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ABSTRACT

This brief makes the case for reform that addresses multiple parts of an educational system, and increases the access, retention, and achievement of students from all subgroups in high quality science and mathematics education programs. It is recommended that those who evaluate these programs develop guideposts comprised of an equity metric, a way to measure progress toward equity. A chart of research-validated indicators of equity and an initial equity plan for a central city school corporation are presented. (DDR)

NISE BRIEF

REPORTING ON ISSUES AND RESEARCH IN SCIENCE, MATHEMATICS, ENGINEERING, AND TECHNOLOGY EDUCATION

Measuring Progress Toward Equity in Science and Mathematics Education

by Jane Butler Kahle

High quality science and mathematics education for all students matters in today's reform.

October 1997 marked the 40th anniversary of Sputnik, which provided an early impetus for reform of science and mathematics education in the United States. Several permutations later, we are still involved in reform. Currently the focus is on making reform systemic and enabling all students to gain literacy in mathematics, technology, and science, rather than just educating relatively few to become future mathematicians, engineers, and scientists.

The reform of the 1960s did not address the interests or needs of many students who, by nature of their culture, gender, or physical or economic condition, were less attuned to, or had less access to, quality science and mathematics education. Rather, classes were tracked and only a few students benefited. In the last 40 years, the numbers of those historically excluded students have increased dramatically.

The driving force behind the current reform movement is the need to remain economically, scientifically, and technologically competitive with other developed nations. Increasingly, as K–12 students have become more diverse — and as the underrepresentation of whole groups of students in science and mathematics has become more visible — we have come to understand that this time the reform of science and mathematics education must be both systemic and equitable. That is, the reform must address multiple parts of an educational system, and it must increase the access, retention, and achievement of students from all subgroups in high-quality science and mathematics programs. Curricula must change to represent varied interests, to implement more effective ways of providing instruction and organizing classrooms and schools, and to use assessments that include multiple ways of demonstrating learning and competencies. In addition, policies that determine both the quantity of courses and the quality of the educational experience (e.g., teacher qualifications, teaching resources, and academic tracking) must be reviewed and changed to ensure equitable reform. As our student population becomes ever more diverse, simple and defensible ways to measure progress toward meeting the needs and expectations of all students have become increasingly important. Equity, or high quality science and mathematics education for all students, matters in today's reform.

One way to approach these issues is to take stock and assess where a system stands along a continuum toward equity in reform. Each system, defined as a school district in this discussion (but, conceptually, a system may be any educational unit—from an individual class to an entire state), needs to identify guideposts along the path to high quality education in science and mathematics for all students. Taken together, those guideposts form an *equity metric*, a way to measure progress toward equity.

This Brief proposes and describes a methodology for developing and using equity metrics in ways that measure genuine progress toward high quality science and mathematics education for all students.

Active engagement enhances both interest and achievement levels of students who historically have been underrepresented in science and mathematics.

Developing an Equity Metric: From Guideposts to Indicators

Guideposts for equity may be found in the analysis of large national and international databases, in research literature, and in the changing policies and practices of the current reforms of science and mathematics education. For purposes of monitoring a system's progress toward equity, it is important to provide easily understood and acceptable data. Therefore, only measurable guideposts, commonly called "indicators," are included in this discussion of equity metrics. These indicators are drawn from three large databases (NELS:88, High School and Beyond, and TIMSS),[1] NSF's indicators of quality mathematics and science education (National Science Foundation, 1996), and the research literature for evidence of inequality in access, retention, and/or achievement across student subgroups. If evidence of inequity on a type of indicator was found in two or more sources (e.g., unequal enrollments by subgroups in eighth-grade algebra), the indicator has been included in the metric.

Next, the identified indicators have been sorted by grade levels. This helps address two questions:

- At which grade levels is information about students collected?
- At which levels are enrollment, participation, and achievement critical for a student's continued access to and/or progress in science and mathematics?

The sorting suggests leverage points in the educational system that are related to critical times in a child's education; that is, periods when educational systems routinely gather data concerning specific placement (e.g., general mathematics or algebra) and performance (e.g., standard achievement tests, high school graduation). The leverage points identified here are preschool and fourth, eighth, tenth, and twelfth grade. Indicators have been sorted by appropriate leverage points.

Lastly, indicators of general reform were identified. Using the above criteria and databases, indicators of systemwide progress have been added to the metric shown in Figure 1.

A primary reason for caution when using this approach is that gender differences may

Figure 1. Research-Validated Indicators of Equity

Indicators	Leverage Point (Grade)				
	Pre-K	4th	8th	10th	12th
ACCESS					
Home Resources	•	•	•	•	•
Minutes/Day of Math/Science		•			
Enrollment in Algebra/Geometry			•		
Enrollment in Calculus/Physics					•
Adademic Program			•	•	
Expected Academic Program			•		
Limited English Proficiency		•	•	•	•
Quantity/Quality of Math/Science Courses			•	•	•
RETENTION					
Instructional Quality	•	•	•	•	•
Teacher Expectation/Behavior	•	•	•	•	•
Teacher Morale		•	•	•	•
Teacher/Student Attitudes and Beliefs			•	•	•
Learning Behavior		•	•	•	•
Critical Mass			•	•	•
Student Mobility		•	•	•	•
Out-of-School Experiences	•	•	•		
ACHIEVEMENT					
Increase in Eighth-Grade Math Achievement			•		
Increase in Graduation Rates					•
College/Labor Market Performance					•
Decrease in "Gap"		•	•	•	•
Meet Local College Admission Requirements					•
OVERALL					
Equity Plan		•	•	•	•
Plan Implemented		•	•	•	•
Teacher Mobility		•	•	•	•
Increase in Availability of Advanced Math/Science Courses			•	•	•
Increase in Math/Science Graduation Requirements					•
Incentives for Change/Equity		•	•	•	•
Quality of Professional Development		•	•	•	•

Note: Indicators in the equity metric are identified with a dot.

Source: Kahle, J. B. (1998).

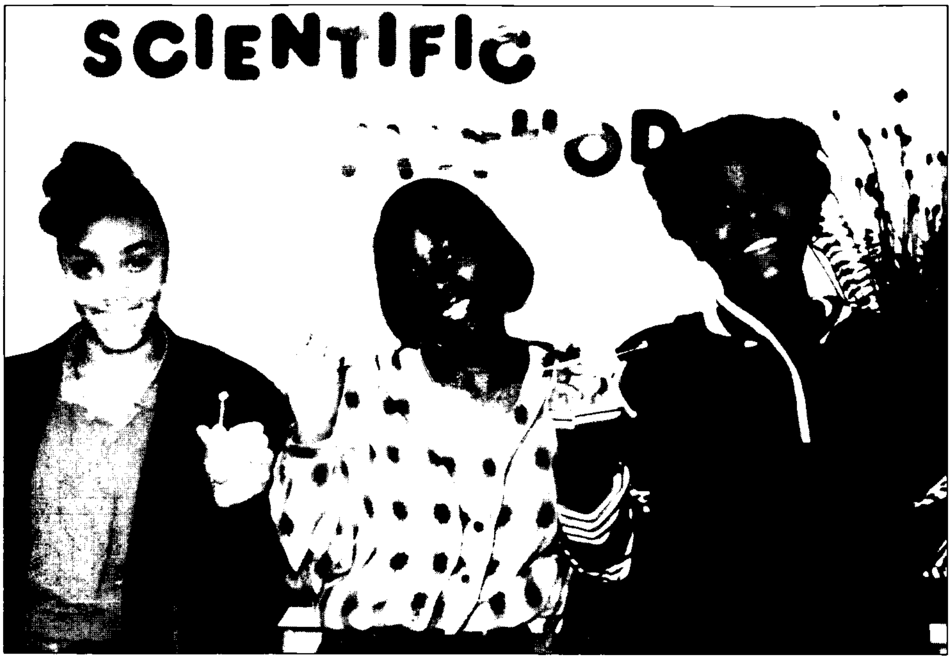
not be identified. Girls and boys enroll in equal numbers in algebra, biology, calculus, chemistry, and trigonometry. Further, on average, girls achieve higher grades in those courses than boys do. However, the enrollment patterns in physics are not equal, suggesting that neither course enrollment patterns nor achievement levels in science and mathematics predict girls' enrollment in physics.[2]

Once indicators have been identified, an educational system can select among them to design its own equity metric. The indicators included in the model equity metric in Figure 1 have been selected to meet the following criteria:

- They are sensitive to diversity among subgroups of students, teachers, and others.
- They can be used to inform action, not just to define the present state.
- They are flexible, because not all metrics are relevant to all parts of the system.
- They distinguish among access, retention, and achievement.
- They are directed toward leverage points in the system.
- They are feasible to use (i.e., affordable).

Constructing a Metric: Selecting Indicators

Indicators may vary across time, changing to address different factors and/or conditions. For example, early studies suggested that teacher qualifications were an indicator of inequity, as they differed between schools serving primarily minority students and those enrolling primarily majority students. However, analysis of current databases indicates that the teachers of minority students are not necessarily less well prepared than teachers of majority students in terms of certification, number of years in teaching, or educational level. There are no significant differences on these indicators in science, and the only difference in mathematics is in the percentage of certified teachers of Native American students compared to all other groups. Therefore, instead of using certification, experience, and attainment of a bachelor's degree as indicators of inequity in



We have come to understand that the reform of science and mathematics education must be both systemic and equitable.

teacher qualifications, indicators of the quality of the teacher preparation and professionalization programs may be needed. For example, more useful indicators may include number of credits in science and mathematics courses, evidence of advanced as well as introductory science and mathematics courses in the undergraduate program, length and quality of practicum or intern experience, and certification by the National Science Teachers Association or the National Board for Professional Teaching Standards.

Other indicators, such as **Home Resources**, may be composed of several factors. For example, attendance at preschool has been found to be an indicator of inequity for Hispanic and Native American children, while presence of a table or desk for a student's own use and presence of a computer in the home differ between minority and majority students and have been linked to student achievement in many of the 41 countries (including the United States) in the Third International Mathematics and Science Study (TIMSS; Beaton, Martin, et al., 1996; Beaton, Mullis, et al., 1996). Those components are easy to measure and may be assessed as part of the indicator.

The indicator **Student Attitudes and Beliefs** addresses the documented decline in positive attitudes in science between fourth and twelfth grades. It is relatively easy to measure and also can be used to address gender equity, because the decline in attitudes is greater for girls than for boys. [3]

Another indicator, **Learning Behavior**, includes absenteeism and tardiness (which are easy to measure and indicate degree of student engagement in learning), the priority students place on learning, and the amount of competition students face for grades (increasing competition correlates with decreasing achievement among non-Asian minority groups).

One of the most interesting indicators is **Quantity/Quality of Math/Science Courses**. Recent studies suggest that to provide equitable education we must move beyond counting the hours or numbers of courses and assuming that courses with similar titles are comparable. Observational studies, teacher logs, teacher and student surveys, and student portfolios are some of the ways by which we can assess the quality of a course. Although indicators of quality (depth of coverage and mode of instruction) are needed, enrollment in key gatekeeping courses (such as eighth-grade algebra or high school geometry) and **Increase in Availability of Advanced Math/Science Courses** are also critical indicators of high quality mathematics and science education. Other key indicators found in Figure 1 are both the intent to enroll in an **Academic Program** in the eighth grade and actual enrollment in one in the tenth grade.

Quality of Professional Development is included as an overall indicator of movement toward equity. Teachers need access to lifelong learning and skill development to implement challenging curriculum, to use varied instructional strategies, to include multiple types of authentic assessments in their classrooms, and to improve their understanding of the backgrounds of students from diverse subgroups. Measurement of the quality of teacher professional development needs to move beyond the number of college or continuing education credits accrued toward the quality of outcomes. Evidence of changing practices, behaviors, and attitudes among teachers and students that may be collected through teacher logs, student journals, audio and video tapes, and interviews is needed. Further, a critical indicator of the quality of professional development is improvement in the retention and achievement of students in all subgroups.

Different Challenges, Different Indicators

Once a system has articulated its equity goals and has identified guideposts or indicators of equity, it must formulate a working plan for becoming more equitable, as well as a timeline for initiating components in its plan. It is estimated that systems will need at least five years to demonstrate progress toward equity using the indicators in Figure 1. Initially, baseline data and appropriate benchmarks of progress must be identified. Next, ways of monitoring progress are needed. Finally, collection and analysis of data, coupled with dissemination and discussion of the findings, must occur. Fortunately, national databases suggest key indicators as well as ones that are applicable for specific student subgroups.

What are key indicators that any system is becoming more equitable? First, retention and achievement in eighth-grade algebra are key indicators of a student's probability of achieving a high quality education in mathematics and science. Second, although not easily quantified, the quality of the content of science and mathematics courses is critical. Third, a clear indication of progress is provided by data from achievement tests that show narrowing of gaps concomitant with increased achievement by all subgroups of students. Fourth, evidence that teaching practices are changing in ways that involve students actively in learning is important, because active engagement enhances both interest and achievement levels of students who historically have been underrepresented in science and mathematics (Stevens, 1996). Although it is tempting to continue to identify key indicators, these four will indicate movement toward equity and provide salient guideposts along the way.

Another approach is to look for indicators that address a given system's priorities. In a rural school system where children have similar ethnic/racial backgrounds and speak English at home, movement toward equity may involve removing differences between girls and boys. What are key indicators of gender equity? First, given that girls exhibit a greater decline than boys in attitudes about science and interest in it, a key indicator of gender equity is sustained positive attitudes and interest levels as girls proceed from fourth grade (where girls are as positive about science and as interested as boys are) through high school. Second, evidence of cooperative learning groups, of activities that relate to everyday life, and of assessments that include writing and explanation would suggest that instruction is meeting the interests and needs of girls.[4] Third, progress would be suggested by indications that girls' out-of-school science and mathematics experiences are similar in frequency and type to those of boys.[5] Fourth, equal enrollments of boys and girls in high school physics would indicate that the system is becoming more equitable.

Different indicators might be the focus of assessment in an urban system whose identifiable subgroups are African-American and white students. Key indicators that such a system is moving toward meeting the needs of the African-American girls and boys — who are underrepresented in terms of enrollment and achievement in science and mathematics courses — would include increased enrollments in preschool programs, proportional enrollment and achievement in eighth-grade algebra, availability of science and mathematics courses that meet the national science and mathematics standards, increased representation of African-American students in academic programs in high school, a decrease in the acceptance or use of behaviors that detract from learning, and proportional enrollment in calculus.

These two brief examples suggest a sorting of indicators based on identified differences between specific subgroups that are of concern in a given district. The following example describes in more detail how a typical urban system developed and used its equity metric. (Because the district was promised confidentiality, a pseudonym is used.)

Equality of the content of science and mathematics courses is critical to achieving equity.

Using an Equity Metric: Measuring Central City's Progress

Central City School Corporation (CCSC) is an urban district that enrolls a mix of students, predominately African Americans (70%) and whites (25%). The district's elementary, middle, and high schools are divided among magnet schools, neighborhood schools, and neighborhood schools with magnet programs. This complex mix is the result of 20 years of court-ordered desegregation guidelines that imposed quotas on the schools in the district.

When CCSC's recent tax levy failed, teachers, administrators, and parents met to discuss the future. They agreed that a major goal for the district was high quality science and mathematics education for all students; they also agreed that any reform needed to be systemic, changing the whole system. CCSC began its systemic reform of science and mathematics education by initiating a self-study. The findings indicated extensive tracking of middle and high school students into basic, general, and academic courses in mathematics and science. In addition, data showed that more than half of the African-American students failed ninth-grade algebra and biology, compared to 35 percent of white students.

When the state initiated proficiency examinations, higher proportions of African Americans failed them. Further, more than half the students who entered high school dropped out prior to graduation, and the rate was higher for African Americans. However, the study also found that the district had a strong program in advanced placement courses, and equal numbers of African-American and white graduates entered college. (Because data were not disaggregated by race and gender, issues of gender equity had not been identified or addressed.) A potpourri of professional development courses was offered to district teachers by several area universities; however, there was no evidence that courses were screened for effectiveness in improving classroom teaching and/or student learning.

With these data as background, CCSC charted a plan of systemic reform to move toward meeting the needs of all children and equalizing opportunities to learn across courses and schools. Although district administrators and teachers realized that many aspects of the system would need to be evaluated, they chose to begin with two, opportunities to learn and achievement in mathematics and science.

First, a comprehensive assessment plan was created so that baseline data, as well as trend data, were available to chart the progress toward equity in science and mathematics education. Initially, CCSC chose the indicators and measures (shown in Figure 2) to assess academic progress in science and mathematics by race/ethnicity and gender.

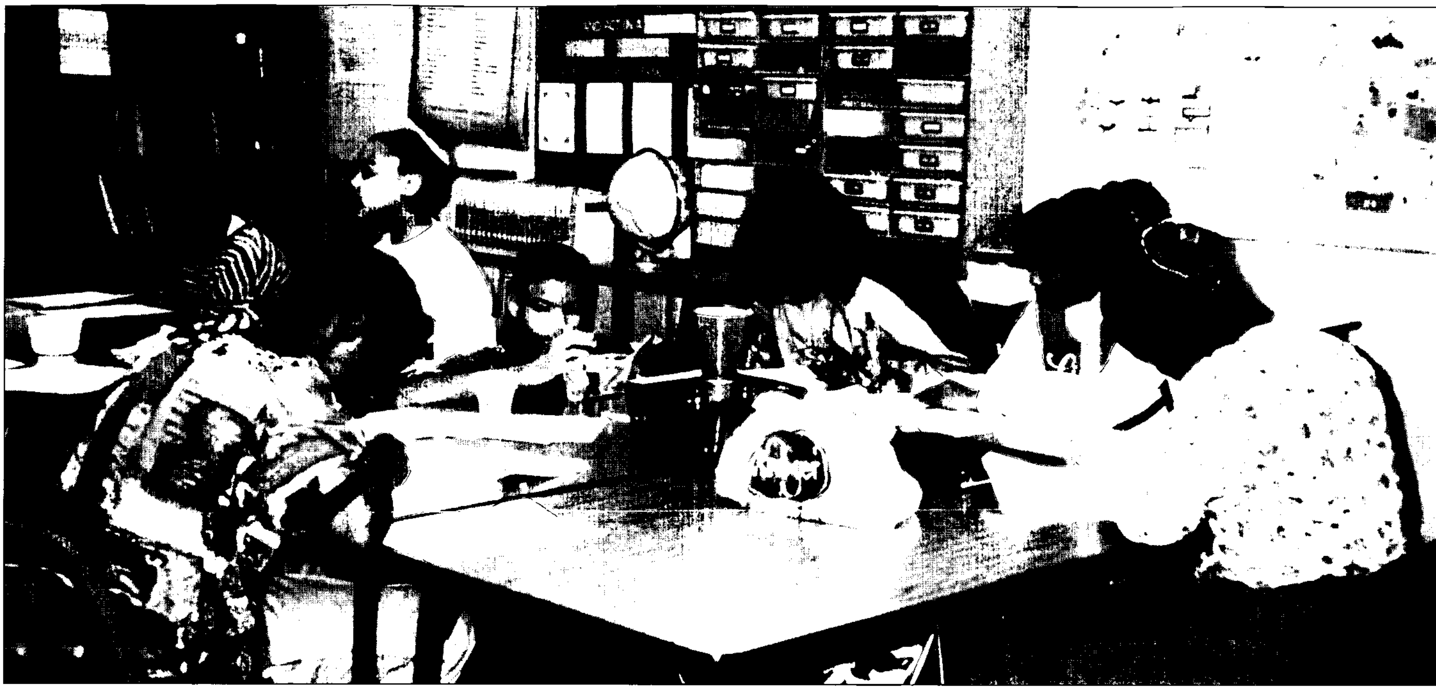
As data were collected, they were analyzed by both race and sex to identify any differences among subgroups, and individual school data were returned to the principals and teachers for discussion and action. As the reform progressed, CCSC (with its union's support) requested that schools set individual equity goals and provided incentives for reaching them. Principals' raises were linked to improvement, as were school-based bonuses. (Union-negotiated contracts prohibited individual teacher bonuses.)

CCSC instituted curriculum reforms (both content and instruction) and developed mechanisms for monitoring progress. All remedial and general mathematics and science courses were replaced with academic courses, and reviews of student transcripts provided progress data. Research-validated, inquiry-based curricula were identified and professional development was provided for school-based teams of teachers.[7] Teachers kept logs of their teaching activities and strategies, and the district surveyed a random sample of teacher logs and student portfolios to assess changes in teaching practice and in the implemented curriculum.

To address the critical issue of unacceptably high failure rates in biology and algebra, as well as high school dropout rates, the district collected data on student mobility and began to allow students to complete the school year in the same

Figure 2. Initial Equity Plan for Central City School Corporation

Leverage Point (Grade)	Indicators and Measures of Progress
4th grade	Stanford 9 Test of Achievement
	State Proficiency Test in Mathematics and Reading
	Minutes/Day of Instruction in Science and Mathematics
	Student and Teacher Mobility
8th grade	Stanford 9 Test of Achievement
	Instructional Assessment Tests (MetriTech Co.)
	State Proficiency Test in Mathematics
	Enrollment in Mathematics by Course
	Selection of Academic Programs
	Student and Teacher Instructional Practice Surveys—Horizon Research Inc., Local Systemic Change Initiatives
10th grade	Passing Rates in Algebra and Biology
	Enrollment in Geometry
	Retention in Academic Program
	Student Mobility by Subgroups (Including Dropout Rates)
	Teacher Mobility
12th grade	State Proficiency Test in Mathematics
	Advanced Placement Scores
	SAT and ACT Scores
	Number of Science and Mathematics Courses Completed
	Graduation Rates
	College Entrance Rates



An equity metric may help reformers to provide equitable education in science and mathematics for all students.

school, regardless of geographic boundaries. Elementary and middle schools were reorganized into multilevel teams so that teachers and students had the opportunity to become learning communities, providing stability and a nurturing environment that was effective in lowering both absentee and dropout rates. Attitudinal data (interest in science, confidence in science skills, perceptions of scientists), behavioral data (numbers of in- or out-of-school suspensions), and attendance data (by specific course) were collected to indicate progress or problems by subgroups. Further, the school system instituted summer programs for eighth-grade students who were at risk of failing ninth-grade algebra and/or biology. The failure rates dropped precipitously, indicating movement toward equity and the need for similar bridge programs throughout high school.[8]

As the reform matured, analyses of teaching practice and achievement data continued to identify leverage points in the system. In addition, it was possible to compare the positive effect of a critical mass of minority students in a calculus class on their achievement and future educational goals and to change boundaries and scheduling to ensure a critical mass in other indicator courses.

As the district's white population became increasingly Appalachian, appropriate indicators were added to the equity plan. For example, attendance in preschool, students' beliefs about the usefulness of mathematics and science, and course selection patterns were monitored for indications of inequity in that emerging subgroup of students.

Early in its reform, CCSC found that past measures of student achievement did not reflect the content of its new inquiry-based curricula. CCSC valued student achievement at the fourth, eighth, tenth, and twelfth grades as indicators of progress and problems, but it needed new achievement measures, such as tests composed of public-release National Assessment of Educational Progress (NAEP) or TIMSS items or new performance-based assessments.

Three to four years into its reform, CCSC's equity metric indicated progress by student subgroups in meeting high standards in mathematics and science. The metric evolved as CCSC's reform evolved, providing useful guidelines and practical measures of progress toward equity. Further, by setting high goals and standards, by systematically measuring progress, and by addressing the needs of emerging subgroups, CCSC garnered community support for its systemic reform.

Summing It Up: Why Is Equity Important in Systemic Reform?

In biology, "systemic" means "affecting all systems" (nervous, digestive, etc.), and each system has self-correcting feedback mechanisms. In education, systemic reform also refers to the whole system, affecting all parts. An equity metric may be used by administrators and teachers to provide continuous feedback during systemic reform, informing and changing components as needed, addressing and correcting inequities, and evolving and adapting indicators and measures. It is not the one and only solution, but it may allow reformers to assess progress and to alleviate problems in providing equitable education in science and mathematics for all students.

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ENDNOTES

[1] For a complete description of these studies, see NELS:88 (Ingels et al., 1989), High School and Beyond (Peng et al., 1981), and TIMSS (Beaton, Martin et al., 1996, and Beaton, Mullis et al., 1996).

[2] More subtle influences, for which we do not yet have adequate or standard measures, seem to affect girls' participation in science and mathematics. Recent studies suggest that more sensitive indicators, as well as varied methodologies for gathering data (such as observations and interviews), may be required to assess progress toward gender equity. Although progress has been made, substantive differences in the science and mathematics education of girls and boys still remain (Wellesley College Center for Research on Women, 1992; Kahle, 1996).

[3] There is a less dramatic decline in girls' interest in and positive attitudes about mathematics, so attitudes about science have been selected as the key indicator (Kahle, 1996).

[4] Gender equity research indicates that girls prefer to learn in cooperative groups and to have science instruction related to real life experiences. Further, there is evidence that girls perform better on written, compared to multiple choice, assessments (Fennema, 1990; Kahle, 1996).

[5] Individual studies suggest that both in- and out-of-school access to and use of technology differ for boys (who have greater access and use) and girls. However, evidence for those differences was not found in the databases used for this Brief. Systems will want to consider adding use of technology to their metric and monitoring the access and type of use by subgroups of students.

[6] For more information see <http://www.horizon-research.com/LSC/default.htm>

[7] A sample of the curricula that meet the criteria include Foundational Approaches to Science Teaching (FAST), Full Option Science System (FOSS), the Biological Sciences Curriculum Study (BSCS) programs, the Connected Mathematics Project (CMP), Algebra Project, Physics by Inquiry, as well as the professional development program Cognitively Guided Instruction (CGI).

[8] Bridge programs refer to special courses or programs that help students meet requirements at the next educational level. In this case, a bridge program in mathematics for eighth graders provided extra preparation for high school algebra. Other examples are summer programs on college or university campuses in English or mathematics to prepare high school juniors and seniors for undergraduate education.

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