DOCUMENT RESUME

ED 245 715 JC 840 301

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TITLE Statistics in the Two-Year College Curriculum.
PUB DATE Jul 84
NOTE 17p.; Paper presented at the Sloan Foundation Conference on New Directions in Two-Year College Mathematics (Atherton, CA, July 11-14, 1984).
PUB TYPE Speeches/Conference Papers (150) -- Reports - Descriptive (141)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *College Curriculum; *College Mathematics; Community Colleges; Course Content; Course Objectives; *Curriculum Development; Secondary School Curriculum; *Statistics; *Two Year Colleges

ABSTRACT

Drawing from recent literature and research, this paper provides an overview of the place of statistics in the two-year college curriculum. First, sources are cited in evidence of the strong support among educators for statistics as one of the most useful topics that can be taught. Next, research findings are presented showing that statistics course enrollments represent a small percent of total mathematics enrollments in two-year colleges (3%); that the percentage of colleges offering a course in statistics is declining (from 41% in 1970 to 28% in 1980); and that there has been an increase in the enrollments in math courses taught outside of the mathematics department. The lack of teachers qualified to teach statistics and the lack of students prepared to take college-level statistics courses are cited as two reasons why statistics is not being taught. The next section focuses on the high school curriculum, looking at the percentage of students who take statistics in high school, problems confronting the high school teacher who wants to offer a statistics course, the amount of probability and statistics covered in other math courses, what students know about the subject, and prerequisites for college-level courses. The next sections look at what material is covered in elementary statistics courses and what should be covered, indicating that new approaches to the subject focus on statistical concepts, the use of real data, and data analysis. Finally, a series of recommendations are presented for improving the curricular position of statistics. (AYC)

STATISTICS IN THE TWO-YEAR COLLEGE CURRICULUM

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Paper presented at the Sloan Foundation Conference on New Directions in Two-Year College Mathematics

Menlo College
Atherton, California
July 11-14, 1984

I have been asked to "make a case for statistics" in the two-year college. No one needs to "make a case" for computers or for calculus or for trigonometry, so why for statistics? It is not as if the case has not been made before. Nearly every major report on curriculum reform of the last twenty years states that a knowledge of statistics is indispensable in daily life and recommends that statistics be taught throughout the grades. For example, the Committee on the Undergraduate Program in Mathematics report on minimal mathematical competencies for college graduates says that four year colleges and universities "should expect graduates to understand and be able to use some elementary statistical ideas,.... This also applies to two-year college students in university parallel curricula." (CUPM Panel, 1982). Most recently, the National Science Board Commission on Precollege Education in Mathematics, Science, and Technology stated that "elementary statistics and probability should now be considered fundamental for all high school students." (National Science Board, 1983).

Mathematicians agree that statistics is one of the most useful topics that we can teach. In CUPM's survey of (mostly) mathematicians, respondents chose the mathematical topics from a forty-item list that they thought should be required of all college graduates. Elementary statistics was chosen by 56%. Only basic arithmetic skills, area and volume of common figures, linear equations, and algebraic manipulations were chosen more often. When asked what standard courses should be required, probability and statistics was mentioned second most often, following college algebra.

Many eloquent statements have been made for requiring statistics at every level of schooling. There is no need to repeat the arguments here. They are based on the fact that it is important for a citizen to be able to understand articles like this one:

> In the latest Gallup survey, 54% approve of Reagan's handling of his presidential duties while 37% disapprove.... The last time Reagan had a significantly higher job performance rating was in August, 1981, when 60% approved and 29% disapproved.
>
> Reagan's strongest showing (although a statistical tie) in this series was recorded last December, when he received 51% of the vote to Mondale's 44%.
>
> The latest results are based on interviews Jan. 13 to 15 with 1,139 adults.... The error attributable to sampling and other random effects could be 4 percentage points in either direction. (Los Angeles Times, 1/29/84)

Unfortunately, a large part of our elementary algebra - geometry - intermediate algebra - trigonometry - precalculus sequence is appropriate only for the student who will make it all of the way through to calculus. A great deal of time is spent on calculus-related skills such as factoring quadratics and manipulating rational expressions. Since the vast majority of our two-year college students never transfer to four-year colleges, much of the mathematics we now teach will be of no use to them. If the goal of our mathematics sequence was statistics instead of calculus, then those students who drop out along the way would still have learned something useful.

How Much Statistics is Being Taught in Two-Year Colleges?

With such strong and virtually unanimous support for statistics, why must I make yet another case for it? Because, in spite of all that has been advocated, statistics is still not being taught to a large number of students.

In two-year colleges, we offer a one-semester course for those students who are required to take it as part of their major. It is rare that statistics is a required part of general education for transfer students, as advocated by CUPM, although it is often an unused option.

Statistics is a small part of total mathematics enrollments. The 1980-1981 Conference Board of the Mathematical Sciences survey found that only 3% of all mathematics enrollments in two-year colleges were in statistics - virtually the same as in 1970. This is about one-third of the enrollment of calculus! The percentage of two-year colleges offering a course in statistics actually declined from 41% in 1970 to 28% in 1980. The percentage offering a course in probability with statistics declined from 16% to 14% (Fey et al., 1981).

Since mathematics departments are teaching so few sections of statistics, are students learning statistics from other departments? There has been a large increase in the enrollments in mathematics courses taught outside mathematics departments until they now equal 13% of the total math enrollment in two-year colleges. However, only about 4.5% of outside enrollments are in statistics and probability. These courses are taught by business (42%), occupational programs (33%), natural sciences (17%), and social sciences (8%) (Fey et al., 1981). The 1980 Center for the Study of Community Colleges survey found that probability and statistics courses made up 5% of total mathematics and computer science sections (inside and outside of mathematics departments) listed in schedules of classes (Beckwith, 1980). These figures are comparable to the ones from the American Mathematical Society survey of four-year colleges offering at most a masters degree (Rung, 1984).

In short, we do not have a good estimate of the percentage of college students who have taken a course in statistics, but the number is small compared to calculus enrollments.

Why Isn't Statistics Being Taught?

Why is so little statistics taught within mathematics department to so few students? One reason may be that statistics is more than just mathematics. Except for the simple data cooked up for textbook examples and exercises, statistical problems seldom have one correct answer or one correct way of proceeding. Good statistics teaching requires a knowledge of the "real world" in which experiments must be designed and surveys carried out in the absence of a perfectly random sample and in the presence of "bad" data. Mathematics teachers are not always comfortable with these difficulties. The typical two-year college teacher has not been trained to teach statistics. If a two-year college teacher has taken a course in statistics at all, it is most likely an upper division course in mathematical statistics. It is rare to find a two-year college faculty member with a degree in statistics (Fey et al., 1981). A 1977 survey of about 10% of the two-year college mathematics teachers in the U.S. found that 74% of those holding a doctorate felt "entirely secure about my qualifications to teach" statistics, but only 46% of those with a masters plus one year and 40% of those with a masters felt this confident (McKelvey, et al., 1979). In contrast, the percentages who felt entirely secure about their qualifications to teach calculus were 91%, 86%, and 85%, respectively.

A second reason that there is not much statistics being taught is that students are unprepared to take it. If a student has had no prior experience with statistics, the introductory college-level statistics course is very difficult. It contains a large amount of material and tricky logical arguments. Probability is the most notorious topic in this regard. In the two or three weeks that one can allot to it, students with no prior training are not able to acquire any indepth knowledge of the subject and usually resort to memorizing formulas and definitions.

How Much Statistics Do Students Learn In High School?

How much probability and statistics can we expect a student to know when he or she enters college? Very little, it appears. Unfortunately, the situation has not changed since NACOME reported in 1975,

> While probability instruction seems to have made some progress, statistics instruction has yet to get off the ground. ... At the high school level probability topics in Algebra I and II texts are commonly omitted. A one semester senior course in probability and statistics has gained only a small audience of the very best students. Furthermore, this course places a heavy emphasis on probability theory, with statistics, if treated at all, viewed as merely an application of that theory. Though National Assessment gives reasonable attention to probability and statistics objectives, current commercial standardized tests do virtually nothing with these topics. (CBMS, 1975)

How many students have taken a one-semester course in statistics and probability in high school? The latest Science Education Databook from NSF says that only 2.7% of 17 year-olds report having taken a course in statistics and probability (Directorate for Science Education, 1980). Of the 42 high schools in New Hampshire, only five offer a course in statistics (Prevost, 1983).

The problems confronting the high school teacher who wants to offer a statistics course are considerable. Unbelievably, there is no up-to-date statistics textbook for secondary school students on the market. Consequently, most high school teachers use a book written for college, typically Newmark (1977).

Fortunately, this situation may be changing. The American Statistical Association - National Council of Teachers of Mathematics Joint Committee on the Curriculum in Statistics and Probability has recently received a grant from NSF to write, field-test, and distribute four booklets for secondary school students on exploring data, probability, simulation, and statistical inference.

The second problem confronting the high school teacher is that there is no popular support for requiring such a course (NCTM, 1981). The number of students themselves electing such a course remains small as statistics is not required for high school graduation, for college admission, or for success on standardized tests. For example, a typical SAT will contain at most one probability question and two or three questions concerning the average. The College Board does not want to disadvantage students who have not been exposed to formal study of probability and statistics (Statistics Teacher Network Newsletter, September 1983).

If high school students are generally not taking a semester course, how much probability and statistics has been included in other courses? A survey of approximately 350 high schools in Wisconsin provides the answer. The percentage of schools which allot more than three weeks in the total high school program to statistics declined from 26% in 1975 to 23% in 1983. In 1975, 43% allotted more than three weeks to probability. This declined to 34% in 1983 (Williamson, 1983).

Since such a low priority is placed on statistics and probability in the high school curriculum, it is not surprising that the National Assessment of Educational Progress has found that students do not know very much about statistics. For example, the terms "mean," "median," and "mode" are unfamiliar to a majority of 17 year-olds (Carpenter, et al., 1980). Less than 30% of 17 year-olds could answer the following question.

> In three tosses of a fair coin, heads turned up twice and tails turned up once. What is the probability that heads will turn up on the fourth toss? (Hope and Kelly, 1983)

As students do not learn much about statistics in high school, two-year colleges do not require any knowledge of probability or statistics for admission to a college-level statistics course. According to the Center for the Study of Community Colleges data, 74% of the courses listed a prerequisite: elementary algebra by 16%, placement test by 3%, intermediate or college algebra by 40%, analytic geometry or trigonometry by 9%, business or technical math by 7%, consent of instructor by 4%, and another course in the discipline offering the statistics by about 10% (Beckwith, 1980). Clearly, there is no nationwide argreement on the necessary prerequisites, except that no prior study of the subject is required.

What Do We Teach in Elementary Statistics?

A survey of the most popular elementary statistics books reveals a tightly organized, highly sequential progression through descriptive statistics, probability, probability distributions, estimation, and hypothesis testing, with other largely optional topics tacked on at the end. The course is so beautifully constructed and mathematically logical that no one wants to change it. Although the topics are generally the right ones, the emphasis is on computation. Students learn to compute various statistics and to follow algorithms to see if the statistics are "significant." Everything is very structured. One enterprising teacher even made up a large flow chart for her students so that when they read a word problem, they would be able to select the correct statistical test. The exercise sets follow the model of elementary algebra texts. Give an example and then provide a bunch of exercises just like the example. Very few exercises test for any understanding. But then, how much can we ask of students who have never seen the subject before?

What Should We Teach?

Statisticians have been telling mathematics teachers for some time that we are presenting an out-of-date approach to statistics. They say they do not very often use the techniques we teach. Several introductory statistics books have recently been written by statisticians in the spirit of the "New Statistics." These include Ehrenberg (1982); Freedman, Pisani, and Purves (1978); Haack (1979); Koopmans (1981); Lindgren and Berry (1981); Moore (1979); Mosteller, Fienberg, and Rourke (1983); and Nemenyi et al. (1977).

How are these texts different from the ones we have been using? First, they emphasize understanding of statistical concepts and deemphasize computation. For example, here is an exercise from Freedman, Pisani, and Purves.

> An investigator develops a regression equation for estimating the weight of a car (in pounds) from its length (inches). The slope is closest to
>
> 3 pounds per inch   30 pounds per inch   300 pounds per inch
> 3 inches per pound   30 pounds per sq.in.   300 cm. per kg.

Here is another from Moore.

> A psychologist speaking to a meeting of the American Association of University Professors recently said, "The evidence suggests that there is nearly correlation zero between teaching ability of a faculty member and his or her research productivity." The student newspaper reported this as "Professor McDaniel said that good teachers tend to be poor researchers and good researchers tend to be poor teachers."
>
> Explain what (if anything) is wrong with the newspaper's report. If the report is not accurate write your own plain-language account of what the speaker meant.

The type of thinking a student must do in order to answer these questions is quite different from the usual exercises which ask him or her to compute the slope of the regression line or the correlation coefficient.

The second major difference between the New and Old Statistics textbooks is that the New Statistics textbooks use real data almost exclusively. As Mosteller, Fienberg, and Rourke state in their preface, "the tang of reality adds zest to the learning process." They provide real data about questions such as, "Do judges in the Olympics give higher scores to athletes from their own countries?" and "How long a chain of acquaintances is needed to connect one person in the U.S. to another?". Nemenyi et al. give the original data from Michelson's 100 measurements of the speed of light. The use of real data in class not only is more fun, but it also prepares students for the messy data they are sure to encounter later.

Finally, the New Statistics textbooks include data analysis. Data analysis is a set of descriptive techniques combined with a flexible attitude. Students are encouraged to use simple and highly visual techniques of displaying data in order to generate hypotheses, in contrast to the usual approach of testing preconceived hypotheses.

In summary, calculus dominates the mathematics curriculum. As a result, statistics is not being taught to enough students and those students who do take a college-level statistics course do not have the appropriate prerequisite skills. Mathematics teachers have not been trained to teach statistics and are largely unaware of the changes in the statistics curriculum that statisticians have been recommending.

Recommendations

1. Statistics should be included in minimal competency requirements for both two-year and four-year degrees.

2. Mathematics courses such as elementary and intermediate algebra should be taught as pre-statistics courses. Calculus should not dominate the curriculum.

3. Coursework in probability and statistics should be required for college entrance.

4. Mathematics departments should commit themselves to teaching statistics well - to insist on as much training for teachers of statistics as is required of those who teach calculus.

5. CUPM should be requested to up-date their basic library list for two-year colleges (1971) and their recommendations for an introductory statistics course (1972) to reflect the New Statistics. This report should include a recommendation on appropriate prerequisites for an introductory college-level statistics course.

6. Summer institutes or short courses should be planned for two-year college teachers who wish to learn how to teach statistics.

7. A committee should be set up to investigate realistic approaches to the problem that two-year colleges generally do not have MINITAB, SPSS, or other statistical packages needed for student work on the computer.

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