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ABSTRACT

A simple model proposing that grading practices in a high school science course are related to the percentage of eligible students enrolled in that course and in the next course in the science sequence was tested using data from 27 California suburban schools. Ease of grading was considered as the discrepancy between students' mean concurrent grades in non-science courses and the science course, averaged across students of each teacher. The teacher was the major source of variance in ease of grading. The teacher's grading index is relatively stable between years female chemistry students were penalized almost half a grade compared to their other subjects. Other groups were penalized less, with almost no discrepancy for male biology students. When teachers were the analysis unit, there was a positive correlation between ease of biology grading and chemistry nrollment for both sexes, but there were no significant relationships in the chemistry-physics transition. When schools were the analysis unit, ease of grading in chemistry was related to physics enrollments for females. The interpretation that grading practices are causally related to enrollment is favored, although alternate possible explanations are discussed. Some suggestions for refining the model are made. (AL)

Final Report

Grant No. OEG 9-9-140148-0045

Severity Of Grading In The Sciences And Its Relation To Science Enrollments

Robert G. Bridgham

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Stanford, California

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U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

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SUMMARY

Low enrollments in the physical sciences have been a professional concern for some time. This study is focused on the relation of ease or severity of grading in secondary school science to enrollments in the sciences. A review of literature indicated that teachers' grading practices have very rarely been the subject of research. In particular, in the few studies that have been done there is no agreement on 1) an appropriate index of ease or severity of grading or 2) the variables most likely to be correlated with ease or severity of grading.

A model of the enrollment effects of ease or severity of grading is proposed which includes the following elements:

1. An appropriate measure of a teacher's ease of grading in a science course is the discrepancy between students' grades in the science course and their grades in other academic subjects, averaged across students of the teacher.

2. The ease of grading in a science course will be directly related to the percentage of eligible students enrolled in the course.

3. The ease of grading in a science course will be directly related to the percentage of students in that course who elect to go on to the "next course" in the science sequence.

4. Because ease of grading in the sciences is presumed to have its greatest effects on students who are marginally committed to the study of science, the relations predicted in 2 and 3 above will appear most clearly after a correction is made for the commitments of students to the study of the sciences.

The model is tested with data gathered in twenty-seven high schools located between San Francisco and San Jose, California. Grades were transcribed for each student in the graduating class of 1968 for each year in which a science course other than general science was taken. In seven of the 27 schools, similar transcriptions were made for students in the graduating class of 1967. Grades were coded so that A = 7, B+ = 6, B = 5, ... F = 0.

Ease of grading defined as

$$\sum_{i=1}^{N} (\text{Science grade} - \text{Non-science grade average})/N,$$

where N is the number of students in the course,

was calculated for each teacher and each science subject in a given school. In addition, the proportion of eligible students (non-seniors) who moved from one science to the next in the typical sequence (biology-chemistry-physics

in all schools but one) was determined. These proportions (enrollment ratios) were determined for each school. The non-science grade average of students eligible to "move on" was also determined for each science in each school.

Schools were also characterized by 1) the presence or absence of a biological alternative to chemistry or physics (a second-level biology course), 2) the presence or absence of a "second-tier" of science courses (life science, earth science), and 3) the proportion of parents in science-related occupations.

Four two-way analyses of variance (teacher by graduating class) indicate that variation due to teachers is the major distinguishable source of variance. Analysis of teachers' ease of grading broken down by subject taught and sex of student indicate that female students are graded more severely than male students, and grading in the physical sciences is more severe than grading in biology. Means for the separate categories are: Biology males, -.05; Biology females, -.29; Chemistry males, -.37; Chemistry females, -.98; Physics males, -.27, Physics females, -.78. Female students in chemistry lose half a grade, on average, compared to their other grades. The grade penalty is smaller for other groups and for male biology students is almost nonexistent.

An analysis of the transition between biology and chemistry, using teachers as the units of analysis, indicated that ease of grading in biology is positively related to students' enrollments in chemistry for both male students ($p \leqslant .05$) and female students ($p \leqslant .01$). A similar analysis for the chemistry-physics transition yielded no statistically significant relationships between the two variables, though again the regression beta weight for female students was larger than the beta weight for male students. The number of degrees of freedom in the chemistry-physics analysis was considerably smaller than the number in the biology-chemistry analysis.

An analysis of the transition between biology and the science that follows it, using <u>schools</u> as the units of analysis, indicated that: ease of grading in biology is positively and significantly related to enrollments in the second science for female students (but not for male students); and ease of grading in chemistry is significantly related to biology students' decisions to enroll in the second science for both male students and female students. The relations remain significant as other variables are "partialled out".

A similar analysis of the transition between chemistry and physics indicated that: ease of grading in chemistry and ease of grading in physics are positively related to enrollments in physics for female students. These relations become statistically significant as other variables are "partialled out". No relation between ease of grading and enrollments in physics was found for male students.

These results are taken as evidence supporting the first three elements of the proposed model, though it appears that some modification of the model to account for sex differences will be appropriate. Estimates based on the observed means for ease of grading in the sciences and the slopes in the computed regression

equations suggest that an increase in science enrollments of practical significance would follow an effort to bring science grades to "par" with other academic grades. A way to further this effort is described. Potential implications of the study for vocational theorizing and possible extensions of the study are described. Finally, the probable inadequacy of efforts directed only at grading practices in the sciences to achieve effective general education in the sciences is pointed out.

INTRODUCTION

Enrollments As A Professional Concern

One of the concerns of those interested in secondary science education, especially education in the physical sciences, has been the decline in the percentage of eligible students enrolled in high school physics. The percentage decline in physics enrollments began around the turn of the century and has continued unabated since then. The enrollment picture in high school chemistry is somewhat better -- it appears that the percentage of high school students enrolled in chemistry has remained reasonably stable over the past decade or so. Even so, only forty per cent of the eligible students choose to study chemistry and since there is an almost complete overlap of the twenty per cent who study physics and those who study chemistry, more than half of the students leaving high school will not have studied a physical science.

The pattern of enrollments in secondary school science is disturbing when one reflects on the extent to which the concepts and practices of the sciences, and especially the physical sciences, have given cultural and technological shape to the present world (Bronowski, 1964). It would appear that a generation of students will graduate from American secondary schools without sufficient background for understanding one of the most potent forces in society today -- the physical sciences. Factors which lower enrollments in secondary school physical science courses act to diminish the relevance of the general education of the American public.

In addition to their effect on the general education of high school students, low physical science enrollments may have an effect on recruitment for critical science-related vocations. The number of baccalaureates whose

major is physics has remained fairly stable over the most recent years for which we have data; their number as a proportion of the total number of baccalaureates has declined. The percentage of baccalaureates who received their degree in engineering has been declining since 1959. Thus, the nation's manpower pool has been receiving a diminishing proportion of those possessing the analytic tools of the physical scientist.[1] One can argue that in the past estimates of the expertise in the physical sciences essential for the health of the nation have been overblown. However, continually waning input of this expertise can hardly be considered desirable.

The relative decline in physics and engineering baccalaureates is likely to have a direct effect on the teaching of the physical sciences in the high school. There is evidence that many science teachers are "converts" from science majors, with the conversion occurring during or shortly after the collegiate years (Lee and Cooley, 1965; Newton and Watson, 1968). A decline in the number of collegiate physical science and engineering majors is likely to result in a proportionately reduced number of qualified teachers of the physical sciences. The lack of qualified teachers has been suggested as a reason for low secondary enrollments in the physical sciences (Commission on College Physics, 1967).

The relation between baccalaureates received and secondary enrollments in the physical sciences, however, does not run in only one direction. In Cooley's (1963) study the greatest loss from the Potential Scientist Pool (students planning careers in science or engineering) occurs in the eleventh

[1]It is important to distinguish between the baccalaureate and the doctorate. In the mid and late '60s the number of doctorates in the sciences was increasing dramatically even though the number of baccalaureates given in the same fields four to five years earlier showed no such dramatic increase. Although the distinction is not often made, it appears that the current "job crisis" is principally affecting holders of the doctorate.

and twelfth grade. Since these are the grades in which chemistry and physics are normally encountered it is a reasonable surmise that the secondary chemistry and physics courses are "screening out" potential science majors. Some of the same factors which lower physical science enrollments in the high school may also be reducing the number of potential collegiate physical science and engineering majors.

It is conceivable that enrollments in secondary school physical science and the production of collegiate physical science and engineering baccalaureates are now locked together in a feedback loop. Some factors are operating which lower secondary school enrollments in the physical sciences and which screen out large numbers of "marginal" (non-Ph.D. bound) candidates for the baccalaureate in physical science. As the number of "marginal" physical science baccalaureates declines, fewer teachers with an adequate background in the physical sciences enter the secondary schools and the enrollment drop and screening become more severe. The circle becomes increasingly vicious and its outcome, if the circle is not broken, is likely to be the eventual disappearance of physics and possibly chemistry as subjects of the secondary school curriculum.

While there may be many factors which are related to low enrollments in the secondary school physical sciences -- suggested possibilities include the already mentioned scarcity of qualified teachers (Commission on College Physics, 1967), the nature of physical science course content (Watson, 1967), and the "difficulty" of courses in the physical sciences (Young, 1965; Kaufman, 1965) -- the study to be described here is focused on only one: the ease or severity of teachers' grading practice.

Earlier Studies Of Teachers' Grading Practices

Although grading is discussed at length in the educational literature, studies which take teachers' grading practices and their effects as their principal focus appear to be scarce items. For example, Carter (1952) found that there was no significant difference between sexes in tested achievement in his sample of introductory algebra students (n=235), but that girls, on average, received higher marks. Farnsworth and Casper (1941) found great variation across schools and subject areas in the failure rates of students; their additional finding of a "striking positive correlation between a high percentage of failure and a high percentage of withdrawal" is hardly surprising. Racchio and Kearney (1956) found low negative correlations (around -.30) between MTAI scores and failure rates in both their sample of academic teachers and their sample of non-academic teachers, but found zero order correlations between age, sex, and subject area of teachers and the percentage of their students assigned failing grades. Bridgham and Welch (1968) found that when the grades of thirty teachers of Harvard Project Physics were adjusted for the tested achievement of their students so as to produce an index of teachers' severity of grading, the severity indices were related to the percentage of dropouts during the course (p = .07) and (for nine of the thirty teachers) to students' response to questions about the desirability of enrollment in and the difficulty of physics courses (p = .02 and .07).

The scattered dates of these references indicate the low level of scholarly attention paid to grading as a teaching practice and to the correlates of grading practices. The references also reveal no convergence of opinion concerning 1) the appropriate index of ease or severity of grading, or 2) the variables most likely to be correlated with ease or severity of grading.

While failures may be striking evidence of grading severity, a high failure rate may indicate something about the teacher, something about his students, or something about both. Moreover, the bulk of grades given by most teachers are not "Fs" and students who receive passing grades are also willing to offer testimony about their teachers' grading practices.

An index of ease or severity of grading should include some information about the ability/achievement of the students graded and is probably best based on the experience of all students and not just those who receive failing grades. Comparison with tested achievement in the subject in which grades are given would appear to provide the necessary information, but it is not clear that the comparison between grade and tested achievement is one that students themselves make. In using a standardized achievement test one assumes commonality of teaching goals and student experiences that may not be found in a diverse set of classrooms, even classrooms that are using the same "national curriculum." One also assumes that the test adequately represents the array of desired outcomes from teachers' courses and this assumption too is suspect. An adequate index of severity of grading would be related to an effective model of the information available to students and of the possible ways in which this information may affect student actions.

A Model Of The Impact Of The Information In Grades

It is assumed that students in choosing courses may have a number of motivations. They may attempt to gain a relevant general education, to arrange for school work that will be reasonably enjoyable, to maintain themselves in a social group, to acquire information and experience that will be of vocational use, to test their interests and abilities. For example, a students who elects to study chemistry may do so in hope of gaining a richer

view of his natural environment, but he may also be using the course as a test of his interest in and ability to pursue a science-related career. During the high school years students are making vocational decisions in which they have varying degrees of confidence. At any one time there will be students who appear to be firmly committed to a science-related career, students who are torn between science-related and non-science careers, and students who appear to be firmly committed to non-science careers. If ease or severity of grading in the sciences has any effect on course choice it is most likely to affect the decisions of the group that is wavering or decisively non-science in vocational commitment. Thus, different student populations may be differentially affected by ease of grading in the sciences because of the different state of vocational commitment in the populations. A similar argument can be formed for many of the other sources of movtivation to enroll in a science.

In some cases it is not strictly appropriate to speak of course choice. For example, many courses in English and Social Studies are required. However, the sciences beyond general science are usually considered to be optional, within the restrictions that may be set by students' aspirations for college and by college entrance requirements. In a sense, the sciences are in a competition with each other and with the other offerings of the school for student enrollments. The language suggests an analogy with an investment market. Students "invest in" a set of courses which carry a "price" (demand level of the courses), and which promise a "return" on the investment. The analogy is rough, but it suggests that differentials in "price" and "return" between different courses will, up to a point, be critical determinants of decisions to "invest" i.e., to enroll in a course.

Perhaps the most potent (and certainly the most public) indicator of the "return" from a science course is the grade received in the course. A grade informs the student and the interested public of the teacher's estimation of the quality of work done in the course. Since the interested public tends to conceive of teachers' estimates as objective it is to the student's advantage to choose courses so that his grades are maximized. A high average grade improves his chances of career advancement; he is more likely to gain admission to a "better" college or start work with a more lucrative job if his grades are high. Thus, within the constraints imposed by vocational decisions already made, a student is likely to select those courses which do not carry apparent grade penalties.

How can a student estimate things like apparent grade penalties, severity of grading in courses, etc? It is assumed that students compare the grades received in their several courses and report the results of this comparison to their fellows. The sum of these reports would then be available to prospective enrollees in a course -- averaged out they would indicate to a student how to adjust his expectations of a grade in a course according to the experience of students who preceded him in the course. Thus it is assumed that for the prediction of enrollments in a course the critical data are not the grades received in the course alone, but comparisons of those grades with the other grades received by the same students. Moreover, it is assumed that students, in forming their expectations of ease of grading in a course, compare the grades received in the course with other grades, rather than with "objective" measures of achievement such as scores on an achievement test. The reference group for estimating ease of grading is thus thought to be in the school rather than some amalgam across schools: ease of grading is school-based.

How students make their comparisons is not immediately evident. As a reasonable first approximation, though, we can take the comparisons to be direct. That is, if a student's average grade in non-science courses is calculated and the average subtracted from the student's science grade, the difference would represent that student's contribution to the summary report. If the differences found for all students were in turn averaged, the summary average would characterize the ease of grading in the science course. The procedure can be formulated as

$$\text{Ease of grading in a science} = \frac{\sum_{i=1}^{N} (\text{Science grade - Non-science average grade})}{N}$$

It is hypothesized that ease of grading in a science, formulated in this way, will be significantly related to the number of students opting to take the science.

It is suggested that students make use of the information provided by the grades in a course in deciding if they will take the course or not. But grades probably affect student choice in another way. The <u>pattern</u> of a student's grades provide him with information about the distribution of his abilities that will guide further course and vocational choices. A student may initially see himself a lawyer, but change his mind when his social studies grades are "Bs" and "Cs" while his math and science grades are "As". A "C" in chemistry or physics may suggest to a student that further course work in the physical sciences would be unprofitable. The information that a student receives in this comparison of his own grades is somewhat affected by his teacher's ease or severity of grading. Since the students of an "easy grader", receive, on average, higher grades in science, more students will find that

their science grades are comparable to or higher than their grades in other subjects. Presumably more students will therefore be encouraged to continue their study of science. The opposite effect is expected for students of a "severe grader."

In summary, the relatively simple model developed here includes these points:

1. An appropriate measure of a teacher's ease of grading in a science course is the discrepancy between students' grades in the science course and their grades in other academic subjects, averaged across students of the teacher.

2. The ease of grading in a science course will be directly related to the percentage of eligible students enrolled in the course.

3. The ease of grading in a science course will be directly related to the percentage of students in that course who elect to go on to the "next course" in the science sequence.

4. Because ease of grading in the sciences is presumed to have its greatest effects on students who are marginally committed to the study of science, the relations predicted in 2 and 3 above will appear most clearly after a correction is made for the commitments of students to the study of the sciences.

STUDY DESIGN

Initial Design of the Study

A test of the adequacy of this model and, particularly of propositions 2 and 3, was planned. In a reasonable number of schools (25 to 35), data was to be taken from permanent record cards and other files for selected students who graduated in the class of 1968. For each year that a student took any science other than general science, his science grade and teacher would be noted. In addition, it was planned to code for each student in the sample: sex, score on a vocational interest test (if available), and whether the occupation of the principal bread-winner in the family was science-related

or not. For approximately one fourth of the schools, the same data would be gathered for students in the graduating class of 1967, to provide a check on the stability of the variables' values.

The basic data was to be manipulated by computer to give values for the following sets of variables:

(1) Ease of Grading of Each Science Teacher in Each Science Course;

(2) Average Non-Science Grade of Students of Each Teacher in Each Science Course;

(3) Ease of Grading of Each Science Course in Each School;

(4) Average Non-Science Grade of Students in Each Science Course in Each School;

(5) Enrollments in Each Science Course;

(6) Percentage Going from One Science Course to the Next, Computed for

a) Students of Each Teacher of the Earlier Science Course, and

b) Students of the Earlier Science Course in Each School;

(7) Correlations Between the Vocational Interest Test Scores and Parents' Occupational Status (Science - Non-Science) and Average Non-Science Grade, and Enrollment in a Succeeding Science, Computed for

a) Students of Each Teacher of Each Science Course, and

b) Students of Each Science Course in Each School.

These values would then be used in an analysis that would provide a test of propositions 2, 3, and 4 in the model. In particular, a correlational and regression analysis would relate:

A. Ease of grading in chemistry (by school) to percentage of students going from biology to chemistry

B. Ease of grading in physics (by school) to percentage of students going from chemistry to physics.

C. Ease of grading in biology (by teacher) to percentage of students going from biology to chemistry.

D. Ease of grading in chemistry (by teacher) to percentage of students going from chemistry to physics.

These correlational and regression analyses would be completed for both the observed data and also for the data after correction for differences between schools (or teachers) in the vocational interests of the students and the science-relatedness of parents' occupations. The analyses for A and B would provide a test of proposition 2; those for C and D would provide a test of proposition 3; and comparison of the results for analyses done on the observed data and those on the "corrected" data would provide a test of proposition 4. Proposition 1 would be tested indirectly: failure of the analyses to yield significant results would suggest an inadequacy in the definition of ease of grading; significant results from these analyses would indicate that the definition of ease of grading provided a reasonable first approximation to the operative factor.

Data Gathering And Some Amendments To The Plan

Nine school districts near Stanford University were contacted to secure their cooperation in the study. Contacts were usually made through the chief guidance officer for the district, though in a few cases an Associate Superintendent for Curriculum or a Director of Science was contacted. The nine districts were all "suburban", located to the south of municipal San Francisco or north and east of municipal San Jose. Urban districts were not contacted because it was thought that including urban schools in the sample would introduce another, more-or-less unevaluable parameter that would make the study's results difficult to interpret.

Five of the nine districts agreed to participate in the study soon after the first contact was made. One district agreed to participate after a second contact was made almost a year later. Three of the nine declined to participate. Reasons given for non-participation were: disinterest of principals of the

high schools that would be involved (two districts) and unavailability of records during the time of data collection (one district). The six districts eventually included in the study contained twenty-seven high schools that had graduating classes in June, 1968. The districts form a singly interrupted strip between San Francisco and San Jose.

In the data transcription, grades were coded as A or A- = 7, B+ = 6, B or B- = 5, C+ = 4 ... to F = 0. Thus if the numbers representing individual grades differ by one, the difference represents a half grade. If they differ by two, the difference represents a whole grade. The difference between grade averages can be interpreted in the same way.

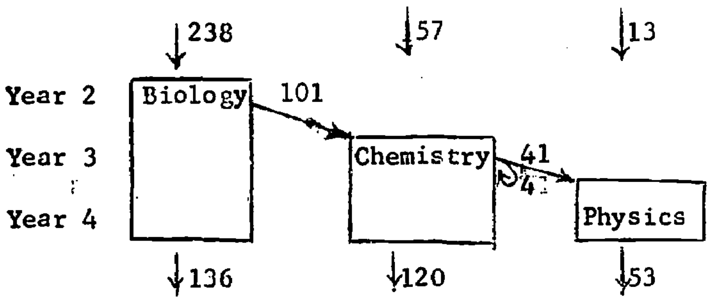
As the data were transcribed it became evident that some portions of the analysis could not be carried out as planned. In most schools vocational interest test data were not available. Information on parental occupation was available in one form or another in all schools but not necessarily for all '68 graduates. Thus the plans to associate the vocational interest score and the science-relatedness of parental occupation with the other data of each <u>individual</u> student were abandoned. The information on parental occupation was reconceived as indexing a characteristic of the <u>group</u> of students at a particular school.

As the individual schools in the study sample were visited it became clear that the initial assumption of a common curricular structure in the sciences was untenable. Biology, chemistry, and physics were taught in all schools and in all but one of them students encountered the sciences in that order. In the lone exception the most common sequence was biology - physics - chemistry. While the "basic three" were common to all schools, a number of other science courses were not. Physiology or a second year of biology were offered in many of the schools. In some of the schools, chemistry was a prerequisite for

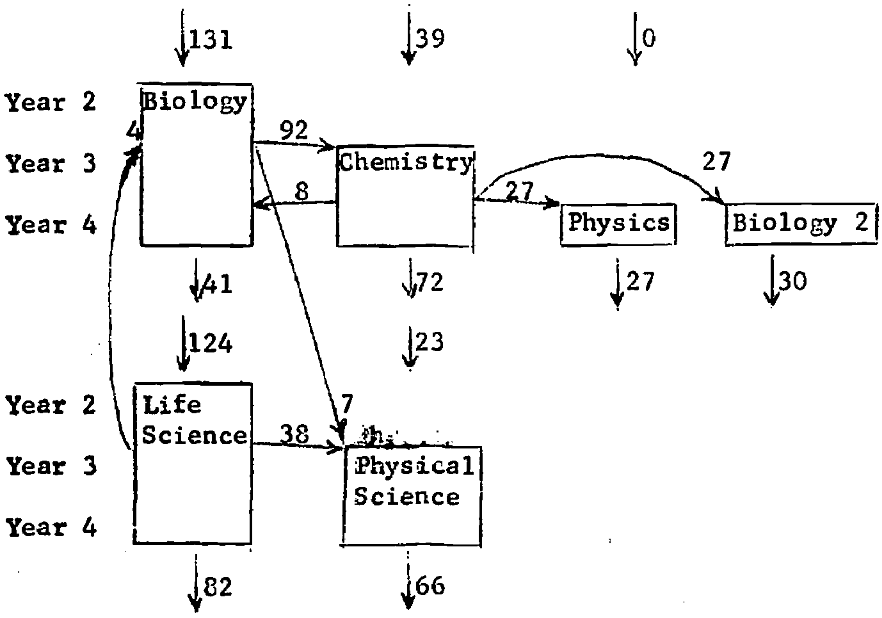
these second courses with a biological orientation and the courses competed with physics for students who had completed chemistry; in other schools chemistry was not required and the second biological course was in competition with both chemistry and physics. Some schools had a "second tier" of science courses -- life science, physical science, etc. - that would serve as substitutes for or introductions to the "academic" sciences. These were the most common additions to the "basic three", but other possibilities were also realized in one or another of the twenty-seven schools. The diversity of course structure is indicated in Figure 1, where the science offerings of three of the twenty-seven schools are diagrammed and the major flows of students between offerings are represented by arrows.

Because it seemed likely that differences in course structure from school to school would affect enrollment choices, some way of characterizing the important differences among the varied arrangements was required. After a number of alternatives were considered a decision was made to use two variables -- availability of a second-level biology course and presence of a "second-tier" of courses -- in the analyses where these seemed appropriate. The presence of a biological alternative was thought likely to cut down the flow into the physical sciences, because it might be an attractive option for students who wanted more science but whose confidence in their ability to handle mathematics was low. The presence of a "second tier" was thought likely to increase the flow from biology to chemistry since the second-tier courses might siphon off from biology students whose abilities and commitments to the study of science were marginal.

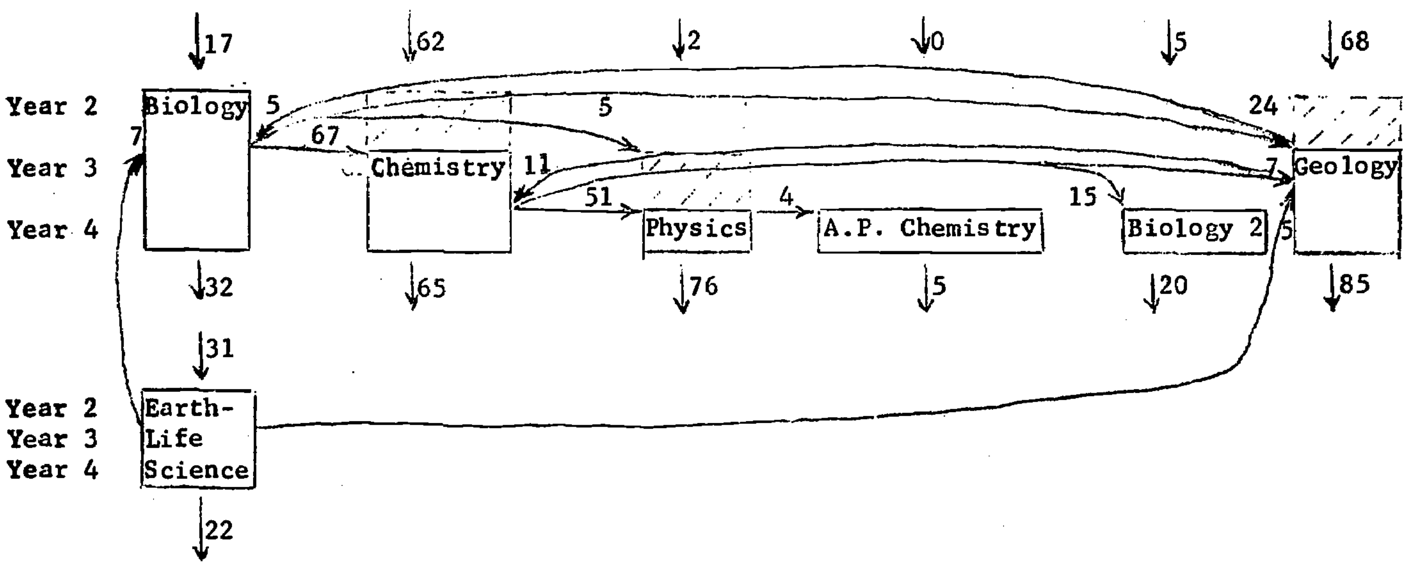
FIGURE 1



1a: School A



1b: School B



1c: School C

re 1 a, b, c. Science courses and the flow of students from course to course in three high schools.

The Variables Of The Study

(1) Ease of grading of each science teacher in each science course.

Each of these values are calculated by using the basic formula ^{N} (Science grade - Non-science average grade)/N, where N in this case is the number of students in the class of 1968 (or of 1967, where appropriate) who took the given science with the particular teacher. The non-science average grade for each student was computed from grades received by him in the same year in which he took the science. Thus, potential added variablity due to changes in a student's efforts from year to year is avoided, and the science grades are compared to grades in courses that were candidates for enrollment at the same time in the student's career. Ease of grading is computed for all students of a teacher, for the teacher's female students, for the teacher's male students, for the teacher's students who were non-seniors, for the teacher's female students who were non-seniors, and for the teacher's male students who were non-seniors.

(2) Average non-science grade for the students of each teacher in each science course.

Each of these values are calculated using the formula, $\sum^{N}$ (Non-science average grade)/N, where N is again the number of students in the class of 1968 (or 1967) who took the given science with the particular teacher. Again the non-science average grade for each student is computed from grades received by him in the same year in which he took the science. Again, too, the values are computed for all students of the teacher and all non-senior students of the teacher, and then by sex within these categories.

(3) Ease of grading in each science course in each school.

The values are calculated using the basic formula applied to the appropriate population -- in this case the grades of students in the class of 1968 (or 1967)

who had taken the particular science in a given sc . Again the values are computed for all students of the science and all non-senior students and then by sex within these categories, and the non-science grades are those received in the year the science was taken.

(4) Average non-science grade for students in each science course in each school.

The values are calculated using the same formulas as was used to compute the values of variable 2, but the population is the students in the class of 1968 (or 1967) who had taken the particular science in a given school. Again the values are computed for all students of the science and all non-senior students and then by sex within these categories, and the non-science grades are those received in the year the science was taken.

(5) Relative frequency with which students in biology elect to study chemistry, computed for a) students of each teacher of biology and b) students of biology in each school.

(6) Relative frequency with which students in chemistry elect to study physics, computed for a) students of each teacher of chemistry and b) students of chemistry in each school

These frequencies are calculated using non-senior students in biology (variable set 5) or chemistry (variable set 6) as the base. They are calculated for the full set of non-seniors and for males and females separately.

(7) The relative frequency with which occupations pursued by the parents of science students in each school are science-related.

This is a somewhat peculiar variable that results from transforming what was to be information about individual students into information about the group of students included in the study in each school. In each school occupational data were taken (when available) from student files for the

parents of all students who had taken a science. An occupation was coded as science-related when it was thought likely that a student would associate performance in the occupation with a background in science. For this reason, occupations such as airline pilot and navigator were coded as science-related as well as the more obvious doctor, dentist, engineer, and scientist. Occupations such as machine-tool operator, technician, etc. were coded as non-science-related. Thus the variable is an index of the joint presence of high S.E.S. and technical relatedness of parental occupations among the students included in the study.

(8) The presence of a "second tier" of science courses in each school.

This is a variable coded zero or one for each school according to the absence or presence of courses such as "life science", "physical science", etc.

(9) The presence of a second-year biological alternative to (a) chemistry and (b) physics in each school.

This is a variable coded zero or one for each school according to the absence or presence of courses such as "physiology", "advanced biology", etc. (a) without an effective chemistry prerequisite or (b) with a chemistry prerequisite.

ANALYSIS

Reliability Of Teachers' Ease Of Grading By Teacher

In seven of the 27 schools, data were transcribed for students in the graduating class of 1967, as well as students in the class of 1968. This permitted estimation of the stability of the ease of grading measure. Stability of the ease of grading measures was estimated in four two-way analyses of variance with dis-proportionate sub-class numbers (Snedecor, 1956). The analyses (teacher by graduating class) were done for female students in biology, male

students in biology, female students in chemistry and physics, and male students in chemistry and physics. Each teacher with at least three male or three female students in both the class of 1967 and the class of 1968 was included in the appropriate analysis of variance. The summary tables for the analyses are presented in Table 1.

From the tables it is evident that the variation due to teachers is consistently a significant source of variance. It is also evident that in biology in these seven schools there is an effect due to the year of graduating class -- the ease of grading is lower for the class of 1968 than for the class of 1967. The significant interaction in the ease of grading for male students in the physical sciences can be attributed to a shift by a single teacher whose ease of grading for males in the class of 1968 was approximately half a grade lower than his ease of grading for males in the class of 1967. Oddly enough, no corresponding change can be noted in this teacher's grading of female students in the two graduating classes.

The central feature of these analyses of variance is the strong consistent finding of a teacher effect and the lack of consistency in the other effects. The instability of a teacher's ease of grading due to sampling errors can be estimated from the tables. The standard error of a mean is just the square root of the variance about the mean divided by the square root of the number in the sample. Estimates of these standard errors for computationally convenient sample sizes are shown in Table 2.

TABLE 1

ANALYSES OF VARIANCE FOR STABILITY OF EASE OF GRADING

1a. Girls in Biology

Source	df	SS	Mean Square	F	
Year	1	4.38	4.38	2.98	$.10 \geq p \geq .05$
Teacher	18	210.24	11.68	7.94	$p \leq .001$
Interaction	18	38.14	2.12	1.44	$.10 \geq p \geq .05$
Individuals	1218	1793.24	1.47		

1b. Boys in Biology

Source	df	SS	Mean Square	F	
Year	1	6.11	6.11	4.16	$p \leq .05$
Teacher	18	248.59	13.81	9.39	$p \leq .001$
Interaction	18	29.63	1.65	1.12	$p \geq .25$
Individuals	1018	1492.22	1.47		

1c. Girls in Chemistry and Physics

Source	df	SS	Mean Square	F	
Year	1	.03	.03		
Teacher	18	195.71	10.87	6.18	$p \leq .001$
Interaction	18	30.73	1.71	.97	
Individuals	739	1301.23	1.76		

1d. Boys in Chemistry and Physics

Source	df	SS	Mean Square	F	
Year	1	.39	.39		
Teacher	19	265.29	13.96	7.67	$p \leq .001$
Interaction	19	59.00	3.11	1.71	$p \leq .05$
Individuals	1399	2543.78	1.82		

TABLE 2

Estimates Of The Standard Error Of Ease Of Grading
For Different Numbers Of Students

Number of Students	Biology Females	Biology Males	Chemistry - Physics Females	Chemistry - Physics Males
4	.61	.61	.66	.67
9	.40	.40	.44	.45
16	.30	.30	.33	.34
25	.24	.24	.27	.27
36	.20	.20	.22	.22
49	.17	.17	.19	.19
64	.15	.15	.17	.17

These estimates of the standard error due to sample size are of interest because they indicate that even when year-to-year variations in ease of grading reach the values found in biology in the seven schools (an average difference of approximately .15), the small size of the samples is still likely to be the major source of "error" variance in estimating the ease of grading characteristic of a given teacher. For example, in the sample of biology teachers in all twenty-seven schools, even when only teachers with nine or more male students are counted, the median number of male students per teacher is twenty-five. Indeed, for each of the analyses that follow, the small number of students per teacher is probably the greatest source of uncertainty in the estimates of teachers' ease of grading.

Distribution Of Estimates Of Teachers' Ease Of Grading

The analyses of variance reported in Table 1 indicate that ease of grading can be thought of as a characteristic of teachers-in-context. Undoubtedly the ease of grading of the same teacher in quite different contexts would be different. From year to year, though, the context of the teacher stays fairly constant and, consequently, the teacher's grading practices remain reasonably stable.

We can ask, though, whether the ease of grading appears to be dependent on the subject taught and on characteristics of the students who are graded. The distribution of teachers' ease of grading (for students in the class of 1968) broken down by subject taught and sex of student is presented in Table 3. Simple inspection will reveal what calculations also indicate: grading tends to be easier in biology than in chemistry, and easier for male students than for female. The means for the separate categories are: Biology males, -.05; Biology females, -.29; Chemistry males, -.37; Chemistry females, -.98; Physics males, -.27; Physics females, -.78. Female students in chemistry lose half a grade, on average, compared to their other grades. The grade penalty for other student groups is less and for male biology students hardly exists at all.

If attention is directed to those teachers who graded <u>both</u> nine or more male students and nine or more female students, tests of significance of sex differences in ease of grading are possible. These tests yield $t_D = 5.98$ ($p \leq .001$) for the sex difference in biology and $t_D = 14.7$ ($p \leq .001$) for the sex difference in chemistry.

Unfortunately, sex is also related to average non-science grade; the groups of female students have, in general, higher non-science grade averages than their male counterparts. This is of some significance since there is typically a low negative correlation between non-science grade average and the difference between science grade and non-science grade average among the students of a given teacher. If a correction is made for the difference in non-science grade average of the two groups, the tests of significance of

TABLE 3

DISTRIBUTION OF TEACHERS' EASE OF GRADING BY
SUBJECT TAUGHT AND SEX OF STUDENT

Subject and Sex of Student	Number of Teachers[a] Whose Ease of Grading Is Between									
	-2.39 and -2.00	-1.99 and -1.60	-1.59 and -1.20	-1.19 and -.80	-.79 and -.40	-.39 and .00	.01 and .40	.41 and .80	.81 and 1.20	1.21 and 1.60
Biology										
Females			3	10	17	20	14	6		
Males			1	7	12	20	18	9	6	1
Chemistry										
Females	2	5	11	12	9	7	1			
Males			3	7	14	18	8	1	1	
Physics										
Females		1	2	3	3	1		1		
Males		1		5	13	2	10	2	2	

[a]Only those teachers who graded nine or more male students and/or nine or more female students in the class of 1968 are included in the table.

sex differences in ease of grading are changed only slightly[1]; for biology teachers t_D becomes 5.00 ($p \leq .001$) and for chemistry teachers t_D becomes 13.3 ($p \leq .001$). Because of these differences in the ease of grading experienced by students of each sex, the remaining analyses are carried out separately by sex, and no analyses are attempted for all students combined.

The difference in ease of grading experienced by male and female students carries no implication that females received lower grades in science. As a matter of fact, for fifty of the sixty-five biology teachers who had the required number of both male and female students, the average science grade for females was higher than the average science grade for males. The mean across biology teachers of the average science grade of teachers' female students is higher than the comparable mean for male students (the difference is .37). The non-science grade average of the female students, however, is even higher than the non-science grade average of the male students (the difference is .63), so ease of grading experienced by the female students is lower (the difference is, of course, -.26). Across chemistry teachers a similar situation obtains. The male-female differences are .10 for average science grade, .72 for non-science grade average, and -.62 for ease of grading.

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[1]The difference between the ease of grading experienced by male and female students was corrected separately for each teacher. The slope of the regression line (for all students of a teacher) of the science - non-science grade difference on the non-science grade average was calculated. This was multiplied by the difference in non-science grade average of the two sex groups to furnish the correction term. The corrected differences in ease of grading were then subjected to a test of significance and it is these differences that are reported.

This correction procedure is definitely <u>not</u> the most defensible that one could use. For the particular case in hand though, it appears to be conservative. More elegant procedures will have the effect of flattening the slope which in this case would tend to counteract any "correction" of the difference in ease of grading.

These results are, in retrospect, surprising only in the findings for ease of grading. If the sciences are in some sense forbidding to students, and if the expectation that one should study science is less for female students, then we might expect only the more academically secure female students to end up in the science. Since these will, in general, be those with higher grades, the female students' non-science grades would be higher, on average, than the male students'. Why the science grades for girls aren't also comparably higher <u>is</u> puzzling, though. The non-erasure of the difference in ease of grading by a regression correction indicates that regression effects alone cannot account for the difference.

<u>Analysis Of The Effects Of Grading In One Science On Enrollments In The Following Sciences</u>

The summary description of the model that was developed earlier included the following proposition:

> The ease of grading in a science course will be directly related to the percentage of students in that course who elect to go on to the "next course" in the science sequence.

In the most typical sequence, this proposition can be tested by examining the relation between enrollment in chemistry and ease of grading in biology and the relation between enrollment in physics and ease of grading in chemistry. The analysis is made difficult by the variation in chemistry enrollments that can be expected from school to school due to differences in curriculum structure, in ease of grading in chemistry, etc. The analysis reported here gets around this difficulty in part.

The non-senior students of a particular biology or chemistry teacher form the basis of the analysis. Thus for the biology-chemistry transition the essential data are the non-science grade average of a biology teacher's non-senior

students, the ease of grading experienced by these students in biology, and the relative frequency with which these students enroll in chemistry. For ease of reference we can say these are the scores for the teacher. The data are used in the analysis not in their "raw" form but in the form of deviations from the mean of teachers in the same school. For example, if there were two teachers of biology in a school their "raw" scores and the scores used in the analysis might look like this: (scores in parentheses are those used in the analysis:

Non-science Average:	Tchr. 1,	3.98	(-.15);	Tchr. 1,	4.29	(+.15).
Ease of Grading:	Tchr. 1,	- .05	(+.35);	Tchr. 2,	- .75	(-.35).
Relative Frequency of Enrollment:	Tchr. 1,	.815	(+.005);	Tchr. 2,	.805	(-.005).

Because the procedure takes deviations from the mean of the scores of teachers in the same school as the useful data, scores for teachers who are the sole teachers of biology or chemistry in their school cannot be used. For this reason data from four schools do not figure in the biology-chemistry analysis, and data from twelve to fourteen schools are eliminated from the chemistry-physics analysis. After the deviation scores for the teachers of a given school are calculated, all the deviation scores are pooled, and a regression of relative frequency of enrollment on non-science grade average and ease of grading is computed. The analysis is done for male and female students separately and a teacher must have graded ten or more male or female students to be included in the appropriate analysis.

Results of the four versions of this analysis are presented in Table 4. For both sexes, ease of grading in biology makes a significant contribution to prediction of the relative frequency with which students in biology will enroll in chemistry. However, for neither sex does ease of grading in

TABLE 4

MULTIPLE REGRESSIONS OF RELATIVE FREQUENCY
OF
ENROLLMENT ON EASE OF GRADING AND NON-SCIENCE AVERAGE

Group	Number of Teachers in Sample	Multiple Regression: Beta Weight (and slope): Ease of Grading	Multiple Regression: Beta Weight (and slope): Non-Science Average	Multiple Regression: Multiple R	Pearson r with Science Grade
Biology - Chemistry					
Female Students	63	.30[b] (.12)	.59[a] (.21)	.69[a]	.67[a]
Male Students	61	.17[c] (.06)	.76[a] (.27)	.76[a]	.60[a]
Chemistry - Physics					
Female Students	16	.29(.16)	.66[c] (.21)	.56[c]	.55[c]
Male Students	31	.00(.00)	.91[a] (.38)	.91[a]	.75[a]

[a] $p \leq .001$, one-tailed test
[b] $p \leq .01$, one-tailed test
[c] $p \leq .05$, one-tailed test

chemistry make a significant contribution to prediction for the chemistry-physics transition. The variance of ease of grading in chemistry is roughly half that in biology, and the number of degrees of freedom for the chemistry-physics analysis, of course, considerably reduced from the biology-chemistry analysis (especially for the groups of female students). Thus it isn't too surprising that an effect that is not large in the biology-chemistry transition is not apparent in the chemistry-physics transition.

One other aspect of the results deserves comment. It would appear that for groups of male students, the best predictor of enrollment in the "next" science is not their average science grade or the ease of grading experienced, but their non-science-average grade (or, more likely, their overall grade average). On the other hand, for groups of female students the average science grade is the best single predictor of whether they will enroll in the next science; knowledge of their non-science average adds little to the prediction.

By School Analysis Of The Effects Of Ease Of Grading

A test of the proposition that the ease of grading in a science course will be directly related to students' propensities to enroll in it can be managed only by comparing ease of grading in a course and enrollments in it across schools. This comparison is achieved by a correlational analysis in which other variables which may affect enrollments are included. These analyses again examine the transition from biology to the second science in the sequence and from chemistry to physics. The criterion variables are the relative frequency with which non-senior biology students enroll in the

"second" science[1] and the relative frequency with which non-senior chemistry students later enroll in physics. The chemistry-physics analysis is over only 25 schools because in one school, as noted previously, the sequence is from physics to chemistry and in another school there were too few physics students to permit a reasonably stable estimate of ease of grading in physics. For both analyses, the sexes are again separated.

Biology-Second Science

Correlations for the biology-"second" science transition are presented in Table 5. Ease of grading is figured for each sex separately and is based on all male students or all female students who received a grade in the second science.[2] The correlations for male students are shown above the diagonal and those for female students are shown below the diagonal.

[1]The "second science" is a clumsy phrase used to indicate that in one school the physical science which "follows" biology in the main sequence is not chemistry, but physics.

There was one additional change in the chemistry-physics analysis. In one school a change in physics teachers occurred between the 1966-67 school year and the 1967-68 school year. The ease of grading of the two teachers differed by 1.7. Because it is anticipated ease of grading that is presumed to matter, the ease of grading values for the 1966-67 teacher are used in the analysis. These are available because, fortunately, the school is one in which data for the class of 1967 were transcribed for use in the estimate of the stability of teacher's ease of grading.

[2]This separation by sex corresponds to assuming, in the terms of our model, that female students form expectations of the ease of grading in a course from the reports of female students who have taken the course, i.e. females listen to females and males to males. If one assumes that each student forms expectations by attending to the report of all students who had taken the course, one would base the ease of grading estimate on all students who had taken the course. If this were done the correlations in Table 5 between ease of grading in the second science and relative frequency of enrollment in the second science would increase slightly.

TABLE 5

CORRELATIONS FOR THE TRANSITION FROM BIOLOGY
TO A
SECOND SCIENCE ACROSS TWENTY-SEVEN SCHOOLS[a]

	Enrollment Ratio[b] (1)	Ease of Grading - Second[b] (2)	Ease of Grading - Biology[b] (3)	Non-Science Average - Biology[b] (4)	Occup. Ratio[b] (5)	Biological Alternative (6)	Second Tier[b] (7)
(1)		.54[c]	-.06	.58[c]	.22	-.49[c]	.18
(2)	.32[d]		.28	.30	.09	-.24	.09
(3)	.26	.15		-.26	-.29	.23	.18
(4)	.23	-.11	-.39[f]		.52[e]	-.40[f]	.27
(5)	.25	-.03	-.11	.53[e]		-.42[f]	-.40[f]
(6)	-.38[d]	-.27	.12	-.19	-.42[f]		-.11
(7)	.39[b]	-.01	.04	.04	-.40[f]	-.11	

[a]Correlations for males above the diagonal; for females below the diagonal.

[b]The variable names have the following meaning: Enrollment Ratio - relative frequency with which non-senior students in biology enroll later in the second science in the "main sequence"; Ease of Grading-Second - ease of grading in the second science for male students only or for female students only; Ease of Grading - Biology - ease of grading in biology experienced by male non-seniors or by female non-seniors; Non-Science Average - Biology - Non-science average grade of male non-senior students or female non-senior students of biology; Occup. Ratio - proportion of students in the total sample of a school whose parents hold science-related occupations; Biological Alternative - presence or absence of a second year biology course without an effective prerequisite of chemistry; Second Tier - presence or absence of a "second tier" of science courses.

[c]$p \leq .01$, one-tailed test

[d]$p \leq .05$, one-tailed test

[e]$p \leq .01$, two-tailed test

[f]$p \leq .05$, two-tailed test

For the biology-second science transition, it appears that ease of grading in the second science has an effect on enrollments in that science. This effect could, however, be an artifact produced by the association of ease of grading with other enrollment-related factors. One way to check on this is to examine the effect of "partialling out" these other factors from the correlation matrix. This partialling out proceeds by removing first the variables indexing particular curricular structures, and then the variables descriptive of the student population. The resulting partial matrices are shown in Table 6. The results indicate that ease of grading in the second science is significantly related to enrollments in that science. The result appears to be reasonably "unshakeable" for male students; for female students the degree of association moves up and down depending on the variables "controlled for" sometimes reaching statistical significance and sometimes not.

Also indicated is the relatively persistent correlation between ease of grading in biology and enrollment in the second science for female students but not for male students. In this analysis the ease of grading in biology and the average non-science grade were values assigned to the total group of non-senior males or female biology students in a school. The differences between these values reflect differences between schools. In the earlier analysis the differences between teachers in the same school were the basis for analysis. Even though the bases for analysis are different, the results are reasonably convergent -- ease of grading in biology is more strongly associated with enrollment in the second science for female students than for male students. In the present analysis the correlations between ease of grading in biology and enrollment in chemistry for male students does not

TABLE 6

PARTIAL CORRELATION MATRICES FOR THE TRANSITION FROM BIOLOGY TO A SECOND SCIENCE ACROSS TWENTY-SEVEN SCHOOLS[a]

6a. Partial Matrix With Curricular Structure Variables Removed

	Enrollment Ratio (1)	Ease of Grading - Second (2)	Ease of Grading - Biology (3)	Non-Science Average - Biology (4)	Occup. Ratio (5)
(1)		.49[b]	.03	.45[c]	.11
(2)	.28		.35	.22	.02
(3)	.34[e]	.19		-.26	-.13
(4)	.18	-.18	-.37		.65[d]
(5)	.36	-.21	-.04	.60[d]	

6b. Partial Matrix With Curricular Structure And Student Characteristic Variables Removed

	Enrollment Ratio (1)	Ease of Grading - Second (2)	Ease of Grading - Biology (3)
(1)		.43[c]	.18
(2)	.39[c]		.45[e]
(3)	.40[c]	.18	

[a]Correlations for males above the diagonal; for females below the diagonal.

[b]$p \leq .01$, one-tailed test

[c]$p \leq .05$, one-tailed test

[d]$p \leq .01$, two-tailed test

[e]$p \leq .05$, two-tailed test

approach statistical significance; in the earlier analysis it was statistically significant but the correlation was computed for a sample with many more degrees of freedom.

The remaining correlations are interesting for their suggestive value. Once again it appears that average non-science grade is a better predictor of enrollments for male students than for female students. It appears that the presence of a biological alternative is negatively associated with second science enrollments for both male and female students, but that the presence of a second tier of science courses affects female students more than males in their transition from biology to the second science. It would appear that in communities containing many parents whose occupation is science-related the average non-science grade is higher and there is less likelihood that there will be either a biological alternative to the first physical science course or a "second tier" of coursework in science. Whether this is a characteristic of only the sample studied or is a set of associations found more widely deserves further study. It was indicated earlier that the occupational variable is somewhat peculiar and any associations found with it, even if they are stable, are difficult to interpret.

The regression coefficients corresponding to the correlation matrices of Table 5 are presented in Table 7. Two sets of coefficients are shown for each sex, for regression equations with and without the occupational variable included. Because of the strong associations between the index of parental occupation, average non-science grade, and the curricular structure variables, the beta weights and slopes for these variables are strongly affected by the inclusion of the occupational index. The beta weights and slopes for the ease of grading variables are somewhat affected, but the

TABLE 7

WEIGHTS FOR THE REGRESSION OF ENROLLMENT RATIO,
BIOLOGY TO THE SECOND SCIENCE,
ON OTHER VARIABLES

Group	Beta Weight (and Slope) of: Ease of Grading - Second	Ease of Grading - Biology	Non-Science Average - Biology	Occup. Ratio	Biological Alternatives	Second Tier	Constant
Male Students	.37 (.10)	-.025 (-.01)	.35 (.10)		-.26 (-.06)	.028 (.01)	(.26)
	.33 (.09)	.003 (.001)	.53 (.15)	-.29 (-.23)	-.34 (-.07)	-.15 (-.03)	(.16)
Female Students	.23 (.07)	.37 (.11)	.33 (.13)		-.28 (-.08)	.33 (.09)	(-.04)
	.28 (.08)	.30 (.09)	.13 (.05)	.39 (.40)	-.095 (-.03)	.52 (.14)	(.18)

pattern remains fairly stable -- ease of grading in the second science is related to the number of male students and female students who make the transition from biology to the second science; ease of grading in biology is related to the number of female students (but not male students) who make the transition from biology to the second science.

Chemistry-Physics

Correlations for the chemistry-physics transition are presented in Table 8. In some schools there were so few female physics students that it wasn't possible to derive a reasonably stable estimate of ease of grading in physics alone. Thus, in the analysis for female students, the estimate of ease of grading in physics is based on data from all physics students.

Ease of grading in both physics and chemistry appears to have little effect on the decisions of male chemistry students to enroll in physics. For male students the most substantial correlation is between the occupational measure and the enrollment ratio. A somewhat different picture emerges for female students where correlations of all other variables with the enrollment ratio are around $\pm.30$. While neither ease of grading measure is correlated with enrollments at a statistically significant level in this initial analysis, both reach statistical significance after partialling out the variables descriptive of curriculum structure and the student population. The matrices of partial correlations are shown in Table 9.

Again it can be seen that in schools where a large proportion of the students have parents whose occupations are science-related, the average non-science grades are higher. There is an inverse association between the occupational variable and the presence or absence of a biological alternative to physics, but the strength of the association is considerably less than

TABLE 8

CORRELATIONS FOR THE TRANSITION FROM CHEMISTRY
TO
PHYSICS ACROSS TWENTY-FIVE SCHOOLS[a]

	Enrollment Ratio[b] (1)	Ease of Grading - Physics[b] (2)	Ease of Grading - Chemistry[b] (3)	Non-Science Average - Chemistry[b] (4)	Occup. Ratio[b] (5)	Biological Alternative[b] (6)
(1)		.03	.02	.39[d]	.63[c]	-.26
(2)	.28		.15	.18	-.13	.11
(3)	.31	.20		.22	.08	-.03
(4)	.34	.12	-.01		.44[f]	-.03
(5)	.38[d]	-.14	.04	.63[e]		-.26
(6)	-.38[d]	.22	.19	-.17	-.26	

[a]Correlations for males above the diagonal; for females below the diagonal.

[b]The variable names have the following meaning: <u>Enrollment Ratio</u> - relative frequency with which non-senior students in chemistry enroll later in physics; <u>Ease of Grading - Physics</u> - ease of grading in physics for male students only or for all students (used in the analysis for female students); Ease of Grading - Chemistry - ease of grading in chemistry experienced by male non-seniors or by female non-seniors; <u>Non-Science Average - Chemistry</u> - non-science average grade of male non-senior students or female non-senior students of chemistry; <u>Occup. Ratio</u> - proportion of students in the total sample of a school whose parents hold science-related occupations; <u>Biological Alternative</u> - presence or absence of a second-level biology course with or without an effective prerequisite of chemistry.

[c]$p \leq .01$, one-tailed test

[d]$p \leq .05$, one-tailed test

[e]$p \leq .01$, two-tailed test

[f]$p \leq .05$, two-tailed test

TABLE 9

PARTIAL CORRELATION MATRICES FOR THE TRANSITION FROM CHEMISTRY TO PHYSICS IN TWENTY-FIVE SCHOOLS[a]

9a. Partial Matrix With The Curricular Structure Variable Removed

	Enrollment Ratio (1)	Ease of Grading - Physics (2)	Ease of Grading - Chemistry (3)	Non-Science Average - Chemistry (4)	Occup. Ratio (5)
(1)		.06	.02	.39[c]	.60[b]
(2)	.41[c]		.15	.18	-.11
(3)	.42[c]	.16		.22	.08
(4)	.30	.17	.03		.45[e]
(5)	.32	-.10	.09	.61[d]	

9b. Partial Matrix With Curricular Structure and Student Characteristic Variables Removed

	Enrollment Ratio (1)	Ease of Grading - Physics (2)	Ease of Grading - Chemistry (3)
(1)		.12	-.08
(2)	.45[c]		.11
(3)	.42[c]	.19	

[a]Correlations for males above the diagonal; for females below the diagonal

[b]$p \leq .01$, one-tailed test

[c]$p \leq .05$, one-tailed test

[d]$p \leq .01$, two-tailed test

[e]$p \leq .05$, two-tailed test

that reported earlier for biological alternatives to the second science in the sequence. Indeed, the correlation in the present case is not statistically significant, and one cannot have much confidence that a correlation with the same sign would appear in another sample of schools.

Multiple regression prediction of the proportion of non-senior chemistry students who enroll in physics indicates little that is not apparent from the correlations themselves. The beta weights and slopes for the multiple regression equations are shown in Table 10.

DISCUSSION

The interpretation of correlational data obtained on a "natural population" is known to be a risky undertaking. It is easy to move unconsciously from a noting of associations to talk of "effects" as though it were obvious that the relations observed were causal and it was clear which variables play the role of "cause" and which those of "effect." The discussion which follows will include a consideration of actions that might be taken on the assumption that the correlations observed are the result of identifiable causal relations. The standard caveat must be entered, though, about the risks of inferring causation from correlations. This is especially the case in discussions of the relation between ease of grading and enrollments. Although it will be assumed that ease of grading in the science affects enrollment decisions, a reasonably persuasive case can be made for causation running in the opposite direction.

The observed severity of grading in the physical sciences might be seen as a consequence of restricted enrollments in the physical sciences. A chemistry teacher may know that chemistry students form a group of high

WEIGHTS FOR THE REGRESSION OF ENROLLMENT RATIO,
CHEMISTRY TO PHYSICS,
ON OTHER VARIABLES

	Beta Weight (and Slope) of					
Group	Ease of Grading - Physics	Ease of Grading - Chemistry	Non-Science Average - Chemistry	Occup. Ratio	Biological Alternative	Constant
Male Students	.10 (.03)	-.09 (-.03)	.14 (.05)	.55 (.61)	- 55 (-.04)	(.25)
Female Students	.36 (.12)	.31 (.07)	.05 (.02)	.28 (.28)	-.44 (-.12)	(.26)

ability and may adjust his grading curve to take account of that fact. However the teacher may underestimate the degree of selection of chemistry students and, consequently, not adjust the curve enough. The end result would be unintentional severity of grading by the teacher, and the degree of severity would, on average, be greater for the more select populations of students. This reading of the data makes severity of grading a consequence of the restricted, high ability enrollments found in secondary physical science courses. Support for this interpretation is found in the negative correlations between ease of grading in biology and non-science grade average of biology students (Table 5). However the correlations are relatively small for male biology students, and the corresponding correlations in chemistry (Table 8) are either near zero or positive. It is possible that the hypothesized effect of selective enrollment on ease of grading is a real one for some teachers, but there is little evidence to support the belief that it is a universal effect.

The Proposed Model of Effects of Ease of Grading

Four propositions concerning ease of grading in the sciences and its effects were presented earlier. In the analyses, evidence bearing on three of these has been developed.

1. An appropriate measure of a teacher's ease of grading in a science course is the discrepancy between students' grades in the science courses and their grades in other academic subjects, averaged across students of the teacher.

   The analysis indicates that the defined measures of ease of grading are reasonably stable from year to year and reasonably characteristic

of an individual teacher-in-context (Table 1). The analyses that follow (Tables 4 to 10) indicate that the measures are associated with the proportion of students who go from one science to "the next." Thus it appears that the measure of ease of grading used in this study _is_ reasonably appropriate and may be used with some confidence in the related studies that may follow.

2. The ease of grading in a science course will be directly related to the proportion of eligible students enrolled in the course.

When "eligible students" is taken to mean "students who had taken the preceding course in the standard sequence in prior years", the evidence bearing on this proposition is, in the main, supportive. Only for male students who might take physics, having had chemistry, is the correlation between ease of grading and enrollment not significant at p .05. For the other three analyses, the correlations and the slopes in a regression equation are statistically significant (Table 5 - 10). The absence of a relation for male students in the chemistry-physics transition is not easily explained. The very high correlation between the occupational variable and the proportion of chemistry students enrolling in physics suggests that school populations may differ in their expectations of the importance and appropriateness of the physical sciences for men's career development, with this expectation overriding other considerations. Clarification of the reason for no association for male students in the chemistry-physics transition will certainly be desirable.

3. The ease of grading in a science course will be directly related to the proportion of students in that course who elect to go on to the "next course" in the science sequence.

   The evidence bearing on this proposition is mixed. The analyses in which within-school deviations are pooled across schools (Table 4) indicate that there is an association between ease of grading in biology and the proportion of biology students going on to the next science in the sequence, although the association is much stronger for female students than for male students. No statistically significant association was found for the analyses involving ease of grading in chemistry, though here too the estimates suggest that if an association is present, it is stronger for female students than male students.

   The analyses across schools (Table 5 - 10) indicate an association for female students but not for male students. The two sets of analyses combined suggest that ease of grading in a science course has significant effect on the decisions of female students to enroll in succeeding sciences but has little apparent effect on such decisions of male students.

Because data on the vocational interests of students were not available, no evidence bearing on the fourth proposition of the model was developed. Altogether, though, the propositions of the model fared well in this initial test of their adequacy.

The Correlations Seen Causally And A Practical Suggestion

If it is assumed that the correlations found in the study adequately represent causal relationships, they can be used to estimate the effects of bringing science grades to a par with non-science grades. The effects are fairly small for male students, but are considerably larger for female students. In the sample of schools as a whole the mean ease of grading that could be anticipated by male students in the second science is -.39. If the regression slope can be used to estimate the effects on enrollment of a change in ease of grading, the percentage of male students in biology going on to the "second science" would increase approximately four per cent, from 60 to 64 per cent. The ease of grading experienced by female students in biology is -.30 and the ease of grading they can anticipate in the "second science" is -1.00. The effect of changing both figures to zero (estimated using the regression slopes) is to increase the percentage of female students in biology going onto the second science by approximately ten and a half per cent, from 42.5 to 53 per cent.

In the chemistry-physics transition, no relation between ease of grading and enrollments was found for male students. For female students, the mean ease of grading experienced in chemistry is -1.15 and the ease of grading that can be anticipated in physics is -.50. The effect of changing both figures to zero (estimated using the regression slopes) is to increase the percentage of female students in chemistry going on to physics by approximately fourteen per cent, from 18 to 32 per cent.

While these estimates are suspect, since they use data gathered under "steady-state" conditions to estimate the effects of a change, they suggest that substantial enrollment gains in the physical sciences may follow an

attempt to eliminate the observed severity of grading in the sciences. But if teachers are to eliminate severity of grading, they must be made aware of it.

Before the widespread use of data processing equipment in the recording of grades teachers often copied the grades they assigned onto both report cards and permanent record cards. In the process they had the opportunity to "pick up" an impression of the overall grade average of their students. Current grade handling procedures remove the requirement that teachers come in contact with the grade record of their students. These grade handling procedures could easily be modified so that after each grading period teachers received a summary distribution of the grades they assigned to their students and a summary distribution of the grades these same students received in their other academic courses. A comparison of the two grade distributions would indicate any systematic differences.

If students' permanent records were computer retrievable, the system could be made anticipatory rather than reflective. As soon as class enrollments stabilized in any grading period a teacher could be given a summary distribution of all the grades received by his current students in the previous grading period. Such a summary might be used, with other data, as a guide for the teacher's grading practices in the current grading period.

Summary distributions of grades (of the type suggested) could be used to begin a discussion of grading practices in the school as a whole. Teacher assignment of grades is a right and duty that is jealously guarded, but it needn't be outside the realm of professional discussion. Data bearing on grade differentials associated with particular subjects or teachers can give focus to that discussion.

Possible Relations Of Ease Of Grading To Career Decisions

Vocational decisions have often been discussed as though they were relatively infrequent acts consciously made. A considerable portion of the literature on vocational decisions is concerned with helping individuals gather and use information that will illuminate these conscious decisions. Consciously vocational decisions can be seen, though, as a visible, explicit subset of a larger set of decisions having vocational importance. Other decisions in the larger set might be made with non-vocational criteria in mind. For example, course choices throughout secondary school have vocational implications, but are not always or even often seen as vocational decisions. The student who avoids the physical sciences or mathematics beyond elementary algebra has made certain careers very unlikely. To the extent that ease of grading affects enrollments, it has an effect on vocational decisions.

Vocational decisions may be affected by ease of grading in other ways. A study by Halpern and Norris (1967) indicates that in making career decisions individuals may make much greater reference to their grades and achievement test scores than they do to the values they hold. In Osipow's (1968) description of Holland's theory of vocational behavior, the influence of a set of variables called the level hierarchy is noted. The level hierarchy includes the individual's self evaluations of competence. In the little research on the influence of the level hierarchy that Osipow is able to cite, there is some indication that level hierarchy has a less powerful influence on males than on females in their choice of college majors. This is consistent with the results reported in this study, where ease of grading in biology is seen to be related to enrollment in a second science and ease of grading in chemistry related to enrollment in physics for female students but not for

male students. The presumed mediator between ease of grading in one science and decision to enroll in the next is the student's estimate of his or her ability in science. Either female students make greater reference to this estimate in their course and vocational decisions or they rely more on science grades in forming the estimate than do male students.

Too much vocational theorizing has taken its determining variables -- aptitudes and the knowledge of aptitudes, interests, vocational stereotypes, etc. -- as either preformed or as uniformly developed. The O'Hara and Tiedeman study (1959) indicates that knowledge of aptitudes may develop slowly over the high school years and still be inadequate on graduation. Cooley's (1967) study indicates that aptitudes and interests converge somewhat through the secondary years. It seems probable that the academic experiences of students and, in particular, the evaluations of student work provided by teachers have a strong influence on the development of the characteristics commonly seen as explanatory in vocational theorizing. For some students, the most effective form of vocational guidance one might devise would be concerned with providing more representative and reliable information to students so that the self-knowledge they develop is a surer guide to decisions. This might take the form of working with teachers rather than students, helping to make the course experiences more honestly representative of the subject and to make the teachers' evaluations of student work less personally idiosyncratic.

Extensions Of This Study

The ordinary student's experience in secondary school is memorialized in three ways: in the recollections and residual gains in capacity of the alumnus, in the photographs and prose of the high school yearbook, and in

the grades noted on the permanent record card. It is remarkable that those grades have so seldom been seen and studied as the joint product of student and teacher behaviors. The role of teachers in grade assignment and the effects of variations in the way that role is filled have been almost completely ignored. The results of this study indicate that study of differences in teachers' grading practices is warranted. Yet in this study the guiding model was fairly primitive and the measures used were deliberately kept simple. The model should be refined and ultimately tested in an experiment.

Two approaches to refinement of the model seem appropriate. They can be pursued individually, though they will almost certainly be most effective if joined together. In one approach a search would be made for more powerful ways of handling the data in hand or similar data that might be gathered. For example, the distribution of grades in the physical sciences tends to be negatively skewed, which is to be expected since the students are highly selected. A transformation would make the grade distribution more normal. A similar transformation would be in order when the enrollment percentages are either very high or very low. One could search for a linear combination of science grade and non-science grade average that will be the best compromise between the measure that is most stable from year to year and the measure that is most predictive of enrollments.

In a second approach one would attempt to determine, through interview and simulation, what meaning students give to the grades received, what information about ease or severity of grading in different courses they possess, what the sources of that information are, and how students use the information available to them in making course decisions. The focus in this approach would be on what students can describe or can be brought to describe of the important factors in course choices.

The two lines of work would complement one another. Transformations of data could be selected to mirror the "weights" that students appear to assign to the data. Correspondingly, transformations of data that yield stable results would suggest an analagous "weighting" of the data by students that could be investigated.

The process of constructing an adequate model for course choice and the effects of teachers' grading practices on course choice would be speeded by experimental manipulation of teachers' grading practices. Given the results of the present study, teachers might be willing to participate in an experiment lasting two or three years in which conscious manipulation of ease of grading was undertaken.

While ease of grading and enrollments have been the central focus in this investigation, adequate understanding of the effects of ease or severity of grading will require research of a wider scope. The sources of the apparent difference between sexes in ease of grading experienced in the sciences and in the enrollment effects of ease of grading should be determined. The relations between ease of grading, demands on students to produce work that meets appropriate standards, and mechanisms of classroom control should be clarified. The cues that signal to teachers the appropriateness or inappropriateness of grading standards should be identified. Ease or severity of grading is not an isolated phenomenon and its ties to its social context should be traced out. These ties must be understood if we are to have any confidence in our ability to predict the important consequences of a change in grading practices.

Science Enrollments And Grading Practices

In the introduction to this study, the enrollment picture in the physical sciences in the secondary school was sketched. What light can the results of this study throw on that picture ?

No claim can be made, of course, that the levels of severity of grading, of enrollments, etc. observed in this study are representative of those found in schools in general. The schools studied were not randomly selected from some defined population, and may not be representative of any population of interest. On the other hand informal discussions with teachers and counselors in a wide array of schools indicate to me that severity of grading in the physical sciences is common. More crucial is the possibility of generalization of the relations found between ease or severity of grading and enrollments. The stability of these relations as a number of other variables descriptive of schools are "controlled" in the analyses suggests that they are probably not strongly affected by the presence of one or another school in the sample. Thus, though we should be cautious in generalization, there is reasonable ground for believing that ease of grading is related to science enrollments in schools in general.

If enrollments in the physical sciences are to be brought to the level required for the general education of high school students, it seems likely that attention must be paid to ensuring that courses in the physical sciences carry no grade penalty. On the other hand, the estimates of possible enrollment increases as a result of eliminating the existing grade penalties indicate that attention to grading, by itself, will not do the job. If the physical sciences are to appeal to secondary school students in general it will be necessary to maintain current emphases on recruiting well-trained

teachers of the physical sciences and to reconstruct the curriculum in the physical sciences. Curriculum reconstruction seems especially important when one remembers that general education involves not just the teaching of all students, but teaching that will enrich the lives of all students. There is widespread doubt that existing curricula in the physical sciences make any effective contact with the lives of most high school students.

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