DOCUMENT RESUME

ED 309 085 SE 050 741

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TITLE	Science and Mathematics Indicators: Conceptual Framework for a State-Based Network.
INSTITUTION	Council of Chief State School Officers, Washington, D.C.
PUB DATE	Dec 86
NOTE	18p.
PUB TYPE	Reports - Descriptive (141) -- Viewpoints (120)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Educational Assessment; Educational Improvement; Educational Quality; Elementary School Mathematics; Elementary School Science; Elementary Secondary Education; *Excellence in Education; Mathematics Achievement; Mathematics Education; Science Education; *Science Projects; *Science Supervision; Secondary School Mathematics; Secondary School Science; *State Programs
IDENTIFIERS	*Mathematics Indicators; *Science Indicators

ABSTRACT

This paper outlines the rationale and basic design for the development of a state-based network for improving indicators of precollege science and mathematics education. The historical background for improving the indicators of the federal and state levels are described. Five elements of a conceptual framework for the network are discussed. These include: (1) "Defining and Identifying Indicators"; (2) "Current Goals for Improving Science and Mathematics Education"; (3) "Using Existing Frameworks and Model Indicators"; (4) "Building on the CCSSO Model of Educational Indicators"; and (5) "Responding to Needs of States." Three phases of this project are discussed. Six categories of the indicators of science and mathematics are listed and described, including student outcomes, instructional time, curriculum content, school conditions, teacher quality, and resources. A total of 15 references are listed. (YP)

Council of Chief State School Officers
State Education Assessment Center

SCIENCE AND MATHEMATICS INDICATORS: CONCEPTUAL FRAMEWORK FOR A STATE-BASED NETWORK

December, 1986

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SCIENCE AND MATHEMATICS INDICATORS:

CONCEPTUAL FRAMEWORK FOR A STATE-BASED NETWORK

This paper outlines the rationale and basic design for the development of a state-based network for improving indicators of precollege science and mathematics education. The project is a new undertaking for the Council of Chief State School Officers (CCSSO) through the support of the National Science Foundation. It is being planned as a major addition to the activities of the Council's State Educational Assessment Center.

The goal of the network project is to work with state education agencies to develop better indicators of the characteristics and quality of science and mathematics in elementary and secondary schools. Improving state indicators through the efforts of CCSSO and the states would have two major benefits: a) improve the quality and usefulness of information at the state level where educational decisions are gaining in importance, and b) develop comparable state data, and thus, provide a more accurate, comprehensive national database on science and mathematics education.

The Education Reforms and Science and Mathematics

The initial impetus for improving educational indicators at national and state levels came from recommendations and reports of several national commissions and study groups, such as the National Commission on Excellence in Education (1983), the National Science Board Commission on

Precollege Education in Mathematics, Science and Technology (1983); the Twentieth Century Fund (1983); and the Education Commission of the States' Task Force on Education for Economic Growth (1983). These reports described serious inadequacies in the quality of elementary and secondary education. A particular concern of the reports was that most U.S. high school graduates leave school with poor preparation in science and mathematics, whether for the job market or for a college education. Specific problems in schools that were cited as contributing to poor science and mathematics education were teacher shortages, quality of teacher preparation, low standards and expectations for learning, and inadequate curricula.

Over the past three years, the federal and state governments have responded to the recommendations for change in education with significant reform legislation, and private foundations and business and industry have also increased their involvement in elementary and secondary education. New federal legislation provided increased funding for training science and mathematics teachers and for curriculum development, improving teaching materials, and research on instruction in science and mathematics. However, the reforms that have most directly addressed the quantity and quality of education in science and mathematics have been initiated at the state level. Many states have increased science and mathematics course requirements for high school graduation, provided incentives to attract and retain teachers, and reviewed and strengthened curricula at the elementary and secondary levels.

Improving Information on Science and Mathematics Education

The recommendations for change in elementary and secondary education were accompanied by recommendations for improvement in the quality and availability of information on the performance of the educational system. For example, the report of the National Science Board Commission, Educating Americans for the 21st Century, noted major problems with the quality and usefulness of data on student outcomes, characteristics of teachers, and school conditions. The Commission cited the need for better measures of education quality and methods of collecting and aggregating data that would allow regular monitoring at national, state, and local levels.

As the various reforms directed toward education quality progressed, federal and state governments have become more aware of the importance of having useful information on the status of education and the effects of educational improvement initiatives. The National Science Foundation (NSF) has been improving its capacity for monitoring the condition of education in science, mathematics, and technology. The shortcomings of existing data and indicators were outlined in the chapter on Science Education in the 1985 edition of NSF's biennual report, Science Indicators. Since 1984, the Science and Engineering Education Directorate of NSF has initiated a series of projects that will provide new information on the status of science and mathematics in our schools, add to existing sources of information, and advise NSF and others on directions for revising current systems for collecting and analyzing data.

The states have placed new emphasis on educational indicators in conjunction with the series of reforms being implemented at that level.

Many state education agencies have developed assessment tests in various subject areas and at a number of grade levels, in addition to state competency tests for promotion or graduation (CCSSO, 1984). State efforts to increase pay and incentives for teachers have been accompanied by tests of teacher competencies and skills. Currently, 35 states require teachers to pass a written test for certification, and some states have developed new methods of assessing teaching performance in the classroom (ECS, 1985). However, with the current education reform activity, states are not only developing new tests, they are looking at their entire systems of information-gathering to determine how well they serve the needs of program managers and policy-makers.

<u>Improving State Indicators</u>

The state-based network to develop science and mathematics indicators is being initiated because of the interest and commitment of the states, and NSF, to improving educational indicators and systems for monitoring education quality. In 1984, the Council of Chief State School Officers made a fundamental shift in its policy on the role of states in educational assessment and evaluation. In a major policy paper, the CCSSO affirmed the responsibility of states to ensure that the data on education collected by states were of high technical quality and useful consistency from state to state (CCSSO, 1984). Similarly, the National Governors' Association has called for "report cards" on states' efforts to make educational improvements in seven areas (1985). In a recent report, the governors recommended steps to improve teaching and provide better information on teachers (NGA, 1986). By building on existing efforts by states to improve data on education, this project provides an excellent opportunity to improve the comprehensiveness, utility, comparability, and technical quality of state indicators of precollege education in science and mathematics.

Elements of a Conceptual Framework for the State-Based Network

The project plan for working with states to improve indicators of science and mathematics is based on a conceptual framework. The framework provides linkages between current work on indicators and the states' role in science and mathematics education.

Five elements comprise the conceptual framework for the state-based network:

1. Defining and Identifying Indicators. The objective of improving state indicators of science and mathematics is not to increase the amount of information that is collected and analyzed by states, but rather to emphasize the use of data and information by policy-makers, managers, and educators. In another field, economic indicators such as the unemployment rate or the gross national product reflect only a very small portion of the data on the American economy that are collected by the federal government, but the indicators are widely known and used.

An "indicator" has been defined by a committee of the National Academy of Sciences as follows:

> ...a measure that conveys a general impression of the state or nature of the structure or system being examined. While it is not necessarily a precise statement, it gives sufficient indication of a condition concerning the system of interest to be of use in formulating policy...Optimally, an indicator combines information on conceptually related variables, so that the number of indicators needed to describe the system of concern can be kept reasonably small. (Raizen and Jones, 1985, p.27)

With respect to states, educational indicators may comprise a selected portion of the data and statistics gathered and analyzed by an education agency.

In developing a system of educational indicators, the local, state, or federal "policy context" plays a major role in the selection and implementation of indicators (Oakes, 1986). A central idea of this project is to organize the identification and improvement of indicators around a network of three representatives from each state education agency. The CCSSO and the network will work on "brokering" improvements with states, and building on the systems of data collection that are in place.

The process of identifying and developing science and mathematics indicators through the state network will involve three steps: a) collecting and synthesizing information on state data collection practices, and comparing the types of information available with model, or "ideal", indicators, b) working with states to develop strategies for improving indicators, and c) assisting individual states with implementing improvements in their systems of indicators.

2. Current Goals for Improving Science and Mathematics Education. Research or analysis of a system typically has an underlying theory or set of assumptions about how the system should function. In our society, there are a variety of well-known values and goals for elementary and secondary education. The recent national commission reports have been quite explicit about the desired directions for improvement in science and mathematics (National Science Board, 1983; Education Commission of the States, 1983; Twentieth Century Fund, 1983; Raizen and Jones, 1985; Carnegie Forum on Education and the Economy, 1986). Several common goals for improving the quality of science and mathematics education in our schools are found in these reports, and many state education reforms have been framed with these goals in mind:

- Advancing Science and Mathematics Literacy of all Students.
Science and mathematics are important core areas of learning for all students, regardless of their career intentions. Students should leave school being literate in science and mathematics and have the preparation for renewing their knowledge of science throughout life.

- Education and the Economy.
Schools need to increase the level of student learning in science and mathematics for the American economy to remain competitive. The growing central role of technology in most areas of the economy demand requisite knowledge in science and mathematics.

- Assessing Learning.
Student achievement in science and mathematics should be assessed with direct measurement of the skills, processes, and content learned in school, and not simply by counting the grade level or number of courses completed by students.

- Improving Teaching Quality.
Improving the preparation of new teachers and attracting and retaining highly qualified people to teach science and mathematics are necessary to advance science and mathematics education in the U.S.

Indicators developed through the project should reflect these current directions for improving science and mathematics education.

3. Using Existing Frameworks and Model Indicators. The work with states to develop and improve mathematics and science indicators will benefit from findings and recommendations from several recent studies and projects.

A committee of the the National Academy of Sciences/National Research Council is developing indicators that are needed to adequately monitor and assess the quality of education in science and mathematics in elementary and secondary schools. This study of model indicators follows an earlier analysis of the quality and usefulness of existing science and mathematics indicators that are available to education policy-makers, program managers, and educators (Raizen and Jones, 1985).

The Rand Corporation is conducting a study of alternative prototypes for a national monitoring system in mathematics, science, and technology education. The project involves a review of research on the relationship of characteristics of schools, classrooms, and teachers to student outcomes in science and mathematics, identification of critical variables in a comprehensive model of the education system, and development of several models for selecting indicators for a national monitoring system.

A mathematics monitoring center has been developed at the University of Wisconsin-Madison, which is analyzing the effects of education reform efforts on mathematics instruction and student learning. To accomplish this task, the center is developing a model to collect and analyze data that explain the performance of students in mathematics and to identify important educational indicators for tracking trends in elementary and secondary mathematics.

The recommendations for science and mathematics indicators from these three projects will inform the selection of "ideal" indicators for analyzing current state data and indicators. In addition, findings and recommendations from other recent national studies on education will contribute to the selection of "ideal" indicators, such as the Carnegie Forum on Education and the Economy (1986), the National Governors Association (1986), and the National Science Board Commission on Precollege Education in Mathematics, Science and Technology (1983). Several national surveys and studies have used data items that are likely to be useful for developing state indicators, including the 1985-86 National Survey of Science and Mathematics Education, the 1985-86 National Assessments of Educational Progress in Mathematics and Science, and the High School and Beyond surveys.

4. <u>Building on the CCSSO Model of Educational Indicators</u>.

In October 1985, the Committee on Coordinating Educational Information and Research (CEIR) of the CCSSO approved a model for state education indicators. The CCSSO model has three components: a) indicators of educational outcomes, b) indicators of school policies and practices, and c) indicators of contextual factors.

CEIR recommended a core set of indicators for the model, and these recommendations provided an outline for the CCSSO program to develop a system of comparable state data on education. Three criteria were established by CEIR for selecting the core indicators: importance/use by states, technical quality, and feasibility; and it was decided that the three criteria should be applied in this order.

Since the adoption of the CEIR report, CCSSO has begun putting the core set of indicators into place. The development of science and mathematics indicators in this project will follow the CCSSO model; the categories of indicators will be consistent with the model, and specific measures will be recommended that meet the review criteria. Thus, the science and mathematics indicators project will serve as a means of implementing the model approved by the Chiefs, but the work will be concerned with developing indicators and measures that are specific to science and mathematics.

Fortunately, a good deal of information about state indicators and data is already available. Existing sources of information include the UCLA study of state assessment tests (Burstein, 1985), the recent ECS reports on graduation requirements (1985) and on state teacher policies (1985), surveys of state competency tests and assessment tests (ECS, 1985; CCSSO, 1984), a CCSSO study of states' uses of automated information systems (1982), a recent study by ETS of state educational standards (Goertz, 1986), and a forthcoming study by the National Research Council on statistical models for teacher supply and demand.

5. Responding to Needs of States. In its indicators program, the CCSSO is working to develop states' capacity to assess educational outcomes by improving the quality and usefulness of information, not by increasing local and state regulation and data burden. The state-based network to develop science and mathematics indicators will be designed with the same view toward balancing the need for a more complete picture of education with the constraint of selecting the most useful, valid, and feasible indicators of school policies and practices and student outcomes.

Reviewers of the CCSSO proposal for this project noted that it is very important that specific information be obtained about current state definitions and practices in collecting information on science and mathematics education. Specific differences between the states need to be compiled and analyzed in order to assist states in improving science and mathematics indicators and developing comparable state data. For example, information on the skills and knowledge in science that are expected in specific state tests for teachers is likely to be more useful to states than simply learning how many states have teacher competency tests in science.

The Council of Chief State School Officers has demonstrated that very specific, useful information on state data collection definitions and procedures can be obtained in an efficient manner. The Education Data Improvement Project that is currently being conducted for the U.S. Department of Education involved analysis of the core-data program, with each state being asked to verify and elaborate the definitions, instruments, and operational procedures they use for each data element. Successive iterations of verification were used to clarify any multiple interpretations that were possible in the state's definitions and procedures.

In the new project, the same type of iterative process will be used to compile a set of highly specific profiles of how each state operationalizes and uses a number of indicators of education in science and mathematics. The completed "inventory" of state definitions and practices will provide the basis for assessing the need for revising and improving state indicators.

Three Phases of the Project

The project will be carried out through three major steps or phases:

1. In the first year of the project, an inventory will be conducted with states on their current definitions and procedures for collecting information with selected types of indicators. A state network comprised of 3 representatives from each state education agency will coordinate the inventory process in each state. A shuttle process will be used to report and verify the information with CCSSO, with the first round of the shuttle to report on the activities of the states with each type of indicator and the second round to provide details on definitions and specific procedures. The plans for the project will be carefully reviewed by a 15-member advisory board. The project staff at the CCSSO will compile the information provided by the states, and compare the recent state definitions and procedures with ideal indicators of science and mathematics education. The results of the analysis will demonstrate the types of indicators that are likely to lead to comparable state information and the indicators that will require more work by some states.

2. In the second year, the state network participants and CCSSO staff will work together to establish priorities and strategies for improving indicators in science and mathematics education and moving towards a cross-state database on science and mathematics. A state-by-state plan will be developed for revising or upgrading the collection of data on science and mathematics indicators, based on the findings from the inventory of state practices and the established priorities.

3. Work will begin on implementing state plans for indicators in the third year of the project. The CCSSO staff will provide technical assistance to each state and coordinate the implementation of an improved system for data indicators in mathematics and science education. The system of indicators will be characterized by high quality, utility, cross-state comparability, and the capacity for aggregation of data and indicators on science and mathematics education across states.

Design for Science and Mathematics Indicators

Initially, six categories of indicators of science and mathematics will be examined: 1) student outcomes, 2) instructional time, 3) curriculum content, 4) school conditions, 5) teacher quality, and 6) resources.

For each type of indicator, information will be collected and verified on current state practices and definitions (including level of aggregation and method of collecting data), plans for developing indicators, and uses of indicators. This draft list of types of indicators will be revised as the project proceeds; it is provided here to outline the structure of the indicators framework.

Student Outcomes

Following indicators by student gender and race/ethnicity:

- o Student achievement based on assessment of learning in science and mathematics, in terms of specified, expected concepts, processes, and skills; assessment at elementary, intermediate, and secondary levels;
- o College majors in science and mathematics (sophomore year);
- o Rate of students entering careers requiring science and mathematics preparation.

Instructional Time

- o Time per week on science and mathematics in elementary grades;
- o Number of science and mathematics courses during grades 7 - 12;
- o Total enrollment by course title in science and mathematics grades 7 - 12;
- o Hours of homework per week in science and in mathematics.

Curriculum Content

- o Characteristics of curriculum frameworks for science and mathematics;
- o Comparison of curriculum frameworks with levels of science and mathematics curricula;
- o Breadth and depth of coverage of content topics, based on information from teachers.

School Conditions

Following indicators by characteristics of students in school:

- o Number of students per science and mathematics teacher;
- o Number of classroom/laboratory aides per science and mathematics teacher;
- o High school course offerings in science and mathematics;
- o Teacher perceptions of working conditions.

Teacher Quality

- Elements of state model to project teacher supply and demand in science and mathematics;

- Characteristics of "new hires" in science and mathematics, including status after two years.

Following indicators by teaching assignment in science or mathematics (subject, grade level):

- Assessment of teachers' knowledge of subject content and pedagogy in subject;

- Observed teaching performance in subject area;

- Education and supervised teaching experience in subject area;

- State certification requirements in science and mathematics;

- Years of experience, total, and in teaching assignment;

- Professional development through formal courses and through in-service and professional activities.

Resources

- Average teacher salaries in mathematics and science by college major;

- Ratio of teacher salary of science and mathematics majors to salary of non-teaching science and mathematics majors in state;

- Availability and use of equipment, instructional materials, texts, and laboratory facilities.

REFERENCES

Burstein, Leigh, Baker, Eva, Aschbacher, P. and Keesling, J.K. Using State Test Data for National Indicators of Educational Quality: A Feasibility Study. Los Angeles: U.C.L.A. Center for Study of Evaluation, 1985.

Carnegie Forum on Education and the Economy. A Nation Prepared: Teachers for the 21st Century. The Report of the Task Force on Teaching as a Profession. Washington, D.C.: Carnegie Forum on Education and the Economy, 1986.

Council of Chief State School Officers. Educational Assessment and Evaluation in the United States: Position Paper and Recommendations for Action. Washington, D.C.: Council of Chief State School Officers, 1984.

Education Commission of the States. New Directions for State Teacher Policies. Denver, Colo.: Education Commission of the States, 1985.

Goertz, Margaret. State Educational Standards: A 50-State Survey. Princeton, N.J.: Educational Testing Service, 1986.

National Center for Education Statistics and Council of Chief State School Officers Committee on Evaluation and Information Systems. An Information Exchange on the Status of Statistical and Automated Information Systems in State Education Agencies. Washington, D.C.: Council of Chief State School Officers, 1982.

National Commission on Excellence in Education. A Nation at Risk: The Imperative for Educational Reform. Washington, D.C.: U.S. Department of Education, 1983.

National Governors' Association. Briefing Book: Education. Washington, D.C.: National Governors' Association, Center for Policy Research and Analysis, 1985.

National Governors' Association Task Force on Teaching. Time for Results: The Governors' 1991 Report on Education. Washington, D.C.: National Governors' Association, Center for Policy Research and Analysis, 1986.

National Science Board Commission on Precollege Education in Mathematics, Science and Technology. Educating Americans for the 21st Century. Washington, D.C.: National Science Foundation, 1983.

National Science Board. Science Indicators: The 1985 Report. Washington, D.C.: National Science Foundation, 1985.

Oakes, Jeannie. Educational Indicators: A Guide for Policymakers. New Brunswick, N.J.: Center for Policy Research in Education, 1986.

Raizen, Senta A., and Jones, Lyle V., eds. Indicators of Precollege Education in Science and Mathematics. Committee on Indicators of Precollege Science and Mathematics Education, National Research Council. Washington, D.C.: National Academy Press, 1985.

Task Force on Education for Economic Growth. Action for Excellence: A Comprehensive Plan to Improve Our Nation's Schools. Denver, Colo.: Education Commission of the States, 1983.

Twentieth Century Fund Task Force. A Report of the Twentieth Century Fund Task Force on Federal Elementary and Secondary Education Policy. New York: The Twentieth Century Fund, 1983.