BU-82-M

June 6, 1956

To: The Committee on Biometry and Statistics
From: R. G. D. Steel, Instructor in PB 210-211

Professor Federer has asked me to prepare a broad report on PB 210-211. This report was to include a statement of aims together with some of the difficulties faced by the students and instructor as well as facts concerning enrollment and course content. This report is enclosed.

Professor Federer also requested that an article which appeared in the New York Times be included with the report, since reference is made to the committee which prepared the report on which the article is based.

REPORT ON

PLANT BREEDING 210-211

1. ENROLLMENT

Enrollment figures are given in the following table.

Course No.	Academic Year 1953-54	1954-55	1955-56
210	115 + 30V	67 + 13V	71 + 10V
211	33 + 10V	38 + 5V	37 + 8V
210A	5 + 25V	12	14 + 1V
211A	--	6	6 + 1V

Figures not followed by V are end-of-term enrollments. Figures followed by V refer to visitors who may be official or unofficial auditors; these are probably somewhat unreliable. Courses 210A and 211A are not listed in the catalogue and refer to the algebra section of the course for which there is a one-hour credit. Visiting the algebra section has been virtually forbidden except in 1953-54.

2. AIMS OF PB 210-211

The aims of this course were broadly stated by the Committee on Biometry and Statistics at the inception of the course, the details being left to the instructor. This seems to me to be the appropriate procedure.

The course, as offered, has the following aims.

1. To promote disciplined thinking on the part of the student with respect to the conduct of experiments. For example, after taking PB 210-211, the student should appreciate that 50% of the Salk vaccine trial was not relevant to the intent of the trial; that an experiment is not necessary to determine the relative precision with which a mean is measured for different sample sizes; that charts, averages, ratios, percentages and non-random sampling can be and are grossly misused.

2. To promote disciplined thinking on the part of the student with respect to the analysis of experimental data. For example, a student should appraise figures critically, appreciating their fallibility and limitations in terms of natural variation and its effects.

3. To present the student with a considerable number of statistical techniques which will be applicable and useful in terms of research. A relatively small survey of graduates of a biometry course suggests that the extent to which any statistical method is used depends largely upon its class coverage and that few methods are learned later. The student's research generally continues beyond his academic career. The statistical needs may differ from campus to off-campus employment.

4. To present material worthy of graduate credit. PB 210-211 is a beginning course in statistics offered at the graduate level. Graduate standing is the sole requirement for admittance. Few students have prior acquaintance with the subject.

3. STATISTICS AND THE BEGINNER IN STATISTICS

Statistics as taught in PB 210-211 is a young subject. The theory of probability, on which statistics is based, grew up as a mathematical discipline and was ill-prepared to cope with problems involving biological variation. This kept the mathematician and the biologist apart until about 1925 when Fisher's Statistical Methods for Research Workers appeared.

Statistics as taught in PB 210-211 is a growing subject. This implies a course increasing in content. Much original material is not in text-books. For example, an F-test may tell us when differences among treatment means exist, but is of little use in locating such differences. For this, we must rely on factorial analyses, comparisons of each treatment with control, comparisons of all possible pairs of treatments, etc. Exact procedures and tabulated probability levels for many of these tests have become available since PB 210-211 was first taught. (These methods were included in the course in the past year.)

The Committee on Biometry and Statistics has recognized the growing nature of the subject by increasing the original biometry course from one semester to the present course of two semesters. Fortunately or unfortunately for the student, the trend continues as statistics finds answers to more of the biologists questions.

Mathematics is deduction. Deduction has long been well developed. Statistics is essentially induction. Induction was not well developed prior to the 20th Century and statistics has contributed to its development.

Statistics and inductive inference imply, for most students, a new way of thinking -- thinking in terms of uncertainties or improbabilities. In mathematics, an error in conclusion comes as the result of misuse of the rules. In statistics, even when the rules are used correctly, there is still the possibility of an error in conclusion. The student confronted for the first time by inductive thinking finds a mental hurdle which may even be emotionally upsetting. Training in mathematics does not necessarily make learning statistics any easier; a course in logic would be more applicable. (Mathematical training does put the student in the position where he is not afraid of the simple formulas and notation we use and is able to demonstrate the sense of some of the computing formulas.) Adding to the difficulties is the admitted aim of getting maximum content in minimum time.

Computation is necessary to statistics and PB 210-211 must teach computation. Computational techniques are arithmetic (with a basis in algebra) and are not statistics. In approaching a problem, disciplined thinking leads to an experimental design (statistics). Data are collected and arithmetically processed (computation). Now comes the difficult part, inductive inference (statistics). Failure to recognize the subsidiary role of computation accounts for much of the variation among statistics courses.

4. STUDENTS' BACKGROUNDS AND ATTITUDES ON ENTERING PB 210-211

Students in PB 210-211 are graduates. Statistics is a supporting course except for the rare case of a major or minor in statistics. Hence in many respects the students constitute a captive audience, providing a problem in motivation. In general, it is not till the student has some working knowledge of statistics that he appreciates how much statistical thinking contributes to the analysis of data. In some cases this comes at the end of his college career and later, rather than during the course.

Students vary in their ability to reason inductively. There is nothing unusual about this. We can't all learn to play the piano nor even to appreciate music. Some students are frightened by the new ideas in statistics. (As a student, I once saw a fellowship winner leave a statistics class to be ill for just this reason. She said "I'd rather give up graduate study than have to complete that statistics course.") Some students consider mathematics

and statistics to be synonymous and are admittedly frightened by mathematics. These students are badly prepared psychologically for a course in statistics. Though PB 210-211 contains no mathematics, these students are never quite convinced of this fact.

Staff members contribute to the students' attitudes. Most helpful is the simple comment that the student needs statistics. Comments to the effect that this is a new course and is meant to be easy are intended to be helpful but aren't truthful. Statistics is rarely easy for the beginner.

The problem of the student, not necessarily foreign born, who is not competent in the English language, is more than doubled when he suddenly encounters statistical terminology. The result may be utter confusion. Many examples, no more intelligible than the following have been offered.

> "In estimating a mean statistics are utilized and serve as computational sample criteria for the estimation of the mean."

> "The effect of factors on a observation which can be explained the effect of the factors when examined separately."

5. TOPICS COVERED IN PB 210-211

The student of statistics requires an acquaintance with some distribution theory before statistical techniques can be appreciated at all. This is accomplished by a comparison of sampling results and statements of mathematical theorems. Discussion of both parent and derived distributions is required. Distributions imply probability. Probability and the use of probability tables follows with little attempt made to discuss discrete distributions except as such discussion contributes to the general aims.

We then go on to use what has been covered to discuss confidence intervals and tests of hypotheses. This introduces type I and II errors, power of a test, and choice of sample size to control the probabilities of both type I and type II errors.

Up to this point the student has been presented with most of the ideas he needs. He can't proceed satisfactorily with less. The ideas are new and difficult to him and we hammer away with a twist here and an elaboration there. If the student leaves at this stage, his thinking may be improved but he will have relatively little knowledge of how he can process data.

Next we discuss experimentation, field and laboratory lay-outs, completely random designs, randomized complete block designs and Latin squares. Advantages and disadvantages of the designs together with the processing of the subsequent data are treated. Techniques for testing independent comparisons, each treatment against check, all possible differences between treatments,

factorial arrangements, etc., are covered together with the choosing of a most appropriate technique and the limitations of the techniques. The topic of n-way classifications is also covered.

Linear regression is discussed prior to and separately from correlation. This is because regression, a topic in its own right, generally yields more useful information than correlation and is often the only correct procedure. Regression and analysis of variance tie together nicely as covariance. Multiple regression and covariance are extensions which involve much arithmetic along with new terms and ideas. Disproportionate sub-class number analyses for 2-way classifications constitute more techniques where the arithmetic is difficult. An attempt is made to show the logic of the various methods instead of simply presenting them as set procedures as is so often the case.

The course is a two-semester course. The material covered in the first term is useful in terms of a one-semester course but the accent is placed on the two-semester aspect of the course.

6. COMPARISON WITH OTHER UNIVERSITIES

The material in PB 210-211 is taught, to my knowledge, in from one to five semesters at other universities.

I feel the student is too rushed and does not benefit sufficiently when this material is covered in one semester -- there are too many new ideas to assimilate, quite apart from the numerous arithmetical procedures involved. Five semesters is too many. For example, one semester will be a course in multiple regression, filled with details to the point of spoon-feeding. There is bound to be overlap.

I believe a two-semester course should be adequate. A one-semester course is insufficient for the subject and a three-semester course, while being easier for the student, cuts too deeply into the time he must spend on his major and minor subjects.

As for enrollments, the drop from the first to a second term seems to be common to universities offering comparable courses. This appears to be true regardless of the number of semesters of statistics that are available. The primary cause seems to be associated with the difficulties inherent in learning statistics although there are always some M.S. candidates who can find time for only one semester.

7. PROGRESS

The first year PB 210-211 was offered, the course suffered from over-enthusiasm on the part of the instructor. Some of this was generated by the enthusiasm of the staff and its desire to have graduate students learn much statistics. In part, it was due to a desire to have a well rounded one-term course for students, e.g. M.S. students. Partly, it was failure to appreciate that statistics is especially difficult for the beginner.

Students' comments in the first year were helpful. These comments were less useful in the second year and only the occasional one has merit at present. For example, some students feel that the text is followed too closely, others that it is not followed closely enough. Some would like algebra included. (This is available in a 4th hour.) Some don't like the lab assignments to contain even the occasional question for which they have been given the necessary material, provided it will be covered in detail in later lectures. Other students would like more lab exercises but have not offered a solution to the time problem. Presently, there is a marked tendency for A's comments to cancel those of B.

The course as offered this past year has covered virtually as much material as in previous years but has moved much more slowly in the first semester. (An average but interested student told me he was "kept reaching" during the first semester.) There is a possibility that the course could move slightly more slowly the first term and faster in the second with profit to the student and without sacrificing topics. This may be due, in part to the type of student who stays two terms.

This is the first year a standard textbook has not been required. I am pleased with this arrangement and feel that the students prefer it. At least, I have only myself to blame for the present topics and their order.

8. ALGEBRA

A one hour course in algebra is offered in connection with PB 210-211. Topics include derivation of computation formulas from definition formulas, verification of formulas and properties of statistics (these are simply stated in class), derivation and solution of least-squares equations, and an introduction to expected values.

The general aims are to broaden the students background, to improve his understanding of statistics where he has some liking for algebra, and to prepare him for certain aspects of PB 213 and 214. The algebra is on an experimental basis with marked changes from year to year. No attempt is made to promote a large enrollment.

9. SUGGESTIONS

The most helpful action relative to teaching and learning statistics at the graduate level must deal with the background of the people concerned. Suggestions are:

1. Improve the attitude of students to statistics by improving the teaching of mathematics and the mathematics curriculum in high schools. This is a long range solution about which something is being done. (Carnegie* has a committee studying the problem and this summer Shell has a program at Cornell for improving science teaching.)

2. Improve communication between the statistics teaching staff and the graduate faculty. This could probably be done best in seminar. (Some staff members do not appreciate the problems of teaching and learning statistics nor the distinction between computations and statistics, simply because no statistician has taken the time to present any of the facts concerned.) An alternative would be for staff members to accompany their students when they consult with a statistician on thesis problems.

3. Give a statistical aptitude test which would serve as a basis for recommending a course prior to PB 210-211. The alternative to taking such a course would be additional application of the student to PB 210-211 and/or help-sessions. (A well-tested statistical aptitude test is presently available. Help sessions are not presently available.)

4. Offer help-sessions. These would be compulsory for some of the class on the basis of prelims and open to others who wished to attend. (More continuity in the assistantship program is necessary for this to be successful and time, at least, is necessary to accomplish this. A start will be made in Fall, 1956.)

5. Offer an undergraduate course. This would serve, in part, as a conditioning course and could be at the level recommended by the Council of the Royal Statistical Society for the secondary school level or at a slightly higher level. (Several elementary texts are available and Professors P. J. McCarthy and J. S. Ahmann currently offer courses which appear to be acceptable to Agricultural Economics, Rural Sociology and Education.)

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*See quotation from N. Y. Times on separate sheet.

Article published in THE NEW YORK TIMES, June 4, 1956, page 1.

TEACHERS CHIDED ON MATHEMATICS

Study Finds Them Deficient, Curriculum Outmoded and Pupils Hostile or Bored

By BENJAMIN FINE

The teaching of mathematics is in a deplorable state, according to a year-long survey sponsored by the Carnegie Corporation.

The survey found that a large number of mathematics teachers not only did not know how to teach the subject effectively, but also were barely able to keep ahead of their students.

As a result, it was noted that mathematics is one of the poorest taught subjects on the elementary and secondary levels and that the students vote mathematics as their "most hated" course.

The survey, conducted by the Educational Testing Service of Princeton, made a first-hand study of sixty classrooms in five states. Thirty-six of these were at the elementary level, and twenty-four at the secondary.

The study was under the direction of six educators, headed by Prof. Samuel S. Wilks of the Princeton University Mathematics Department. The Carnegie Corporation gave $21,000 for the project.

Among the findings were these:

Of the sixty mathematics teachers reached in the study, only ten were competent; the other fifty were "confused" and unable to teach the subject.

The mathematics curriculum is outmoded and must be brought up to date if mathematics is to take its rightful place in the public schools.

Most students are not only indifferent, they are downright hostile to the teaching of the subject.

Most of the teachers do not like mathematics and teach it only under compulsion or under protest.

These conclusions are particularly serious, the survey suggests, because of the need for trained engineers, scientists and technicians in the atomic era. Mathematics is the basis of engineering.

The study notes that most students "back away" from mathematics at an early year. Even superior or gifted students are indifferent. It has the dubious honor of being the least popular subject in the curriculum.

Parents Greatly Concerned

Parents are more concerned with the failures of their children in mathematics than in almost any other subject. And business men complain that graduates have a blind spot in this area of training.

The study lays much of the fault at the feet of the teacher. A sampling of 211 prospective elementary school teachers showed that 150 had a long-standing hatred of arithmetic.

The survey found that half of a random sampling of 370 candidates for elementary school positions failed to solve a simple problem in fractions.

"It seems pretty clear that many elementary school teachers have a hard time keeping even half a jump ahead of their pupils," the report stated. "Their salvation lies in memorized answers, rather than in any genuine understanding of arithmetical concepts."

Little knowledge of mathematics is expected of prospective school teachers. Many, the survey says, can enter a teachers college without any high school mathematics and graduate without studying any college mathematics.

The survey continues: "Future teachers pass through the elementary schools learning to detest mathematics. They drop it in high school as early as possible. They avoid it in teachers colleges because it is not required. They return to the elementary school to teach a new generation to detest it."

Toughening up requirements for professional certification would be only half a solution, the survey says. That excludes incompetent persons, but it would not add competent teachers.

The Princeton survey proposes the creation of a Remedial Mathematics Course for Teachers of Mathematics, designed to unravel the teacher's numerical neurosis. This would "nourish him on the why's and how's of mathematical phenomena and liberate him from the confinements of the text book so that he may enjoy a lively appreciation of the thousands of important uses that mathematics has in the modern world," the report says.

Not the Entire Solution

But, the survey concedes, not all the trouble can be eliminated by retraining teachers.

"When our observer visited sixty classrooms to verify at first hand what the books and the experts were saying about the deplorable state of mathematics teaching," the survey says, "he found ten in which the teaching was reasonably effective.

"In the other fifty the instruction was so confused that learning of any kind seemed to be largely accidental and unillumined by any learning theory whatever."

The survey is quick to add that the teachers themselves could not be censured for the conditions under which they work. Most of them were struggling with classes of 35 to 40 pupils who sometimes spread over two different grade levels and almost always ranged widely from the bright but bored to the dull and bewildered.

"It takes more than brains, good will and a sparkling personality to conquer this kind of situation," the survey adds. "It takes a fundamental change in the conditions of teaching -- a change that only the public, acting through its representatives on school boards, can bring about."

The curriculum is taken to task, too. The survey notes that it has changed very little during the past century. This is what is being offered: the elementary school provides arithmetic and some intuitive geometry; the college preparatory curriculum in high school consists of algebra in grade nine, demonstrative geometry in grade ten, more algebra in grade eleven, and trigonometry, solid geometry and advanced algebra in grade twelve.

This curriculum looks remarkably like the 1890 model, the study observes. It adds that there is evidence that the usual sequence in arithmetic may not be in line with the natural development of the pupils.

Flexibility is Needed

Another problem is to get enough flexibility into the arithmetic curriculum to serve the bright, the not so bright and the dull equally well. Often the teacher is afraid to let the bright child move too rapidly, the survey notes -- the youngster might outstrip the instructor!

"The high school curriculum today shows few, if any, signs of the important developments that have taken place in mathematical science since the seventeenth century," the report says.

The results have been devastating. An engineering school reports that 72 per cent of its students entering last September were found so inadequate mathematically that they had to take a review of high school mathematics before they could qualify for the regular freshman course. Similar complaints are frequently heard.