or multiply). The taxonomy defines topics at the intersection of these three dimensions (e.g., knowing multiplication facts, solving story problems, division of whole numbers with remainder, understanding the relationship between addition and subtraction).

Because our studies were of teacher content decision making, our taxonomy was based on interviews of teachers to determine the distinctions they make in planning and evaluating their mathematics instruction and to determine the language they use for communicating those distinctions (Schwille et al., 1980). In general, our taxonomy makes slightly finer distinctions in the areas of conceptual understandings and applications than do elementary school teachers, while the topics defined for skills are slightly more global (e.g., many teachers distinguish between subtraction involving one or more zeros in the minuend and subtraction not involving zeros in the minuend). This taxonomy was used to describe topics in the first study and was the starting point for defining topics in the content catalog used in the second study, although in the catalog only topics previous research had shown were taught were included and some slight aggregation of topics occurred. In either study, it was possible to describe content at the level of a specific topic or at some more general level (e.g., amount of time spent teaching applications, amount of time spent on multiplication).

Emphasizing Problem Solving

Since the report A Nation at Risk (National Commission on Excellence in Education, 1983), which kicked off the current wave of reform initiatives, one particularly visible theme of complaints about American education is that students fail to demonstrate adequate achievement in problem solving and higher order thinking. For example, the second IEA math study assessing mathematics achievement for eighth-grade students at the end of the 1981-82 school year (McKnight et al., 1987) found that U.S. students were slightly above the international average in computational arithmetic but well below the international average in problem solving. Worse, U.S. eighth graders' achievement in geometry placed in the bottom 25% in a sample of which nearly 25% were third world nations. It can be asked of content determinants data if one possible explanation for these disappointing international comparisons lies with what U.S. elementary school teachers emphasize in their instruction.

In the two studies of Michigan teachers,[4] 70 to 75% of mathematics instruction was spent teaching skills, essentially how to add, subtract,

---

[4] While most of the recent reforms in education have taken place since our data were collected, the reforms have been at the state and local level. Michigan policies concerning elementary school mathematics are little changed thus far.

multiply, and divide, and occasionally how to read a graph. One teacher spent as much as 93% of her mathematics instruction on skills, leaving only 6% for the development of conceptual understanding, and 1% for the study of problem solving. There was, however, one important exception to this picture of teacher preoccupation with skill development. One school in an especially affluent school district had adopted the Comprehensive School Mathematics Program (CSMP) (Armstrong et al., 1985). The teachers in that school were the only ones in either study to spend more time on conceptual understanding and applications than on skill development.

Of the time not spent on skill development, teachers in both studies spent about half of it developing conceptual understanding and the other half teaching problem solving skills, primarily story problems. One caveat is necessary here: For our analyses, applications consisted of work in which the operations necessary to solve a problem were not explicitly stated but were implied in the presentation of the problem. Nevertheless, we counted all work on story problems as applications, even if students worked on a page in which every story problem involved the addition of single digit numbers. I recognize, however, that at some point in completing such work, the ambiguity of the solution must disappear. The remaining problems become more like skill practice than problem solving. Thus, the finding that fourth-grade teachers averaged only 11% of their mathematics instructional time teaching applications/problem solving must be viewed as an overestimate of the true percentage.

Drawing primarily from the second study, it is possible to identify topics for which there was consensus among teachers for heavy emphasis (300 minutes or more across a whole school year). Not surprisingly, these topics are highly skill-oriented: multiple digit multiplication, long division, number facts (addition, subtraction, multiplication, and division), and subtraction with borrowing. There was no consensus among teachers to emphasize any topic having to do with conceptual understanding or applications.

To add perspective to this picture of relatively little attention given to problem solving, some additional examples are helpful. Two hundred and sixty of the 288 possible topics in the content catalog were taught at least a little by at least one teacher. Yet not one teacher spent one minute teaching applications involving percents. A full two-thirds of the fourth-grade teachers spent less than one hour across the full school year on story problems involving multiplication of whole numbers, yet multiplication skill development typifies the fourth-grade curriculum. Similarly, while developing computational skills with decimals and fractions is a priority for fifth-grade instruction, two-thirds of the fifth-grade teachers gave less than one hour of instruction to developing problem solving abilities with fractions and a full half of those teachers gave less than one hour of instruction to problem solving involving decimals.

Attention given to geometry was also minimal, though an isolated teacher here or there was found who emphasized such topics as recognizing and naming geometric shapes, developing skills in using a compass, ruler, or protractor to make geometric constructions, and plotting points on a two-dimensional graph. Still, there were whole districts in which the fourth- and fifth-grade teachers spent virtually no time teaching geometry, even the most rudimentary geometry.

Our findings of heavy emphasis on skill development and slight attention to concepts and applications are consistent with the United States' relatively poor standing among other nations on mathematics problem solving ability of students. In some ways, the U.S. curriculum is even more out of balance than the above suggests. Much of the whole number computational drill and practice instruction is focused on skills rarely needed these days. For example, there was consensus among teachers to emphasize instruction on long division; yet arguably this tiresome chore could be left to hand-held calculators.

What little attention is given to problem solving is largely limited to artificial story problems and, as noted above, story problems presented in a repetitive format that tends to diminish their problem-solving character. Students are rarely if ever asked to formulate a problem for themselves, yet problem formulation may be the most important and most difficult aspect of the kind of higher order thinking that students need. After all, most of us believe the cliche that properly formulating a problem is 90% of the solution. Finally, nowhere did we see evidence that teachers were concerned about making sure that their instruction helped students understand that mathematics is a discipline worth knowing in its own right, as well as an essential skill, or that knowledge of mathematics is an important determinant of future study and job opportunities.

The emphasis on skill development we found among teachers is mirrored by the textbooks they use. In content analyses of fourth-grade textbooks, we found 65 to 80% of the exercises were on skill practice, while 10 to 24% were on conceptual understanding, and 6 to 13% on problem solving. It is unclear whether the emphasis on skills by teachers is a result of the emphasis on skills in their textbooks or vice versa. The textbooks are developed at least in part with a profit motive. Nevertheless, if teachers are to shift their emphasis away from skills and toward problem solving and higher order thinking, they will need materials that support that shift. California is one state that is addressing this problem through textbook adoption procedures.

Thus, in judging the extent to which problem solving and higher order thinking is emphasized in elementary school mathematics, I conclude that it is not. Rather, I conclude that teacher content practices are wholly consistent with the disappointing results of student achievement. There is some small reason for optimism, however. In the one school where teachers used a mathematics curriculum emphasizing conceptual understanding and problem solving (i.e., CSMP), those teachers stood out from all the rest by devoting much larger percentages of their mathematics instruction to those areas. I must note also that those teachers were teaching students from highly affluent families known for their valuing of education.

Teaching for Exposure

There is a second characteristic of elementary school mathematics instruction which content determinants descriptive work has revealed and which I find nearly as troublesome as the lack of emphasis given to problem solving and conceptual understanding. A very large percentage of the topics taught receive only brief, perhaps cursory coverage. On this point, data from the first study of seven teachers are most useful. With one important exception, those teachers devoted less than 30 minutes of instructional time across the full school year to 70% or more of the topics they covered. Put another way, only 20 to 30% of what they taught received as much attention during the year as one short 30-minute lesson. This striking finding runs directly counter to the advice from Whitehead (and many other mathematicians and educators) with which I began.

To gain some further insight into this practice of teaching many topics for brief periods of time, I talked with teachers in our studies and other teachers working as teacher collaborators in the IRT at the time (Porter, 1987). These teachers were neither surprised nor particularly troubled by the finding. In fact, many had developed a language for describing the practice, referring to it as "teaching for exposure." Some of the reasons given were as follows: to introduce work to be covered in future grades, as review of work "mastered" in previous grades, and for assessment purposes. Undoubtedly these explanations are true, at least for some teachers, but they are not necessarily sufficient justification of the practice nor do they fully account for the findings. Introducing work for future grades should happen near the end of the school year and review seems most likely at the beginning. Yet the percentage of topics taught for exposure was not systematically higher at the beginning and ending of the school year. Further, the percentage of skills topics taught for exposure was approximately 50%, while the percentage of concepts topics taught for exposure was approximately 80%, and the percentage of applications/problem-solving topics taught for exposure varied from 80 to 95%. Teachers are much more likely to teach concepts and applications for exposure, without an expectation of student mastery, and much less likely to teach skill topics for exposure only.

Of the teachers in the second study, 80% reported teaching at least some of their mathematics content for exposure without any expectation of student mastery. The content area most frequently identified by those teachers as taught for exposure was geometry, indicating once again that our nation's poor performance in eighth-grade student achievement of geometry can hardly be surprising when the nature of the mathematics curriculum to which those students were exposed is taken into account.

Teachers' practice of teaching large percentages of topics for exposure parallels topic coverage in textbooks, where large percentages of topics are included but receive scant attention. In our content analyses of commonly used fourth-grade textbooks, 70 to 80% of the topics covered in a book were allotted 25 or fewer exercises; often these few exercises were spread across several separate lessons. Whether or not textbooks are the cause of teachers teaching for exposure remains unclear. When correlating the extent to which a topic is emphasized in instruction with the extent to which the topic is emphasized in the textbook being used, correlations ranged from .7 to .8. Thus, emphasis in the textbook "explains" only 50% of the variation in teacher topic emphasis. Still, there was some evidence suggesting that teachers who followed their textbook most closely were likely to cover more topics and a higher percentage of topics for relatively brief periods of time than teachers who followed their text less closely.

I am not certain what to make of the practice of teaching for exposure in elementary school mathematics. On the one hand, teachers are not apologetic about the practice. On the other hand, teaching for exposure seems unlikely to benefit student achievement and likely to send unintended messages to students. Because a higher percentage of topics having to do with conceptual understanding and application are taught for exposure than are topics having to do with skills, students may come to believe that conceptual understanding and application are less important than speed and accuracy in computational skills. Clearly the reverse is true.

Further, teaching for exposure may communicate to students that knowing a very little about a lot of different things is more valuable than knowing a few things really well. I am not inclined to agree with this conclusion either. Twenty years ago there was more worthwhile mathematics that might be taught and learned in elementary school than there was time available for teaching that content. In the last 20 years what is known about mathematics has more than doubled. It would be surprising if this rapid growth in knowledge was totally without implications for what is most appropriate to be taught in elementary school. Thus, even a goal of superficial exposure to all appropriate content would be well beyond the time available, not to mention the knowledge of teachers. I am inclined to agree with Whitehead (1929), that a more appropriate aim for elementary school mathematics instruction is to teach a few important ideas thoroughly.

A Slow Moving Curriculum

A third distinctive feature of elementary school mathematics is the slowness with which content changes as students progress through the grades. Clearly, the division of elementary school mathematics into grade levels is somewhat artificial. To some extent, overlapping content across grades is explained by topics begun at the end of one grade being continued into the beginning of the next grade. To some extent, topics can be returned to again and again, each time seeking a greater depth of understanding. To the extent that there is variation in what is covered among classrooms within a grade, there will be overlap, at least at the aggregate level, in what is covered in adjacent grades. Thus, like the issues of problem-solving emphasis and teaching for mastery, questions about content overlap between grades are questions of degree. Nevertheless, content determinants data lead me to believe that fifth-grade content is too much like fourth-grade content.

The best data for comparing what is taught in one grade level versus another came from the second study of 34 fourth- and fifth-grade teachers in 17 Michigan schools. Not only does that study provide a good estimate of fourth-grade content and a good estimate of fifth-grade content, but between-school variation is controlled in the grade-level comparison.

Out of 260 topics taught by one or more of the fourth- and fifth-grade teachers, the median squared correlation between grade level and emphasis of the topic was .03 (and the mean squared correlation was .07). Thus on average, grade level accounted for well less than 10% of the variation among teachers in emphasis of a topic. Despite this picture of variation among teachers in their content emphases overwhelming grade level distinctions, there are some topics that distinguish between fourth- and fifth-grade content. The amount of time spent teaching multiplication facts had the single highest correlation with grade level of any topic taught, approximately -.7. Other topics that typify the fourth-grade curriculum are addition, subtraction, and multiplication of whole numbers and division facts. Topics distinctive of fifth grade are fractions, decimals, ratios and proportions, geometry, and multiple digit division with whole number remainders.

Even for these topics which differ in their emphasis across grade levels, there are surprising examples of overlap in content between grade levels. For example, in one school, multiplication facts were taught for 825 minutes in fourth grade and again for 307 minutes in fifth grade. In another school, multiplication facts were taught 661 minutes in fourth grade and only 18 minutes in fifth grade. In one school multiple digit multiplication was taught for 604 minutes in fourth grade and again for 571 minutes in fifth grade; in another school the fourth-grade teacher taught multiple digit multiplication for 753 minutes, but the fifth-grade teacher spent only 73 minutes on that topic. Other examples of heavy content overlap within some schools and virtually no overlap within other schools can be found for virtually every topic for which there were grade-level effects. Such grade-level overlap is even more common among the other 75% of the topics for which emphasis failed to differ across grade level.

There is one positive finding from these grade-level contrasts. The percent of time spent teaching skills dropped slightly from fourth to fifth grade (i.e., from 76% to 70%), while the percent of time spent teaching application/problem solving increased from approximately 10% to approximately 20% (the percent of time devoted to developing conceptual understanding remained relatively constant at 13% for fourth grade and 11% for fifth grade). This finding, coupled with the finding that on average teachers spend slightly more time teaching mathematics in fifth grade than in fourth grade (8485 minutes in fifth grade versus 7860 minutes in fourth grade), means that fifth graders are receiving more than twice as much instruction in problem solving than they did as fourth graders.

How Much Time to Spend

In most U.S. elementary school classrooms, mathematics is viewed as the second most important subject, reading being the subject given top priority. This importance placed on mathematics, while generally shared, is difficult to document. One reasonable indicator of subject matter status and an indicator of interest in its own right is the amount of instructional time allocated. At least since release of the final report from the California Beginning Teacher Study (Berliner, Fisher, Filby, & Marliave, 1978) over 10 years ago, amount of instructional time has received a great deal of attention, both as an important input into student achievement and as a variable over which teachers and policymakers have relatively direct control.

The data on instructional time for mathematics revealed yet a fourth deeply troubling characteristic of elementary school mathematics. When teachers described how they allocated instructional time to mathematics, those descriptions supported the common perception. Teachers allocate substantially less time to mathematics than to reading and language arts, but as they do with reading, all teachers devote at least one period of instruction to math every school day. Science, social studies, the arts, and physical education each receive less attention. My concerns do not stem from teacher plans, however, but rather from what we found when we investigated the mathematics curriculum as it is experienced by students in the classroom.

Despite their plans, the teachers in the two studies did not teach mathematics every day. Across teachers the number of days for which mathematics was taught during the school year ranged from 139 to 178, a difference of 39 days or roughly eight weeks of instruction. The median number of days during which mathematics was taught, 164, came to three weeks less than the standard 180-day school year.

Number of days in which mathematics was taught is not the only dimension of time allocation on which extreme differences among teachers were found. On days when math was taught, the average length of the math period ranged from 35 minutes per day to 65 minutes per day (with a median of approximately 50 minutes). This difference in length of math period equals a factor of 2. Combining number of days when math is taught with length of math period, it is possible to describe teachers' total math time for a school year. Here again the finding is one of diversity in teaching practices. Total math time ranged from a low of 5,250 minutes to a high of 11,040 minutes, again a difference equal to more than a factor of 2. If we use 50-minute lessons as a metric, one teacher taught math for 116 "days" or 23 "weeks" more than another teacher.

Clearly a student's opportunity to learn mathematics in school varies dramatically, depending upon the classroom to which he or she is assigned. I can think of no defensible reason why public school students should be subjected to such large differences in opportunity to learn mathematics. The problem is not so much teacher intentions, since every teacher in our sample planned to teach mathematics every day for a "reasonable" period of time. Apparently teachers feel great flexibility in their math schedules. Not only do they vary among themselves in the ways reported here, they also vary within themselves across the school year. Only one-fourth of the teachers we studied appeared locked in to delivering a standard-length lesson. The standard deviation across days for length of lesson was greater than 10 minutes for three-fourths of the teachers studied. This feeling of flexibility in scheduling has resulted in large differences in amount of time actually spent on mathematics.

The IEA math study referred to above found that the average amount of time per year allocated to eighth-grade mathematics instruction in the U.S. was equal to or greater than that for most other countries in the study. But these data were based on teacher self-report. Judging from content determinants data, self-report obscures a great deal of variability among teachers in the amount of time actually spent teaching mathematics. Further, in many U.S. schools instruction at eighth grade is departmentalized, with fixed periods and schedules for each subject studied. Content determinants studies suggest that international comparisons at lower grade levels and of the implemented curriculum might find quite different results. In any event, differences in amount of instructional time as large as a factor of 2 either require convincing justification or they should be eliminated.

Recommendations

As have most other recent critiques of U.S. education, this analysis has focused on negative characteristics of instruction. I believe this focus on the negative is justified. First, improvement requires identifying weaknesses, and improvement is what we are after. Mathematics may be the second most important subject in U.S. elementary schools, but during the elementary school years, students' initial positive attitudes about the subject plummet (National Science Foundation, 1982), and achievement in the U.S. lags behind that in other countries. Second, while there were some instances of excellent mathematics instruction, they were rare. Content determinants data describing the implemented curriculum in elementary school mathematics (how much time is allocated, what topics are covered, for which students, and to what standards of achievement) paint a picture of "a curriculum that lacks challenge and vitality" (McKnight et al., 1987, p. 9).

The above analysis suggests the following recommendations for change:

- Elementary school teachers should place greater emphasis in their instruction on the development of conceptual understanding and on providing opportunities to apply concepts and skills in formulating and solving mathematical problems.

- Fewer topics should be covered in greater depth. Every effort should be made to create an expectation on the part of students that topics taught are topics to be learned. This should improve both achievement and attitudes about the subject matter.

- The mathematics curriculum should be better coordinated across grade levels in ways that decrease the extent to which what is taught one year is taught again the next. This too should help students take mathematics seriously. As it stands now, the reward for learning something when it is first taught is to be bored with needless repetition of it in subsequent years.

- Mathematics should be given the status and priority of a subject that is taught at a regularly scheduled time. That time should be rarely interrupted or preempted by other activities.

These recommendations, while revolutionary, are not unique. The first three are similar to recommendations made in the report from IEA's second math study, though arrived at independently. This analysis provides additional empirical justification.

The recommendations are offered with a firm belief that they can be achieved. At least there is no strong reason to believe they cannot be achieved. Current school policies with potential content relevance are either at odds with the recommendations or they fail to address them at all. When objectives go beyond minimum expectations, they typically call for additional topics but fail to provide guidance on what should be eliminated from the curriculum to make room for the new material. This is especially troublesome since teachers are more readily convinced to add topics to what they have been teaching than they are to discontinue teaching topics (Floden, Porter, Schmidt, Freeman, & Schwille, 1981). Minimum competency tests to which school administrators and teachers pay a fair amount of attention all push for an emphasis on skills and away from conceptual understanding and applications. Analyses of textbooks make clear that mandating a textbook is likely to promote the practice of teaching for exposure. Surprisingly, policies concerning the amount of time that should be allocated to mathematics are either nonexistent or offered in the form of weak guidelines.

In short, what advice elementary school teachers get largely pushes in the opposite directions from those recommended here. A promising approach to accomplishing the recommended changes is to redesign the policy environment as it relates to elementary school mathematics.

References

Armstrong, R., Giamdrone, T., Harpel, J., Heidema, C., Kaufman, B., Pederson, P., Papy, F., & Schneider, J. (1985). CSMP mathematics program for the intermediate grades. Kansas City, MO: Mid-Continent Regional Education Laboratory.

Berliner, D.C., Fisher, C.W., Filby, N., & Marliave, R. (1978). Executive summary of Beginning Teacher Evaluation Study. San Francisco: Far West Regional Laboratory for Educational Research and Development.

Carroll, J. (1963). A model for school learning. Teachers College Record, 64, 723-733.

Floden, R.E., Porter, A.C., Alford, L.E., Freeman, D.J., Irwin, S., Schmidt, W.H., & Schwille, J.R. (1987). Instructional leadership at the district level: A closer look at autonomy and control (Research Series No. 182). East Lansing: Michigan State University, Institute for Research on Teaching.

Floden, R.E., Porter, A.C., Schmidt, W.H., Freeman, D.J., & Schwille, W.H. (1981). Responses to curriculum pressures: A policy-capturing study of teacher decisions about content. Journal of Educational Psychology, 73, 129-141.

Freeman, D.J., Belli, G.M., Porter, A.C., Floden, R.E., Schmidt, W.H., & Schwille, J.R. (1983). The influence of different styles of textbook use on instructional validity of standardized tests. Journal of Educational Measurement, 20, 259-270.

Kuhs, T., Schmidt, W., Porter, A., Floden, R., Freeman, D., & Schwille, J. (1979). A taxonomy for classifying elementary school mathematics content (Research Series No. 4). East Lansing: Michigan State University, Institute for Research on Teaching.

McKnight, C.C., Crosswhite, F.J., Dossey, J.A., Kifer, E., Swafford, J.O., Travers, K.J., & Cooney, T.J. (1987). The underachieving curriculum: Assessing U.S. school mathematics from an international perspective. Champaign, IL: Stipes.

National Commission on Excellence in Education (1983). A nation at risk. Washington, DC: U.S. Government Printing Office.

National Science Foundation (1982). Science and engineering education: Data and information. Washington, DC: Author.

Porter, A. (1987). Teacher collaboration: New partnerships to attack old problems. Phi Delta Kappan, 69, 147-152. [Also Occasional Paper No. 105, East Lansing: Michigan State University, Institute for Research on Teaching.]

Porter, A., & Brophy, J. (in press). Good teaching: Insights from the work of the Institute for Research on Teaching. Educational Leadership.

[Also Occasional Paper No. 114. East Lansing: Michigan State University, Institute for Research on Teaching.]

Porter, A., Floden, R., Freeman, D., Schmidt, W., & Schwille, J. (in press). Content determinants in elementary school mathematics. Educational Leadership [Also Research Series No. 179. East Lansing: Michigan State University, Institute for Research on Teaching.]

Schwille, J., Belli, G., Floden, R., Freeman, D., Knappen, L., Kuhs, T., Porter, A., & Schmidt, W. (1980). The content of elementary school mathematics from the perspective of teachers. Paper presented at the annual meeting of the American Educational Research Association, Boston.

Shavelson, R., & Dempsey, N. (1976). Generalizability of measures of teaching behavior. Review of Educational Research, 46, 553-611.

Whitehead, A.N. (1929). The aims of education. New York: New American Library of World Literature.

$3.00

Research Series No. 191

A CURRICULUM OUT OF BALANCE: THE CASE OF ELEMENTARY SCHOOL MATHEMATICS

Andrew Porter

Published By

The Institute for Research on Teaching
College of Education
Michigan State University
East Lansing, Michigan 48824-1034

January 1988

This work is sponsored in part by the Institute for Research on Teaching, College of Education, Michigan State University. The Institute for Research on Teaching is funded from a variety of federal, state, and private sources including the United States Department of Education and Michigan State University. The opinions expressed in this publication do not necessarily reflect the position, policy, or endorsement of the funding agencies.

Institute for Research on Teaching

The **Institute for Research on Teaching** was founded at Michigan State University (MSU) in 1976 by the National Institute of Education. Following a nationwide competition in 1981, the NIE awarded a second five-year contract to MSU. Funding is currently received from the U.S. Department of Education, Michigan State University, and other agencies and foundations for individual research projects.

The IRT conducts major research projects aimed at improving classroom teaching, including studies of classroom management strategies, student socialization, the diagnosis and remediation of reading difficulties, and teacher education. IRT researchers are also examining the teaching of specific school subjects such as reading, writing, general mathematics, and science and are seeking to understand how factors outside the classroom affect teacher decision making.

Researchers from such diverse disciplines as educational psychology, anthropology, sociology, and philosophy cooperate in conducting IRT research. They join forces with public school teachers who work at the IRT as half-time collaborators in research, helping to design and plan studies, collect data, analyze and interpret results, and disseminate findings.

The IRT publishes research reports, occasional papers, conference proceedings, a newsletter for practitioners, and lists and catalogs of IRT publications. For more information, to receive a list or catalog, and/or to be placed on the IRT mailing list to receive the newsletter, please write to the IRT Editor, Institute for Research on Teaching, 252 Erickson Hall, Michigan State University, East Lansing, Michigan 48824-1034.