

Chapter 3

Standards-Based Mathematics Assessments

Appearances May Be Deceiving

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Large-scale, standards-based assessments in mathematics have the potential to improve student achievement at a low cost. They enable students to judge their strengths and weaknesses and to monitor their own progress. They can help educators identify successful instructional methods and curriculum materials. They also provide an objective way to determine the worth of a high school diploma and compensate for the effects of years of grade-inflation and social promotion on the utility of traditional indicators of academic success.

However, a fully developed and coordinated assessment system based on standards of learning in mathematics does not guarantee substantial achievement gains. Much depends on the specificity and difficulty level of the standards themselves at each grade level assessed, as well as the design of the assessments and related reporting mechanisms. Tests that emphasize low-level content may not stimulate significant overall student improvement and may even mask a lack of high-level performance. This possibility is suggested by the findings and conclusions of a landmark report issued by the American Federation of Teachers (AFT) in July 1998, *Setting Higher Sights: A Need for More Demanding Assessments for U.S. Eighth Graders*. This report compared the content and rigor of five eighth grade mathematics tests used in the United States (three commercial tests and two designed for states—one for Texas and one for New York) with the content and rigor of tests used at this educational level in Japan and France.¹ The AFT's findings and conclusions deserve repeating:

The United States does appear to have a de facto national test in mathematics that is visible in current mathematics test content. Large percentages of students across the country take the same or similar tests of math achievement.

Those tests assess low-level content and difficulty at the eighth-grade level.

Existing tests are incapable of providing information about high-end performance because such performance is not tested.

Since existing tests drive what gets taught and what mathematics materials get published, they cannot move us to achieve our goal of being first in the world.

Our analysis of the content and rigor of the Texas Assessment of Academic Skills (TAAS) mathematics tests used from 1995 to 1998, as we reported earlier,² corroborates the findings and conclusions of the AFT report. We analyzed the content and rigor of the Texas mathematics tests for grade 10 (the high school exit test) and the Algebra 1 end-of-course tests, and can now comment more broadly on the Texas assessment system. Its mathematics assessment system has important features. Its design links assessments to achievement standards and curriculum materials. School textbooks align with the contents of the tests. In addition, private industry provides study materials and instruction tailored to the exams. The purpose of this chapter is to present the results of our analysis of the content and rigor of the high school exit tests and the Algebra 1 end-of-course tests used from 1995 to 1998 to describe the model that Texas seems to be using for improving mathematical learning, and to raise questions about the real impact of this model on the mathematics curriculum and student achievement.

Test Policy Issues

Before we turn to our analysis of the items on these tests, we need to comment on the influence of public policy decisions on test construction. Whether or not the effects are explicitly noted, policy decisions that guide test development can have a dramatic impact on the level of achievement measured by the tests.

One important policy decision that affects test content is the stipulation that test items represent content offered in current curriculum materials. The rationale is reasonable enough—students are not to be tested on material they have not had the opportunity to study. However, this stipulation may interfere with a criterion-referenced test design (that is, assessments can potentially be kept from addressing what assessors might want to see tested). The stipulation limits the capability of assessments to drive advancements in student learning. Implementation of such a policy decision tends to perpetuate existing deficiencies in the curriculum. Indeed, during the screening of potential TAAS items, a review was conducted to insure that item content was reasonably well addressed by the existing curriculum in Texas.

Another important policy decision is a legislative mandate that state assessments must measure a state's learning or achievement standards. In Texas, the TAAS system had to be designed to measure the achievement indicators in the Texas Essential Elements, the grade-by-grade standards in force until 1998, when they were superseded by newer ones. In effect, this placed an upper limit on the achievement levels measured by the Texas assessment system. A detailed analysis of the mathematics standards cannot be provided here, but we do provide evidence later to suggest that the tests address mathematics at lower levels than in high-achieving countries.

The TAAS design also seems to have achievement goals that are below the grade level expectations of the Essential Elements in mathematics. To judge from the Texas Education Agency's own cross-reference between the grade-level expectations of the Essential Elements and TAAS's Instructional Targets, the Instructional Targets typically map onto grade-level standards that include the standards for the two prior grade levels.³ For example, the Instructional Targets for grade 8 mapped onto Essential Elements standards for grades 6 and 7 as well as for grade 8. This means that, on average, the test specifications for a particular grade-level test center roughly on standards that are one grade lower in difficulty.

Worse yet, according to this cross-reference provided by the Texas Education Agency (TEA), the items in the TAAS grade 10 exit exam map onto learning standards that are not significantly different from those for the grade 8 test. The relationships between the test objectives and the learning standards in the Essential Elements are summarized in Figure 1.

Mean Grade Level of TAAS Items
Based on Essential Elements

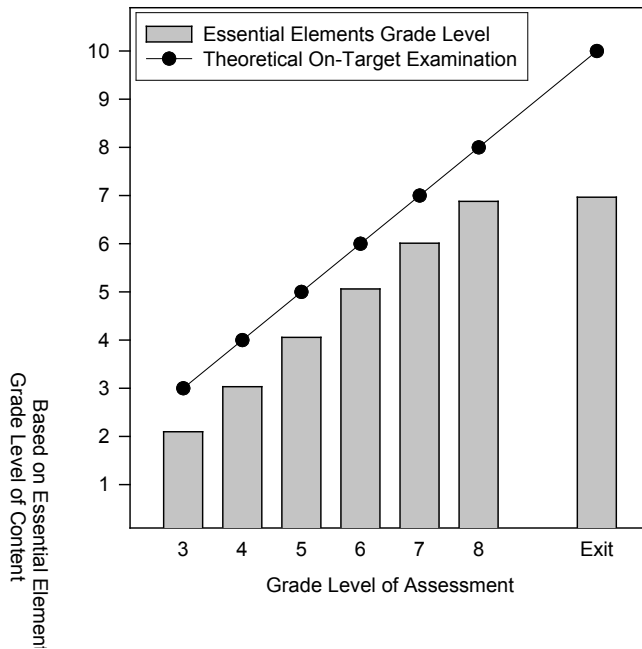


Figure 1

Thus, relative to the Essential Elements, the TAAS grade 8 tests appear to be below grade level and the grade 10 exit tests appear to be similar to the grade 8 tests. However, this observation is based upon information provided by TEA’s documents and addresses only the relationship between the Essential Elements and the TAAS tests. This observation does not speak to how use of the Essential Elements may improve overall achievement, and it does not clarify the actual difficulty level of item content. For a better understanding of the expectations embedded in the tests, we provide a detailed analysis of the content and rigor of the grade 10 high school exit tests and the Algebra 1 end-of-course tests.

The TAAS Grade 10 Exit Tests

The high school exit test in mathematics is first given in grade 10, and students must pass it as a requirement for graduation. By law, items in the tests are released to the public after use. Thus it is possible to inspect and evaluate actual item content. Our inspection of 240 test items—60 per year for four years of tests—revealed several areas of mathematical knowledge weakly represented or missing; answers requiring minimal mathematical knowledge; and items too easy for the grade level assessed. Here are examples of the problems we found in each of these three areas.

Areas of Mathematical Knowledge Not Represented or Underrepresented

Since we reviewed tests from four years, any content area with fewer than four items found means that the content area was not tested at all in some years. The omission or paucity of examples in the areas below clearly suggests the limitations in the mathematical content of the exit tests.

- We found only six items requiring the addition or subtraction of fractions with unlike denominators. In each case, the denominators were simple small integers.
- We found no instances of the multiplication of two fractions. There was only one instance of the division of a mixed number by a fraction.
- We found no items on the relationship between repeating decimals and fractions.
- We found no items directly addressing factors of numbers, prime and composite numbers, greatest common factor, or least common multiples.
- For powers, roots, and exponents, we found only two items calling for the squares of integers (15 and 40). Only one item required finding two consecutive integers that bound the root of a number.
- We found only two items dealing directly with the distributive property and asking for the equivalence of two expressions.
- We found no items involving absolute value. Only one item required sorting signed integers; only one asked for the distance between two altitudes, one of which was below sea level; and only one required evaluating an expression containing a sum in which one addend was negative.
- Regarding area and volume, we found only one item asking for the lateral surface area of a cylinder (although the formula was supplied). There was one item asking for the volume of a rectangular prism.
- We found only one item asking for a median, none for a mode.
- Only two items required the solution of an equation. The equations to be solved were: $1.5x - 6 = 4.5$ and $c = \$15 + \$7.50p$ when c is \$45.

Answers Requiring Minimal Mathematical Knowledge

Multiple choice items are often difficult to write because students can work backwards to the right answer by using a process of elimination. In other cases, correct answers can be found by methods other than those intended; sometimes too much information is given in the item. The result is that the mathematical knowledge an item is intended to test is not drawn upon by the students. Here are some examples from the TAAS exit tests:

- Students were asked for the ordered pair that represents the intersection of two lines given by linear equations. However, the lines were clearly graphed. This problem thus only required being able to identify a point on a coordinate grid.
- Students were told that two ladders are leaning against a building at the same angle. They were given the lengths of both ladders and the distance from the base of the longer ladder to the wall. (A figure showed that the ground forms a right-angle with the wall.) Students evidently were expected to use similar triangles and proportions to determine the distance from the base of the shorter ladder to the wall. Unfortunately, only one answer choice was

reasonable, given the illustration that accompanied the problem. In fact, all incorrect choices exceeded the length of the shorter ladder.

- To solve for unknown lengths of the sides of a right triangle, three items appeared to require the use of the Pythagorean theorem or, at least, the recognition and application of Pythagorean triples. However, the figures were drawn reasonably close to scale and only one response choice for each item was reasonable, given the figure. Thus, students were likely to employ simpler solution strategies than those intended in some of the most difficult content areas addressed in the TAAS exit tests.

Items Too Easy for the Grade Level Assessed

The items discussed above were among the most advanced TAAS items with respect to content. To illustrate the lower end of the spectrum, we list below some of the items showing the lowest level of mathematics content.

The total attendance recorded at the 1984 Summer Olympic Games in Los Angeles, California, was 5,797,923. What is this number rounded to the nearest thousand?

Mrs. Ramos has a plastic cube on her desk that holds photographs. There is a picture on every face of the cube except the bottom. How many pictures are displayed on the cube?

What is the approximate length of a new pencil before it is sharpened? (Response choices are 1.9 millimeters, 19 millimeters, 19 centimeters, and 1.9 meters.)

Devon's house is on a rectangular block that is 330 yards long and 120 yards wide. What is the distance around his block?

Kenyon is 5 feet 6 inches tall. His sister Tenika is 7 inches taller than he is. How tall is Tenika?

At a restaurant Steve ordered food totaling \$6.85. If he paid with a \$20 bill, how much change should he receive?

Certainly every high school graduate should be able to solve problems of this nature easily. However, these items do not reflect the kinds of skills and knowledge appropriate for testing high school students. These items are more appropriate for tests in the elementary grades.

Comparisons with the Content of Tests in Japan

In Japan, 12-year-old students are given a mathematics examination that consists of 225 story problems. These items show a depth of content that is striking in contrast to the TAAS exit test items. Some of these items have been translated into English and we reproduce them by permission.⁴

Jenny wanted to purchase 2 dozen pencils and a pen. Those items cost \$8.45 and she did not have enough money. So she decided to purchase 8 fewer pencils and paid \$6.05. How much was a pen?

Hose A takes 45 minutes to fill the bucket with water. Hose B can do the same in 30 minutes. If you use both hoses, how long will it take to fill the bucket?

A job takes 30 days to complete by 8 people. How long will the job take when it is done by 20 people?

Bob, Jim, and Cathy each have some money. The sum of Bob's and Jim's money is \$18.00. The sum of Jim's and Cathy's money is \$21.00. The sum of Bob's and Cathy's money is \$23.00. How much money does each person have?

Tom's mother is 30 years old. The three children are 5, 3, and 0 years old. 12 years later, the total age of Tom's mother and father is twice as much as the total ages of all three children. How old is Tom's father?

Ellen baked cookies for the neighborhood children. She gave each child 6 cookies and she had 7 cookies remaining. So, she gave one more cookie to each of the children until she ran out of cookies. She was one cookie short. How many cookies did she bake in total?

It is 6 miles between Joe's house and Larry's house. Joe and Larry started to walk to each other's houses at noon, meeting at 12:30. Joe walked 2 miles per hour faster than Larry. How fast did Larry walk?

Grade Level Ratings of the Items on TAAS's Exit Exams

To assess the target grade level of the TAAS exams against external criteria, individual exit exam items were evaluated for their grade level based on the newly established California Mathematics Standards.⁵ These standards provide a desirable benchmark for several reasons. They are perhaps the most highly detailed of all the sets of state mathematics standards, greatly facilitating item evaluation. And they have been judged as the best available mathematics standards among all sets of state standards, even better than those from Japan.⁶

Two of the authors of this chapter independently judged the grade level of every item on the TAAS mathematics exit exams for 1995 to 1998 using California's mathematics standards as the external criterion. There was a high level of rater reliability ($r = .813$). When they disagreed on the grade level of an item, the grade levels were averaged. The average distribution of the grade levels for all the items is shown in Figure 2.

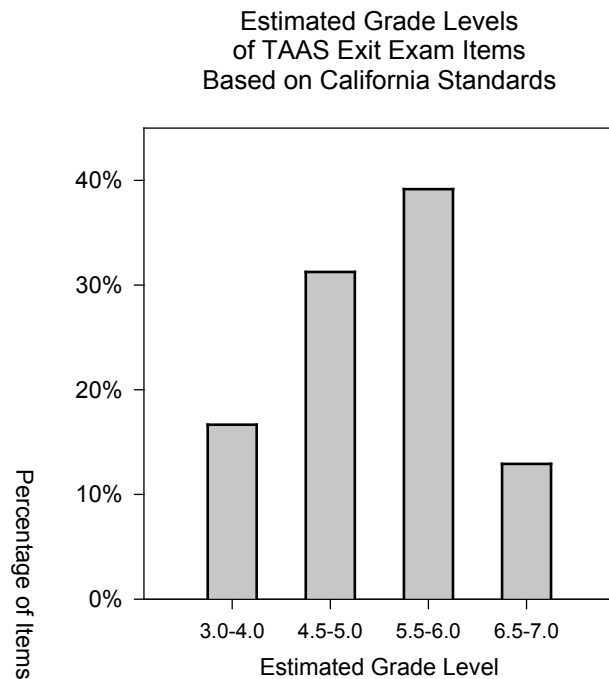


Figure 2

Use of California's Mathematics Standards as the criterion yielded a mean grade level of 5.3 for the items on TAAS's exit exams over the four-year period. The most advanced items on the TAAS exit tests were judged as equivalent to the California grade 7 standards. Admittedly, the California Standards are set at a high level and are roughly equivalent to those in Singapore and Japan. Nonetheless, the low mean grade level of the items on the Texas tests is striking. Moreover, it should be noted that California's standards are designed to complete the content of pre-algebra by grade 7, so that students are ready to study algebra and geometry in grades 8 and above.

The low mean grade level we estimated for the items on the TAAS exit tests raises the possibility that students could pass the TAAS exit test in grade 10 and still not be ready for the study of algebra. This possibility is consistent with the fact that Texas students do better on the TAAS exit tests exams than a more exclusive subset of students do on the Algebra 1 end-of-course test. The problem of a low mean grade level for the items on the TAAS exit tests leads to their insensitivity to high achievement levels.

Insensitivity to High Achievement Levels

The distributions of actual student scores on the TAAS exit exams are given in Figure 3 for three test years. These show strong negative skews, meaning that most students score near the top of the scale range. The presence of a negative skew is not surprising, given that a majority of students get more than 70% of the items correct. However, the skewing is sufficient to confirm that the TAAS tests cannot identify high achievement levels. This means that the tests cannot tell us how well the most able students do, or if there are students who do very well at all. In effect, these tests are blind to high achievement.

There is no way as yet to know the extent to which these ceiling effects are affecting actual achievement—that is, keeping able students from going as far as they could. However, the lack of sensitivity to high achievement levels in the tests does call into question TAAS's capacity to motivate high levels of achievement or instructional objectives. By emphasizing low-achievement levels, they may serve to lower the level of instructional objectives or at least prevent them from advancing.

The use of test scores to address equity issues is also negatively affected by this distribution of scores. There is an incessant relationship between socio-economic status and achievement in mathematics that bodes poorly for the disadvantaged. However, the strength of this relationship will appear to decrease if the top of the achievement distri-

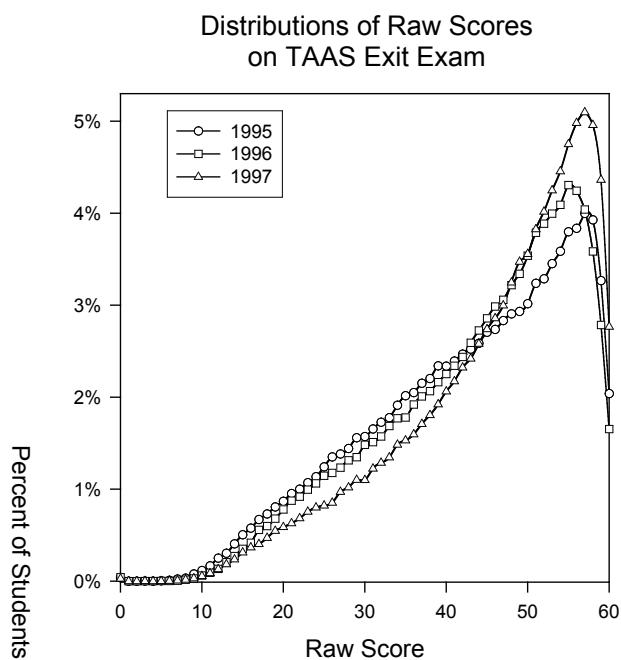


Figure 3

bution is truncated by the use of a test that is too easy. The inherent risk is that data generated by the assessment system would be misleading with respect to equity issues in education.

The Algebra 1 End-of-Course Exams

Students enrolled in introductory algebra must take the Algebra 1 end-of-course test and may use a passing score on this examination to fulfill their high school graduation requirement in mathematics. Our analysis of these tests indicated problems similar to those we found on the grade 10 exit tests—omission of significant content and problems that could be answered with minimal mathematical knowledge.

How the Algebra Items Were Rated

In order to comment on both the content coverage and difficulty level of the Algebra 1 end-of-course exams, we evaluated all the exam items for the four-year period. To accomplish this, we prepared a list of common algebra concepts and skills by looking at several standard pre-algebra and Algebra 1 textbooks and the tests themselves. This list gave us a means to identify objectively the content of each item. Each item also received a 1–5 rating with the following identifiers:

1. *Prior to Pre-Algebra*: roughly fourth or fifth grade mathematics competence without algebra readiness implied.
2. *Pre-Algebra*: standard pre-algebra, as judged against standard texts.

3. *Low Difficulty Algebra*: standard but easy algebra, the level of algebra mastery that might be universally expected.
4. *Moderate Difficulty Algebra*: a more sophisticated level of algebra competence for solution, such as clearing fractions and then solving a linear equation, or finding an obvious least common multiple of the denominators of two rational functions and adding them.
5. *High Difficulty Algebra*: even more sophisticated but still appropriate for a broad screen, end-of-course algebra test, such as clearing the fractions and then solving a resulting quadratic equation, or solving an equation involving radicals that requires squaring both sides twice.

Generally speaking, an item was rated at the pre-algebra level if it appeared that an algebra-ready student who had not yet studied the subject could solve the problem by simply looking at it or by eliminating wrong answer choices rather than using actual algebraic techniques. That was especially true if a student could solve a problem, for example, without clearing fractions, squaring both sides, or factoring as algebraically indicated. Some of the items received higher ratings if response grids rather than a multiple choice format were used.

How Items Were Distributed

The distribution of item ratings for the Algebra 1 end-of-course exams is indicated in Figure 4. The mean rating across all items was 2.46 on the 5-point rating scale. This means that the exams are a combination primarily of pre-algebra material and easy algebra material.

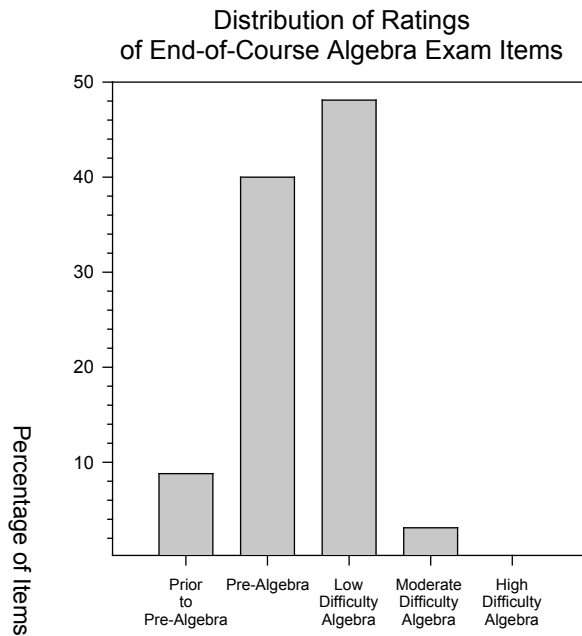


Figure 4

Approximately 14% of the items would have received higher ratings had alternative, less-advanced solution strategies not been available for the item in context (mostly if response grids could replace the multiple choice format). If these alternative solution strategies were not available, the mean rating would increase to 2.62 on the 5-point rating scale.

Missing or Weak Algebraic Content

It is disturbing to see almost no factoring required in the tests. In fact, almost no competency in algebraic simplification or arithmetical operations was tested. Factoring appears to be intended in several items on each test, but it is always possible to get around it, sometimes trivially, as in solution checking, or by using pictures (“factoring blocks”) that give the actual factorization in an artificial form. The ability to factor simple polynomial expressions is very helpful in subsequent algebra courses. The omission of factoring in these tests may signal to the state’s algebra teachers that symbolic manipulation skill does not matter.

Poorly set up problems constitute another shortcoming. Many problems do not require algebraic understanding for solving them. For example, one item on the 1997 test asks, “What are the solutions to the equation $x^2 + 5x = 36$?” One of the answer pairs offered is “ $x = 4$ and $x = -9$.” Checking these values by substitution, the student can immediately conclude that this answer pair is correct without solving the equation.

Direct and inverse variation problems such as asking students to find a constant without a given model to follow, or problems such as “How much water should be added to 20 quarts of a 30% solution to obtain a 14% solution,” have strong practical application in science and would have been useful questions to include. Integer number problems like the following also test algebra skills in greater depth: “The quotient of the successor of an integer number and one-third of the number is 4. What is the number?”

Standard questions involving linear equations and properties of lines are important but poorly done in the Algebra 1 end-of-course test. Much space on the exam is devoted to graphs and pictures attached to problems which probe only the most superficial understandings of linear equations and their graphs. Much better assessment items for this essential topic are easily available. For example, without graphs or pictures, students could be given two distinct points and asked to find the slope, the y-intercept, and the x-intercept of the line containing them. A more demanding problem would provide coordinates for two pairs of points and require students to find where the respective lines determined by these two pairs of points intersect. Carefully constructed questions of these types would not easily lend themselves to shortcuts such as eliminating wrong answer choices. Moreover, the skills tested by these kinds of questions are fundamental prerequisites for more advanced high school and college courses.

The following weaknesses were also noted:

- Too many formulas are given. Many, such as the area of a rectangle or the slope of a line, should not be provided.
- There is almost no confirmation of standard algebraic manipulation skills at all, such as by reduction of fractions involving products of monomials.
- Simple applications of the distributive property, such as factoring polynomials, do not appear.

- Word problems whose solutions require the use of algebra are inadequate in number and in depth.
- Test items on linear equations and their graphs are numerous but superficial to the point of being vacuous. No items involving the relationship of slopes of perpendicular lines appear, for example.
- Many items can be answered by eliminating given answer choices or by inspection. Even the simple inclusion of a “none of the above” response choice would improve some items.
- No test item requires students to use the Pythagorean Theorem or even the special case of the distance formula. Correct answers may be deduced by testing the answer choices until the correct one is found.
- No items requiring the simplification of radical expressions were found.
- Scattergram questions are trivial.
- Even when there is an exact and correct answer among the choices, “Which BEST describes...” language is used in the stem.
- The response-grid format (machine-readable numeric response) is insufficiently used. It was down to one item in 1998.

In summary, the tests for the end of Algebra 1 are more algebra readiness tests than they should be. There are no items that require more than the most trivial symbolic manipulation, and many of the items do not actually require any algebra at all. The statistics and probability questions are not at algebra level even with the most generous interpretation.

The Model Used in the Texas Assessment System

To judge from our analysis, Texas has a relatively stable mathematics assessment system in place. That is, the kinds of items tested and their distribution are similar across the four years we examined. There is also evidence to suggest there has been some improvement in student achievement in mathematics. The percentage of students meeting minimum expectations on the TAAS tests has been rising, and the mathematics scores for Texas students in grades 4 and 8 on National Assessment of Educational Progress tests look promising relative to the rest of the country.⁷ Because the tests are stable, we may conclude that this improvement is real. But, to judge from international comparisons like the Third International Mathematics and Science Study (TIMSS), this may not be saying much.⁸

An Anecdote

It was a warm evening in Arizona, and some of the vacationers at the hotel were lounging by the Jacuzzi. A 14-year-old from Texas chanced to strike up a conversation with a math instructor from California. The instructor asked the teenager about the TAAS exam in Texas. “Oh, that...” replied the youth, “well, the math is very easy and that’s all they teach us, so it gets pretty boring.”

As our analysis consistently shows, Texas assesses mathematics achievement at a low level. Indeed, the content of the high school exit test is more appropriate for the sixth grade. Grade 10

students could pass this test and yet have difficulty with the national exam given to 12-year-old Japanese students. Whether the use of low-level content items on high school level tests stimulates higher overall achievement in mathematics is a critical strategic question. The consequences for many students may be similar to the experience of the teenager in the anecdote above. Use of low-level content items is not consistent with the high expectations for mathematics achievement that are being called for throughout the country.

The risks inherent in using low-level content items in a state assessment seem to be compounded in Texas by its particular emphasis on minimal competence in reporting test results. The TEA uses several methods for reporting TAAS performance data. These include average scale scores, Texas Learning Index scores, Texas Percentile Rank scores, Normal Curve Equivalents, and the percentage meeting minimum expectations. However, the primary focus is on the percentage of students meeting minimum expectations, which is bound to affect the instructional focus in the schools.

The low expectations embodied in the test items for the grade 10 exit test and Algebra 1 test, and the fact that instruction is geared toward these exams, are cause for concern. The results of the analysis of Texas's grade 8 tests (the AFT judged 98% of the items on the grade 8 test as easy) amplify this concern. Moreover, the level of the grade 8 tests suggests that the entire mathematics curriculum up to that point is not demanding enough to promote meaningful achievement in Algebra 1 and in higher level mathematics courses. Algebra is often referred to as a gateway course. Without it, a wide spectrum of career opportunities that depend on mathematics will be denied to students. A recent report from the U.S. Department of Education articulated the need to:

- Provide all students the opportunity to take algebra 1 or a similarly demanding course that includes fundamental algebraic concepts in the 8th grade [to enable students to take] more advanced math and science courses in all four years of high school.
- Build the groundwork for success in algebra by providing a rigorous curriculum in grades K-7 that moves beyond arithmetic and prepares students for the transition to algebra.
- Ensure that all students, parents, teachers, and counselors understand the importance of students' early study of algebra as well as continued study of rigorous mathematics and science in high school.⁹

To judge from our analysis (and that of the AFT), the mathematics assessment system in Texas is not designed to meet these objectives.

Concluding Remarks

The mathematics assessment system in Texas is a comprehensive model but is too highly focused on minimal achievement. The incentives for improvement that accompany the assessment system do not emphasize high achievement sufficiently. The design of the assessments does not permit measurement of high achievement levels. Without a substantial adjustment in the content of the exam items themselves, it seems unlikely that the assessment system will promote development of the curriculum and instruction necessary for students to obtain a rigorous mathematics education.

As the report from the American Federation of Teachers suggests, the shortcomings of mathematics assessment in Texas resemble similar problems across the country. There is no evidence to suggest that a model which focuses on minimal competency can drive overall achievement higher. There is certainly no reason to believe that such a design can help us to catch up to our international competition.

Notes

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