Chapter 5

Postscript

This chapter reflects on the process of developing statistical indicators of science and mathematics education. These indicators, which are statistics that shed light on important policy issues, inform policy makers about the state of current science and mathematics education and recommend areas for future investigation. The chapter reviews the frameworks for choosing the statistical indicators in this report. It also reflects on the status of data sources for the chosen indicators and suggests areas that require greater attention in future volumes as well as additional research.

The selection of topics for this report reflects the major issues that are important to the Directorate for Education and Human Resources (EHR) of the National Science Foundation (NSF). EHR is actively involved with conducting research and supporting projects that lead to improvements in student achievement in science and mathematics for all students in the United States. Thus, the indicators in this volume reflect the concerns about how the current efforts to establish standards for science and mathematics education are understood and implemented. They also reflect the changes that are occurring to establish greater equity among male and female students and students of all races and ethnic groups.

Indicators in the Current Volume

The indicators presented in this volume are a synthesis of available statistics about science and mathematics education. Authors selected them from existing national surveys. The authors of this report attempted to select indicators of evidence of change in the Nation's mathematics and science education system. They examined sources of data on trends in student achievement, teacher knowledge and practices, content of curriculum, high school coursetaking, and changes in characteristics of postsecondary students, graduates, and faculty.

The authors of this volume selected indicators of shifts toward the standards of excellence and equity of the education system during the past 2 decades. Moreover, they selected indicators to monitor U.S. efforts to reform the entire education system by setting high expectations for all students' performance and obtaining a greater alignment among components of the education system. For elementary and secondary education, the selection of indicators monitors curriculum coverage, teacher practices, and student achievement. This selection was influenced by national standards, which were developed by professional education associations. For postsecondary education, the selection of indicators monitors the extent of access to science and engineering postsecondary education by underrepresented minorities and females.

Many of these indicators were informed by three commissioned reports about science and mathematics education. These reports followed the Commission on Excellence report of 1983 that brought renewed national attention to the need to reform the elementary and secondary school system. The following section reviews the recommendations of three of those reports in light of the topics addressed by this volume.

Indicators for Elementary and Secondary Education

Three major reports were prepared during the 1980s to define issues of concern to NSF—

- *Educating Americans for the 21st Century: A Plan of Action for Improving Mathematics, Science and Technology Education for All American Elementary and Secondary Students so that Their Achievement Is the Best in the World by 1995*,
- *Indicator Systems for Monitoring Mathematics and Science Education*, and
- *Improving Indicators of the Quality of Science and Mathematics Education in Grades K–12*.

These reports suggested means for developing indicators of science and mathematics education.

Educating Americans for the 21st Century

The Commission on Precollege Education in Mathematics, Science and Technology prepared a plan to improve science, mathematics, and technology education and presented it to the National Science Board in September 1984. This report said that objective measurement of achievement and participation in mathematics and science was necessary and should be performed. It recommended that the National Assessment of Educational Progress (NAEP), which began in 1968, be modified to include assessment of states and the Nation in order to monitor progress using the most up-to-date testing techniques. The report writers' assumption was that the Nation's best students ranked equally with those of any other nation, but that the average American stu-

dent's achievement was low compared with other advanced countries of the world. Thus, the report encouraged efforts to measure the progress of all students. It recommended that certain skills be monitored, including the ability to write for a purpose and apply high-level problem-solving skills to analyze and draw conclusions.

Many of the policies that were implemented after the report was released were consistent with these recommendations. For example, in 1990, the NAEP began to include state-by-state comparisons on a trial basis. These comparisons became a regular part of the survey in 1992. In addition, new forms of national testing were developed to measure high-order thinking skills. Indicators' development also extended into monitoring the changes in student achievement levels for students at high and low levels of achievement.

No specific indicators have been developed for this volume to measure writing skills or the ability to analyze information. Current performance assessment scoring methods recognize these goals, but in practice, national data collection strategies were still under development at the time of writing the current report. Future reports should be able to include reliable indicators of trends in student performance of thinking and writing skills consistent with the recommendations by the 1984 NSF Commission from new survey information that is currently being collected by the NAEP. The future analyses should maintain a focus on how such new indicators would measure progress toward good practices, such as toward adopting the standards of mathematics and science and achieving greater equity of performance among students.

Indicator Systems

In 1987, the RAND Corporation released *Indicator Systems for Monitoring Mathematics and Science Education*. This report sought to identify for NSF a set of indicator systems that would allow monitoring of precollege science and mathematics education. The report focused on science and mathematics indicators since other agencies, such as the National Center for Education Statistics, have major responsibility for collecting information on all aspects of education. RAND's report suggested that a "patchwork" of existing indicators be constructed from existing data sources (such as NAEP) and that developmental research be undertaken to create better indicators that could be used constructively by policy makers and educators. Specific recommendations were that

- an indicator system be developed both to describe and to relate essential elements of the mathematics and science education system;
- key indicators be developed for both the national and state levels;
- critical gaps in existing indicators and analytical methods be identified;
- the amount and quality of data available on mathematics and science education be expanded;
- studies be conducted to analyze the causes of observed changes and suggest alternative policy implications;
- new measures on student achievement be developed to measure knowledge such as the ability to think critically and apply knowledge in solving problems;
- new measures be developed on teacher quality, depth of coverage, and scientific accuracy of the curriculum; and
- procedures be developed to analyze and report indicators that ensure that results are well reviewed and disseminated appropriately.

The report suggested a general model for the specific elements of an indicator system. This model was organized around inputs, processes, and outputs of school systems. The system identified student achievement, attitudes, and aspirations as the main outcomes of schooling. Process indicators were divided into curriculum, instruction, teaching, and school quality. Inputs included fiscal resources, student background, and teacher quality. For each of these areas, the report recommended 99 specific indicators that should be monitored, and it linked them to existing data sources. Additionally, RAND recommended that NSF develop state-level information and create comparisons of different natures (across time, with normative standards, with other countries, and with different populations). The report recommended that NSF not develop its own expensive surveys, but that it develop new measures for existing data collection efforts and develop new measures from them.

Since the report's publication, many of the recommendations have been implemented. For instance, NSF adopted this biennial indicators report with a defined review process. Also, cooperation between the Department of Education and NSF has continued. This has increased the amount of information available about science and mathematics. In addition, the number of state-level indicators has increased. However, these indicators are not yet as well developed as the national indicators because the sample sizes are too small to permit comparison of change over time for each state. Therefore, they cannot be reported regularly as evidence for change within particular states. Finally, as the RAND report recommended, researchers have performed some studies that explore the causes of student achievement (DeAngelis & Talbert, 1995, April; Miller, 1992, April; Schiller, 1995, May 30; Schneider, Plank, & Wang, 1994, August; Sui-Chu & Willms, 1995, April). These studies provide alternative strategies for education policies. They are written for the purpose of describing correlations between schooling experiences and student achievement.

Since 1987, the amount of survey data for elementary curriculum, instructional techniques, and assessments increased substantially. Iris Weiss' (1987) surveys of teachers have increased the amount of information available on what teachers know and how they present materials in class. (See also Weiss, Matti, & Smith, 1994.) Additionally, surveys of students and teachers in several longitudinal studies have increased the information available about the science and mathematics topics that students are exposed to in school. The general model suggested in RAND's report encouraged investigative models of the effects of changes in curriculum and teacher experience to student performance.

Improving Indicators

Recommendations in *Improving Indicators of the Quality of Science and Mathematics Education in Grades K–12* were based on the premises that

- all students need to leave school with adequate knowledge and reasoning skills to be able to renew their knowledge of science and mathematics throughout their lives; and
- student learning is determined by what teachers and students do in schools.

The report, written by the Committee on Indicators of Precollege Mathematics and Science for the National Academy of Sciences, reviewed the needs of the education system and recommended a series of topics that required further development and monitoring. It recommended seven key indicators and a set of supplementary indicators to expand the issues.

The key indicators involved

- learning among students,
- literacy among adults,
- enrollment in science and mathematics courses,
- nature of classroom instruction,
- teachers' knowledge,
- salaries of college graduates, and
- quality of curriculum content in state guidelines and materials.

The supplementary indicators involved

- amount of time spent on science and mathematics homework,
- college courses completed by teachers,
- teachers' use of time outside the classroom for activities related to teaching,
- materials used for instruction,
- Federal financial support, and
- resources committed by scientific bodies for school improvement.

The report recommended that these 13 indicators cover five areas: student learning, student behavior, teaching quality, curriculum quality, and financial support. It recommended that

- an accelerated program of research and development be carried out to construct free-response materials and techniques that measure skills not measured with multiple-choice tests—these materials would help in the development of indicators of learning in science and mathematics;
- information be gathered on the number of minutes per week that elementary students devote to science and mathematics, as well as the number of semesters of science and mathematics that secondary students take, to develop indicators of student behavior;
- teachers be tested on the same content and skills that their students are expected to master and that information be gathered on teacher preparation, such as undergraduate and graduate college coursework, in order to develop indicators of teaching quality;
- exemplary frameworks of science and mathematics content coverage be constructed for elementary and secondary grades, with the highest priority given to early elementary and middle schools, in order to develop indicators of curriculum quality—the frameworks would be used to match textbooks, state guidelines, and materials, such as tests and exercises, to analyze the content of the implemented curriculum for indicators of content coverage; and
- a set of accounts be developed on the expenditures of science and mathematics education from departments and agencies of the Federal Government for indicators of financial and leadership support.

This volume incorporated many of the recommendations in *Improving Indicators of the Quality of Science and Mathematics Education in Grades K–12*, including using indicators on learning among students, coursetaking, nature of instruction, amount of time spent on science and mathematics, courses completed by teachers, teachers' use of time outside the classroom, materials used for instruction, and Federal financial support. However, some recommendations have not yet been developed into indicators. The areas involve adult literacy, teachers' knowledge, and the number of resources committed by scientific bodies.

Some work is being done to remedy this situation. For instance, measures of adult literacy currently are being developed by NSF. However, attempts to develop measures of teachers' knowledge have been difficult because of objections by the teaching community that teacher assessment should not be a concern of policy makers. Studies of resources committed to science and mathematics education by government and nongovernment sources have not yet been conducted. This is an important area for future study. Other areas for future study are discussed below.

Future Directions

The publication of indicators of science and mathematics education require reliable sources of data from elementary, secondary, and postsecondary institutions. Typically, special data collection efforts are required for specific subject areas of science and mathematics because these subjects represent small components of a large education system. The reports discussed in this postscript have suggested mechanisms for integrating the existing surveys of students and teachers into a systematic collection of data. Such efforts could enhance the amount of information available for science and mathematics education.

This indicators report has shown the value of integrating subject area topics into existing surveys, such as the assessment of student learning, the measure of teacher practices in the classroom, and the relationships between secondary school coursetaking with field choice in higher education. However, the development of indicators that measure the issues raised by reform efforts will require new efforts with new types of survey techniques. For instance, monitoring of systemic reform efforts will require indicators on

- alignment among parts of the education system;
- changes in governance;
- number of community, business, and school partnerships; and
- integration of elementary and secondary school systems with postsecondary education.

In addition, new indicators will be required to

- measure changes in student achievement, coursetaking, and teaching practices for states;
- show the relationship between planned and implemented changes to elementary and secondary science and mathematics curriculum, including adoption of technology, as reform efforts continue;
- measure coursetaking and course content within postsecondary institutions;
- monitor the science and mathematics literacy of college graduates; and
- monitor the transition of graduates into the workforce.

Indicators will need to be developed specifically for postsecondary education, because the sources of data concerning students and faculty in undergraduate institutions are limited. The issues of the quality of teaching and learning in colleges and universities have been infrequently addressed in national reports that review the condition of science and mathematics education. Few data sources inquire about teaching practices or the content covered by students. Also, the quality of teaching is infrequently covered in national surveys of higher education or faculty.

NSF has asked the Grants Board of the American Educational Research Association (AERA) to map out a strategy for developing indicators of undergraduate mathematics education. The project is developing a conceptual framework for indicators that will be useful in monitoring the status of undergraduate mathematics education, especially with respect to assessing effects of the various reform initiatives of NSF. The project targets lower division programs for the entire population of students, not just those majoring in mathematics. Concern is for the broad spectrum of public and private institutions including community colleges, liberal arts colleges, comprehensive universities, and research universities. A national panel of experts in undergraduate mathematics education and assessment is expected to release a report in early 1996.

Undergraduate indicators are proposed for

- curriculum and instruction—the content and pedagogy of educational programs;
- student outcomes and assessment—what students know about mathematics and how that knowledge is assessed;
- student participation—the characteristics of students served by mathematics programs; and
- educational institutions and systems—the context within which the teaching and learning of mathematics takes place.

The recommendations of the AERA committee will form a useful basis for restructuring the current data collection efforts for postsecondary education. New surveys and strategies for expanding existing surveys may be needed to provide a strong basis for continued monitoring of undergraduate education.

Concluding Remarks

This biennial assessment of trends in science and mathematics education has found that significant progress has been made in the scope and analysis of national surveys to monitor significant changes in the educational systems of the United States. Yet, as efforts to reform the elementary and secondary system expand, new indicators of governance, partnerships, and alignment among various parts need to be developed, and research on the measurement of learning of science and mathematics must be extended into undergraduate education. Future reports of trends in science and mathematics education shall address the areas outlined in this postscript. ■

Chapter 5 References

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