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Sample Design

A. Design Overview

The sample design for the 2000 National Survey of Science and Mathematics Education is a national probability sample of schools and teachers in grades K–12 in the 50 states and the District of Columbia. The sample was designed to allow national estimates (totals and ratios of totals) of science and mathematics course offerings and enrollment; teacher background preparation; textbook usage; instructional techniques; and availability and use of science and mathematics facilities and equipment. Every eligible school and teacher in the target population had a known, positive probability of being drawn into the sample.

The sample design involved clustering and stratification. The first stage units consisted of elementary and secondary schools. Science and mathematics teachers constituted the second stage units. From the science and mathematics classes taught by sample teachers, a sample of one class was selected for each teacher. The target sample sizes were 1,800 schools and 9,000 teachers selected within sample schools. These sample sizes are large enough to allow sub-domain estimates such as for particular regions or types of community.

The sampling frame for the school sample was constructed from the Quality Education Data, Inc. database, which includes school name and address and information about other characteristics needed for stratification and sample selection. The sampling frame for the teacher sample was constructed from lists provided by sample schools identifying active teachers and the specific science and mathematics subjects they were teaching.

B. School Sample

This section describes the sample design features of the school sample. It is organized as follows:

- Target Population;
- Sampling Frame;
- Stratification;
- Sample Allocation;
- Sample Selection; and
- School Weight.

Target Population
The target population for the school sample includes all regular public and private schools in the 50 states and the District of Columbia. Excluded from the target universe are vocational/ technical schools, schools offering alternative, special or adult education only, and preschool/kindergarten-only schools.

Sampling Frame
The sampling frame for the school sample was constructed from the Quality Education Data (QED) school-level database. Educational institutions classified by QED as public, private and Catholic elementary and secondary schools were included. Excluded were Bureau of Indian Affairs schools and Department of Defense schools. A file was extracted from the original QED file including records for all eligible schools.

For all schools in the database, QED included information on grade span by indicating the lowest and highest grade offered in the school. Schools eligible for the survey were classified on the basis of the grade span variables into one of three sampling frames corresponding to the three primary sampling strata. In schools with nonconsecutive grade spans, school eligibility and assignment to strata were based on the four grade-level fields on the QED file that provide the low and high grades for the nonconsecutive grade levels.

Stratification
Three primary sampling strata were defined for the school sample. The strata definitions are based on grade span as follows:

- Stratum 1: Schools with any grade 10, 11, or 12;
- Stratum 2: Schools not in stratum 1, but with no grades lower than 5; and
- Stratum 3: All other schools.

Secondary strata were defined by Census geographic region—Midwest, Northeast, South, and West; metropolitan status—urban, suburban and rural; and private (including parochial schools) versus public auspices. Implicit stratification was achieved by sorting the file by Orshansky percentile (i.e., proportion of the students in the school district who live in families with incomes under the poverty line) within secondary stratum.

Sample Allocation
The allocation of the total school sample (1,800 schools) among the three primary strata was based on the minimum sample size desired for each stratum and the desired sample sizes for teachers of advanced mathematics and physics/chemistry. The sample allocation was the following:

- Stratum 1: 940 schools;
- Stratum 2: 430 schools; and
- Stratum 3: 430 schools.

Sample Selection
The school sample was selected with probability proportional to size (PPS). The measure of size was defined for each of the primary strata as follows:

- Stratum 1: Estimated number of teachers in grades 10–12 [computed as: (number of grades in 10–12 range) x (total teachers from QED/number of grades)];
- Stratum 2: Total number of teachers, from QED; and
- Stratum 3: Total number of teachers, from QED.

For school records with missing teacher counts, the measure of size was estimated by imputing a total number of teachers in the relevant grades based on grade-specific student to teacher ratios, estimated separately for private and public schools.

Within primary stratum, the file was sorted by secondary strata and two independent half-samples of the specified sizes were selected using the standard PPS selection procedure. Independent random starts were generated to achieve independent half-samples within secondary strata. In the process of sample selection, a half-sample identifier was assigned to each sample record. Table A-1 shows the distribution of the sample by primary and secondary stratum.

Table A-1
Distribution of Sample, by Stratum

	Secondary Stratum			Primary Stratum		
	Region	**Status**	**Public/ Private**	**1 Grades 10–12**	**2 Grades 5–9**	**3 Other**
1	Midwest	Urban	Public	52	28	29
2			Private	9	—	5
3		Suburban	Public	113	58	43
4			Private	15	—	9
5		Rural	Public	53	14	20
6			Private	2	—	2
7	Northeast	Urban	Public	42	24	21
8			Private	11	—	5
9		Suburban	Public	103	51	38
10			Private	18	—	9
11		Rural	Public	25	7	11
12			Private	2	—	1
13	South	Urban	Public	90	57	48
14			Private	15	1	6
15		Suburban	Public	149	89	65
16			Private	14	—	6
17		Rural	Public	57	22	25
18			Private	4	—	1
19	West	Urban	Public	50	29	29
20			Private	9	—	4
21		Suburban	Public	82	44	40
22			Private	8	—	5
23		Rural	Public	16	6	7
24			Private	1	—	1
	TOTAL			**940**	**430**	**430**

School Weight

A base weight, W_{hs}—the reciprocal of the school's probability of selection—was assigned to every school in the sample as follows:

$$w_{hs} = \frac{MOS_h(total)}{n_h \; MOS_{hs}}$$

where:

MOS_h (*total*) = Total measure of size in primary stratum *h*
MOS_{sh} = Measure of size for school *s*

This is also the base weight associated with program heads since science and mathematics program questionnaires were distributed in every sample school.

C. Teacher Sample

The following section describes the sample design features of the teacher sample. It is organized as follows:

- Target Population;
- Sampling Frame;
- Stratification;
- Sample Allocation;
- Sample Selection; and
- Selection of Classes.

Target Population
The target population for the teacher sample consists of teachers in eligible schools (see School Sample, Target Population) who teach science and/or mathematics. Science includes biology, chemistry, physics, earth science, and other science.

Sampling Frame
The sampling frame for the teacher sample was constructed by requesting that principals in all sample schools provide a list of eligible teachers and identify the courses taught by each teacher. To assist the school in providing the information necessary to build the frame, a listing sheet was provided with appropriate column headings depending on the school's primary stratum. For schools in stratum 1 the following science and mathematics categories were listed:

- High school physics or chemistry;
- Other science;
- Mathematics: High school calculus or advanced mathematics; and
- Mathematics: Other mathematics.

For strata 2 and 3 the categories listed were:

- Science and
- Mathematics

Stratification
Based on the course information provided for teachers on the school list, each teacher was assigned to one of the following five teacher strata:

- Physics/chemistry with or without other science, no mathematics;
- Advanced mathematics with or without other mathematics, no science;
- Other science only;
- Other mathematics only; and
- Any combination of mathematics and science.

Sample Allocation
The target allocation of the sample of 9,000 teachers to the three primary school strata was the following:

- Stratum 1: 4,700 teachers;
- Stratum 2: 2,150 teachers; and
- Stratum 3: 2,150 teachers.

To meet the objectives of the survey, teachers in the higher grades and teachers teaching advanced mathematics and/or physics and/or chemistry were over sampled.

Sample Selection
The sampling rate for teachers in teacher stratum l (l = 1 – 5) was computed as follows:

$$f_l = \frac{n_l}{N_l}$$

where:

f_l = Overall stratum sampling fraction in teacher stratum l
n_l = Target sample size in stratum l
N_l = Number of listed teachers in stratum l

Within each primary school stratum and teacher stratum, an independent sample was selected at the specified rate. For each of the three school groups, Table A-2 shows the number of teachers selected in the cooperating schools and the sampling rate in each teacher stratum.

Table A-2
Teachers Selected in Each School Stratum

	Sample Size (n_l)	Sampling Rate (f_l)
School Stratum 1: Grades 10–12	**4446**	
1. Physics/chemistry with or without other science, no mathematics	1106	0.496
2. Advanced mathematics with or without other mathematics, no science	1062	0.478
3. Other science only	1049	0.289
4. Other mathematics only	1061	0.253
5. Any combination of science and mathematics	168	0.402
School Stratum 2: Grades 5–9	**1969**	
1. Physics/chemistry with or without other science, no mathematics	7	0.496
2. Advanced mathematics with or without other mathematics, no science	16	0.478
3. Other science only	776	0.450
4. Other mathematics only	801	0.418
5. Any combination of science and mathematics	369	0.608
School Stratum 3: Other	**2255**	
1. Physics/chemistry with or without other science, no mathematics	3	0.496
2. Advanced mathematics with or without other mathematics, no science	1	0.478
3. Other science only	58	0.470
4. Other mathematics only	81	0.470
5. Any combination of science and mathematics	2112	0.386

Selection of Classes

Sample teachers were sent a questionnaire by mail. As part of the sampling process, teachers in sub-stratum five in each stratum were assigned to receive either a science or a mathematics questionnaire. This represented an additional stage of sampling since only half of the sample teachers in this stratum were assigned to report on science and the other half on mathematics. This one-in-two sub-sampling must be reflected in producing science- or mathematics-specific estimates.

Some of the items on the questionnaire apply to individual classes. Teachers with multiple science or mathematics classes each day were asked to report on only one of these classes. Teachers were asked to list all of their science and mathematics classes in order by class period. The questionnaire instructed the teachers to refer to a pre-printed sampling table to make a random selection from among their classes listed. The sampling table was randomly generated so that a random selection of classes would be achieved overall.

D. Weighting and Variances

In surveys involving complex, multistage designs such as this national survey, weighting is necessary to reflect the differential probabilities of selection among sample units at each stage of selection. Weights were developed to produce unbiased estimates of the population of schools and teachers. Weighting is also used to adjust for different rates of participation in the survey by different types of schools and teachers.

Variance computation must also take into account the survey design. Sampling errors generated by available procedures in SAS, SPSS, and other standard statistical software packages are not appropriate because they assume simple random sampling. To accommodate the sample design used in this study, the WesVar statistics package was used to calculate direct estimators of the variance of an estimated total or ratio based on the two independent half-samples.

Weighting

Weights were developed to permit unbiased estimates for school and teacher characteristics. The base weight associated with a school or teacher is the reciprocal of the respective probabilities of selection. To adjust for different rates of participation in the survey by different types of schools and teachers, both school and teacher non-response adjustments were developed and applied to the base weight.

In addition, because in some cooperating schools the person designated to answer questions about the school science or mathematics program may have failed to participate, it was necessary to adjust the weights for school science and mathematics program level estimates. Accordingly, three distinct school non-response adjustments were developed:

- NRA1: To be applied to the school weight to produce teacher-level estimates
- NRA2: To produce mathematics program level estimates
- NRA3: To produce science program level estimates

For non-response adjustment cell *c*, the general form of the NRA is given by:

$$NRA_c = \frac{\sum_{(elig)\,in\ c} w_i}{\sum_{(resp)\,in\ c} w_i}$$

where w_i is the base weight of the i^{th} school in cell *c*. The numerator of the three adjustment factors is the same—all eligible schools. The denominator (respondents) for NR1 includes all schools that provided lists of teachers for sampling; respondents for NR2 and NR3 include only schools that completed a program questionnaire in science and mathematics, respectively.

Since non-response adjustment through weighting assumes that response patterns of non-respondents are similar to that of respondents, *c* corresponds to a secondary sampling stratum, except in cases where two or more secondary strata were collapsed because of small cell sizes (all private schools and suburban schools in a region were collapsed into a single stratum).

The three school weights adjusted for non-response are given by:

$$w_1{}^*_{sh} = w_{sh} \cdot NR1_{h \in c}$$
$$w_2{}^*_{sh} = w_{sh} \cdot NR2_{h \in c}$$
$$w_3{}^*_{sh} = w_{sh} \cdot NR2_{h \in c}$$

where:

w_{sh} = Base weight associated with school *s* in stratum *h*
$NR1_{h \in c}$ = School non-response adjustment for estimates of teacher characteristics in cell *c*
$NR2_{h \in c}$ = School non-response adjustment for estimates of mathematics programs in cell *c*
$NR3_{h \in c}$ = School non-response adjustment for estimates of science programs in cell *c*.

The final weight associated with a teacher includes additional components related to teacher selection and participation. That is:

$$w^*_{shl} = w^*_{sh} \cdot w_{tl} \cdot NRT_l$$

where:

w_{tl} = Reciprocal of the probability of selection for teacher stratum *l*
w^*_{sh} = Final weight associated with the teacher's school
w^*_{shl} = Final weight associated with teachers in stratum *l*, school *s*
NRT_l = Non-response adjustment for teacher stratum *l*,

$$NRT_l = \frac{\sum_{t \, \varepsilon \, (elig) \, l} n_t}{\sum_{t \, \varepsilon \, (resp) \, l} n_t}$$

where:

n_t = Weighted number of teachers.

Variance Computation

With the survey design, direct estimators of the variance of an estimated total are available. Estimating the variance of a ratio, requires estimates of the variances of the numerator and denominator as well as estimates of their covariance. Direct estimates of the covariance are also available. The variance of a total for a given secondary stratum is estimated by:

$$var\ X = \sum_{h=1}^{100} (X_{h1} - X_{h2})^2$$

where X_{h1} and X_{h2} are the sums of the weighted values of the two half-samples in secondary stratum *h*.

The estimated covariance is:

$$cov\ X,Y = \sum_{h=1}^{100} (X_{h1} - X_{h2})(Y_{h1} - Y_{h2})$$

with similar definition of the *y* values. The estimated variance of the ratio Y/X is then simply:

$$var\ Y/X = 1/X^2 [var\ Y + (Y/X)^2 var\ X - 2(Y/X) cov\ X,Y]$$

For the entire universe, the variance of a total is estimated by the sum of the estimated variances of that total over all relevant primary and secondary strata. The same holds for the covariance. The variance of a ratio for the entire universe is estimated by the same formula given above for a single primary stratum.