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ABSTRACT

With the help of widely available microcomputers, it is possible to demonstrate certain statistical phenomena which students of statistics are usually expected to take on faith. Two demonstrations are described. In the first demonstration, three common types of sampling (simple random, biased, and stratified-random) are used to compare statistics with population parameters. In the second demonstration, it is shown that the standard error of the mean is an imperfect estimate of an ideal population mean, and that it is actually the standard deviation of the distribution of the sample means. Suggestions are provided for the classroom use of these demonstrations and their variations. (Author)

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TWO CLASSROOM DEMONSTRATIONS OF STATISTICAL CONCEPTS

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The teaching of statistics often suffers from a dry and detached style in which abstract principles are axiomatically presented to the learners. In a previous study, it was shown that, not unlike other disciplines (see, for example, Maury, Betbeder-Matibet, & Hulin, 1983; Voss, 1983, esp. pp. 327-347), the teaching of statistics can also benefit from classroom demonstrations (Moore, 1981). The work at hand provides two further examples of this principle, utilizing the widespread availability of microcomputers. The statistical concepts demonstrated below are 1) simple-random-, biased-, and stratified-random-sampling, as well as 2) the standard error of the mean.

Demonstration 1: Sampling Techniques

Practically every statistics, measurement, or methodology class expects its students to believe in the usefulness of (random) sampling; furthermore, both teachers and textbooks provide useful statements about the superiority of certain sampling techniques over others. While in most of the cases these statements must be taken on faith, the frequent reservations in the typical textbook do not make this task very easy. A few examples will illustrate this point: "A random sample should be fairly representative of the population. . ." (Guilford & Fruchter, 1973, p. 123, emphasis added); " . . . a stratified-random sample is likely to be more representative of a total population than a purely random sample" (Guilford & Fruchter, 1973, p. 125, emphasis added); "When we draw a random sample, we hope that it will be representative. . ." (Kerlinger, 1973, p. 119).

The demonstration that follows provides several concrete examples of three common types of sampling, and compares the obtained statistics with population parameters. It is based on a computer simulation of empirical data, with the integers between 1 and 500 serving as the population. From this population several samples are drawn with replacement. The three types of sampling used are:

-Simple random, i.e. a randomly drawn p% of the population, using the pseudo-random generator of an Apple-type microcomputer.

-Biased, where the 1st (2nd, 3rd, etc.) p% of the population is considered as a sample.

-Stratified-random, where the population is sequentially divided into 10 strata, with each sample then consisting of 10 randomly drawn sub-samples of p% of each stratum.

Table 1 illustrates the output of the demonstration program, with ten independent samples of 10% appearing in each type of sampling.

INSERT TABLE 1 ABOUT HERE

Even a casual inspection of the output (that is to say, viewing the monitor in the classroom) provides a convincing argument for the following points:

-The means (and standard deviations) of simple random samples considerably diverge both from one another and from the population parameters;

-biased sampling results in ridiculously biased statistics;

-stratified random sampling constitutes a pronounced improvement over simple-random sampling.

These conclusions may be augmented through variations of the demonstration. The latter may include:

-Providing students with a hard copy of the output;

-repeating the demonstration several times;

-varying either the number of samples drawn, or the value of p, or both;

-computing the standard error of the mean (i.e. the standard deviation of the distribution of sample means) in each type of sampling. It is by design that this value is not provided b the demonstration program, thus requiring the student to perform a simple but crucial calculation.

Demonstration 2: Standard Error of the Mean

Closely related to the general issue of sampling, and as difficult to convincingly illustrate in the traditional classroom or textbook, is the concept of the Standard Error of the Mean (SE). The student of statistics or measurement is told that sample means are imperfect estimates of some ideal population mean; that this estimate could be improved if the population standard deviation were known (but it rarely is); and that the SE of the mean is actually the standard deviation of the distribution of sample means (cf., for example, Guilford & Fruchter, 1973, pp. 126-132). The output of the demonstration program in Table 2 illustrates all these points.

INSERT TABLE 2 ABOUT HERE

The population in this demonstration is the integers between 1 and 100. The output (see Table 2) first provides the mean and the standard deviation of the population, then computes the SE, that is $S.D._{pop}/\sqrt{N}$, where N is the sample size to be subsequently used. Now several random samples of size N are drawn with replacement and independently. The output provides each sample's mean, S.D., sum of squares, and estimated standard error, the latter equaling $S.D._{sample}/\sqrt{N-1}$. The mean of the sample means, as well as their S.D. is computed next. For the printed output, the frequency distribution appears graphically as well.

As in the previous demonstration, the results may be interpreted on several levels. A casual inspection of the output indicates:

- the considerable dispersion of the sample statistics;
- the relative convergence of the mean of the sample means on the population mean;
- the similarity between the SE calculated from the population parameters and the S.D. of the distribution of sample means.

Further conclusions may be drawn if the demonstration is repeated, and especially if the number of samples and/or the sample size N is varied.

Discussion and Evaluation

The employing of classroom demonstrations is an example of heuristic teaching in general and of the discovery method in particular. In the present case the teaching method is best described as "guided discovery", which has been found to facilitate learning, retention and transfer (e.g. Ausubel, 1968; Ausubel & Robinson, 1969; Gage, 1969). Since the demonstrations described in this work utilize a microcomputer and highly flexible programs, they have the further advantage of being interactive: they readily provide an answer to "What would happen if. . ." -type questions. The demonstrations have been used by the author in several classes, and while no formal evaluation has been undertaken, student response has been extremely positive. When subsequently asked about the demonstrations, students claimed they has been both interesting and informative. A recurrent theme in their comment was that the demonstrations enabled them to see concrete examples and applications of some rather abstract principles, whose use had been far from obvious.

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Table 1

Sample Output for Demonstration #1

	MEAN	S.D.
ENTIRE POPULATION		
0 .	250.5	144.337279
SIMPLE RANDOM SAMPLES		
1 .	276.76	164.194087
2 .	247.52	135.012525
3 .	247.44	143.283854
4 .	250.58	140.058917
5 .	232.22	142.218767
6 .	260.04	141.343028
7 .	272	151.666121
8 .	264.56	161.518579
9 .	235.36	155.[illegible]48836
10 .	235.82	160.[illegible]61671
BIASED SAMPLES		
1.	25.5	14.4308697
2.	75.5	14.4308697
3.	125.5	14.4308692
4.	175.5	14.4308639
5.	225.5	14.4308693
6.	275.5	14.4308661
7.	325.5	14.4308663
8.	375.5	14.4308677
9.	425.5	14.4308618
10.	475.5	14.4308639
STRATIFIED RANDOM SAMPLES		
1.	245.96	142.602098
2.	249.92	146.529566
3.	251.72	142.198177
4.	248.58	147.59283
5.	245.32	145.991978
6.	252.52	143.54473
7.	250.02	145.809806
8.	250.18	142.502868
9.	251.18	143.026388
10.	251.92	143.577553

Table 2

Sample Output for Demonstration #2

POPULATION MEAN=50.5
POPULATION S.D.=28.86607
STANDARD ERROR=9.12825285

SAMPLE MEANS	SAMPLE S.D.'S.	SAMPLE SUMS OF SQ.	EST'D STAND ERRORS
45.9	31.143	30767	10.381
47.2	28.311	30294	9.437
45.4	26.859	27826	8.953
74.6	17.878	58848	5.959
56.8	27.737	39956	9.245
50.1	37.705	39317	12.568
54.3	26.593	36557	8.864
64.2	33.828	52660	11.276
47.1	25.7	28789	8.566
46.7	26	28569	8.666

MEAN OF SAMPLE MEANS=53.23
S.D. OF SAMPLE MEANS=9.12316269
SAMPLE SIZE=10
NUMBER OF SAMPLES=10

DISTRIBUTION OF SAMPLE MEANS

X	F	X	F	X	F
45	1	46	1	47	3
50	1	54	1	57	1
64	1	75	1		

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