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other colleges, are important not because they are novel, but because of the unique possibilities they provide. The lectures are more than a deluge of facts and principles—they are also a carefully organized set of ideas which may give the student some insight into the nature of science, may even stimulate him to the point where he feels he would like to be a member of the scientific group. And if the student becomes interested in teaching science, the class may teach him how to solve problems experimentally, not by the substitution of anwsers from the textbook to the laboratory manual. Nor will the student rely on a textbook as his sole source of reference material. We are to a great extent slaves to our habits; therefore, let's try to inculcate those habits which are needed in both our future teachers and lay citizens. Let's explore the possibilities of these newer methods of teaching in our science classes.

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PROGRAMS FOR THE PREPARATION OF TEACHERS OF THE PHYSICAL SCIENCES AND MATHEMATICS

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THE STATUS OF SCIENCE EDUCATION

Science education seems to have arrived at a critical stage both from the standpoint of enrollment and availability of science teachers. Youth seems to be beginning to wonder if science offers a fruitful and desirable career. There are also factors operating to reduce the number who are preparing to become teachers of science. Statistics on enrollments in junior and senior high school courses in science and on colleges preparing teachers of science seem to support this trend of events.

A sample survey[1] by the United States Office of Education of the status of enrollment in science courses covering the first

term of 1947-48 reports such findings as the following:

1. Around 60 percent of the pupils in the 7th and 9th grades was enrolled in general science.
2. Around 75 percent of the pupils in the 8th and 10th grades was taking courses in general science and in biology, respectively.
3. Less than half of the senior high schools offered chemistry, and less than half offered physics. The combined enrollment in chemistry and physics was about one-third of the pupils in the eleventh and twelfth grades.
4. The study indicated that slightly more than 50 percent of the high school pupils was enrolled in the four courses: general science, biology, physics, and chemistry.
5. Boys and girls enrolled in about equal numbers in the science courses except in chemistry, where there was a small majority of boys and in physics where there were more than three times as many boys as girls.

Maul[2] reported on the number of college graduates, the number prepared to teach in high school, the number prepared to teach mathematics, the number prepared to teach science, and the percentage of year-by-year changes since 1950. The total number of graduates who were prepared to teach (see Table 1) mathematics were as follows:

1950	4,618
1951	4,118
1952	3,142
1953	2,710

This decline represents a reduction of 41.3 percent from 1950 to 1953.

The situation in four sciences was:

General science	:	from 3,009 to 1,746
Biology	:	from 3,473 to 1,830
Chemistry	:	from 1,660 to 722
Physics	:	from 954 to 317

In the four sciences the percentage reduction of graduates preparing to teach was 48.7 percent from 1950 to 1953.

While these national data are relevant and of great importance, it is possible to report data on the mathematics and science teacher situation for our own state. These are more directly related to the topic of this paper, viz., teacher preparation programs.

TEACHER PREPARATION AND INDUCTION IN MINNESOTA

We shall first report the number of teachers who were graduated in 1954-55 with mathematics or science as a major field (Table 2). By type of institution we find the following:

	Mathematics		Science	
	M	W	M	W
University of Minnesota	9	7	19	6
State Teachers' Colleges	20	2	44	2
Private Colleges	47	17	93	19
Total	76	26	156	27

TABLE 1

Total Number of College Graduates, Number Prepared to Teach in High School, Number Prepared to Teach Mathematics, Number Prepared to Teach Science, with Percent of Year-by-Year Changes Since 1950
(After Ray C. Maul, the Science Teacher, September, 1953)

Year	Total Bachelor degree graduates	Percent change from 1950	Total graduates prepared to teach in high school	Percent change from 1950	Total grad. prepared to teach math.	Percent change from 1950	Total graduates prepared to teach: Gen. Sc.	Biol.	Chem.	Phys.	Total	Percent change from 1950
1950	433,734	------	86,890	------	4,618	------	3,009	3,473	1,660	954	9,096	------
1951	384,353	—11.4%	73,015	—16.0%	4,118	—10.8%	2,772	2,815	1,342	578	7,507	—17.5%
1952	331,942	—23.5	61,510	—29.2	3,142	—32.0	2,216	1,995	842	373	5,426	—40.3
1953	----------	------	55,468	—36.2	2,710	—41.3	1,796	1,830	722	317	4,665	—48.7

Source: Figures in Col. 2 were taken from Robert C. Story, *Earned Degrees* conferred by Higher Educational Institutions, 1952-53. Circular 260A. December, 1953, U. S. Office of Education, Federal Security Agency. All other basic figures were taken from annual N. E. A. reports on teacher supply and demand.

The total number of mathematics teachers prepared was 102 and of science teachers was 183. Of the mathematics teachers 15.7 percent were prepared at the University, 21.5 percent at State Teachers' Colleges, and 62.7 at private colleges. The percentages of science teachers for the three types of institutions were 13.7, 25.1 and 61.2 respectively.

In the endeavor to set up programs for the preparation of teachers in the state, institutions should be informed of the conditions of the state which, particularly from the practical standpoint set certain restrictions with respect to numbers of teachers to be trained and the pattern of the training programs. We now present data on these matters.

We shall consider first the teaching assignments (Table 3). Our data are for persons teaching for the first time in 1954-55 and for former teachers who returned to the profession during this same year. The numbers in each category were not available. There were 55 teachers who taught full-time in mathematics. There were 39, who were teaching the minor portion of their time in science, but the major portion of their time in mathematics. Other combinations consisted of mathematics with social sciences, 13; mathematics with physical education, men 8, women 5.

With respect to teaching assignments in science the major findings are these: There were 59 teachers who taught full time in science. There were 36 who taught the minor portion of their time in mathematics, but the major portion of their time in science. The next largest combination was science with physical education, men 11, women 6. There were 7 combinations of science and social studies, 4 of science and driver education. Other combinations of small frequencies were science and industrial arts 3, science and English 2, science and business subjects 1, and science and home economics 1. These data also furnish information on supply and demand of beginning teachers. The total demand for teachers in terms of the number of beginning teachers whose major class assignment was mathematics, was 128; and in science was 130. The total supply in terms of the number of graduates from Minnesota teacher preparing institutions in 1953-54 was 65 in mathematics and 112 in science. The figures reported above include teachers teaching on Minnesota Teachers' Certificates and on limited permits. It may be of interest to note that the total number of high school teachers in service in 1953-54 was 10,167.

The data just reported do not clearly indicate the relation between the field of preparation of the teacher and the actual teaching assignment. Since this information is of first importance in setting up certification requirements and also of value to teacher training institutions we proceed now to present the evidence on this relationship (Table 4). The source is in the comparison of the major area of training of persons teaching for the first time in the

high schools of Minnesota in 1951-52 and their actual teaching assignment. The data do not include persons returning to the profession or those doing their first teaching in Minnesota but having experience outside of the state. Our findings are as follows:

There were 44 teachers whose major area of training was in mathematics and who were actually teaching the major portion of their time in that field. There were twelve teachers, whose major area of training was in mathematics, who were teaching the major portion of their time in areas other than mathematics: 8 in science, 2 in English, one each in social science and physical education. Of the total number (56), then, it may be said that 78 percent were teaching in their major field of preparation.

TABLE 2

Major Field of Training of Graduates of Minnesota Teacher Preparing Institutions for 1954-55 (After Adams)

Type of Institution	Major Field				Total		Total All Fields	
	Mathematics		Science					
	M	W	M	W	M	W	M	W
UNIVERSITY								
University of Minnesota	9	7	19	6	28	13	174	181
Total	9	7	19	6	28	13	174	181
STATE TEACHERS COLLEGE								
Bemidji	1	----	4	----	5	0	32	3
Duluth Branch (U. of Minn.)	4	----	4	----	8	0	84	32
Mankato	3	----	10	----	13	0	85	39
Moorhead	5	----	6	----	11	0	44	16
St. Cloud	5	2	17	2	22	4	72	26
Winona	2	0	3	0	5	0	23	15
Total	20	2	44	2	64	4	340	131
PRIVATE COLLEGE								
Augsburg	----	----	2	----	2	0	13	20
Carleton	----	1	----	1	0	2	1	17
Concordia	4	2	6	4	10	6	39	48
Gustavus A.	3	----	----	----	3	0	20	29
Hamline	2	----	3	2	5	2	16	19
Macalester	2	----	6	2	8	2	31	25
St. Benedict	----	2	----	----	0	2	0	20
St. Catherine's	----	3	----	----	0	3	0	35
St. John's	5	----	2	0	7	0	46	0
St. Mary	----	----	6	0	6	0	34	0
St. Olaf	2	----	1	1	3	1	22	56
St. Scholastica	----	----	----	1	0	1	0	10
St. Teresa	----	----	----	----	0	0	0	12
St. Thomas	----	----	4	----	4	0	40	0
Total	18	8	30	11	48	19	262	291
Grand Total	47	17	93	19	180	36	776	603

TABLE 3

Number of Teachers in the Public Schools of Minnesota in 1954-55 Who Did Not Teach in 1953-54. Recorded According to Their Teaching Assignments. (After F. R. Adams, Director State Department of Education, Division of Teacher Personnel.)

Teaching Assignment	Business Subjects	English	Foreign Languages	Industrial Arts	Library Sciences	Mathematics	Music	Phy. Ed. (Men)	Phy. Ed. (Women)	Science	Social Studies	Driver Ed.	Home Economics	Total Demand	Total Supply
Mathematics	2	2	1	1	1	**55**	1	8	5	**39**	13	----	----	128	65
Science	1	2	----	3	----	**36**	----	11	6	**59**	7	4	1	130	112

TABLE 4

Comparison of Major Area of Training of Persons Teaching for the First Time in the High Schools of Minnesota in 1951-52 and their Actual Teaching Assignment. (This Table Does Not Include Persons Returning to the Profession or Those Doing Their First Teaching in Minnesota But Having Experience Outside of the State.)

MAJOR AREA OF TEACHING ASSIGNMENT

Major Area of Training	Commercial	English	Library Science	Mathematics	Music	Phy. Ed. (Men)	Science	Social Science	Total	Percentage Tchg. Major Portion in Major Area of Training
Mathematics		2		44		1	8	1	56	78
Science	1	4	1	12	2	1	66	3	90	73
Social Studies									125	71
English									164	86
Phys. Ed.—Men									66	17

The data for 90 teachers of science follow: Sixty-six teachers of science were actually teaching the major portion of their time in their field of preparation. The next largest single number, 12, with major training in science were teaching the major portion of their time in mathematics. The dispersion of the remaining 12 with major training in science and major teaching assignments in areas other than science was 4 in English, 3 in social science, 2 in music, and 1 each in library science, physical education, and 1 in commercial subjects. Thus, 73 percent of the science teachers were teaching the major jortion of their time in their field of specialization.

TABLE 5

Placement or Occupation as of November 1, 1954, of Persons Who Graduated Between September 1, 1953 and August 31, 1954, from Secondary Teacher Preparation Programs in Minnesota (After Adams)

MAJOR		TEACHING				NOT EMPLOYED AS TEACHER									
		Public Schools in Minnesota	Private Schools in Minnesota	Outside of Minnesota	Total	Otherwise Employed	Continuing Formal Study	Military Service	Seeking Teaching Jobs	Seeking Non-Teaching Jobs	Miscellaneous	No Information Available	Homemaking	Total	Grand Total
Mathematics	M.	22	1	4	27	2	4	22	1	----	----	3	----	32	59
	W.	5	----	3	8	2	----	----	----	----	----	1	1	4	12
Science	M.	33	1	5	39	3	27	25	----	----	1	6	----	62	101
	W.	7	----	4	11	4	1	----	----	----	----	1	3	9	20
English	M.	23	4	14	41	4	8	16	1	1	----	3	----	33	74
	W.	77	3	15	95	5	4	----	----	----	----	6	13	28	123
Social Science	M.	55	4	11	70	9	16	44	----	----	2	7	----	78	148
	W.	8	1	8	17	9	2	----	----	----	----	4	----	15	32

Our final set of data relates to the placement of graduates from Minnesota institutions who were enrolled in secondary teacher preparation programs (Table 5). The information with respect to placement is as of November 1, 1954 for graduates of the Minnesota institutions between September 1, 1953, and August 31, 1954.

Of 71 graduates with a major in mathematics 35 were teaching (27 in Minnesota public schools, 1 in a Minnesota private school, and 7 in schools outside of Minnesota). Of those (76) who were not employed as a teacher, 22 were in military service, 4 were continuing formal study, 4 were otherwise employed, 4 provided no data and 1 was in homemaking.

Of 121 graduates with a major in science, 50 were teaching (40 in Minnesota public schools, 1 in a private school and 9 outside of Minnesota). Of those (71) not employed as a teacher, 25 were in military service, 28 were continuing formal study, 3 were homemakers, 7 were otherwise employed and no information was available for 8.

It is clear that military service and the pursuit of graduate work (likely until called up for military service) claim most of the men who have not gone into teaching positions upon graduation.

TYPES OF TEACHER PREPARATION PROGRAMS

In the College of Education of the University of Minnesota, a program designed for the preparation of teachers of science to meet the needs of the beginning teacher in the small high school was set up about twenty-five years ago. Over 50 percent (52.4 percent) of the high schools of the state have enrollments less than 100 students. Approximately four-fifths of the schools have a faculty of eight teachers or less. To serve this type of situation the teacher of science was required to teach all or most of the science program in the small high schools, consisting usually of general science, biology, physics, and chemistry, the latter two often being alternated in the junior or senior year. This program was called the Natural Science Curriculum and has at present the following science requirements:

1. Completion of a sequence of thirty quarter credits in one of the four natural sciences: chemistry, physics, botany, or zoology.
2. Completion of at least fifteen credits in another science (excepting the one chosen under 1) selected from the following: physics, geology, botany, zoology, chemistry.
3. Completion of at least 10 credits in physics, botany, chemistry, and zoology when these subjects are not used to satisfy requirements 1 and 2. In addition a minimum of 5 credits in geology and 5 credits in astronomy are required.

An alternative program was available from the start of the College of Education which continued until about 1946. This was the traditional plan of majors and minors in the teaching fields, *e.g.*, a major in chemistry and a minor in physics; a major in zoology and a minor in chemistry, etc., this plan was abandoned because of the fact mentioned above, namely, the small school in which the inexperienced teacher first taught, required the teacher of science to be prepared in all the sciences taught.

Last year (1954-55) a program designed to prepare teachers for the physical sciences and mathematics was inaugurated. There were several reasons for setting up this program. From data presented above it is clearly indicated that the most frequent combination of subjects taught by both teachers with majors in mathematics and with majors in science is that of courses in mathematics and in science. While the particular courses in science were not specified, an inventory indicated that they were most often physics, chemistry, physical science, and general science. Under the Natural Science Curriculum the number of students who selected either chemistry or physics as their core subject had been becoming less and less. This was at least partly due to demand of industry, government, and universities for physical scientists. Moreover, the broad requirement in the curriculum did not appeal to some students, at least, who were interested in the physical and not the biological sciences. It is also true that the extensive development in all sciences makes it very difficult, if not impossible, to obtain competency in both physical and biological sciences. Finally, it may be noted that mathematics has become more and more indispensable for the pursuit of science, particularly the physical sciences.

In conclusion, time permits only a brief summary of the science and mathematics requirements in the new program for majors or minors in physical science.

Requirements for a major in physical science (Note: Specific courses making up the listed credit requirements are not indicated here):

Option A. Major concentration in chemistry: 33 credits in chemistry; 20 credits in physics.

Option B. Major concentration in physics: 33 credits in physics; 20 credits in chemistry.

Minor requirement in mathematics under either Options A or B: 23 credits in mathematics beyond trigonometry.

Requirements for a major in mathematics with a minor in physical science:

Major requirements (33 credits).
Courses through integral calculus.
Synthetic metric geometry.
Five credits of electives from courses beyond integral calculus.

There is, of course, also the program in mathematics for students who wish to major or minor in this subject.

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THE CONVERGENT IMPROVEMENT TEST OF THE GENETIC BASIS OF HYBRID VIGOR

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Dominance and overdominance are the two major theories of the cause of hybrid vigor. According to the dominance theory, the vigor of an F_1 hybrid results from the masking of deleterious recessive genes from one parent by their dominant alleels from the other, each parent contributing different recessives and dominants to the hybrid. According to the overdominance theory, the vigor is a direct result of the heterozygosity *per se*. Although both theories are in accord with observed breeding behavior, the heterozygous state is obligatory if overdominance is the genetic mechanism of vigor and the degree of vigor should be proportional to the degree of heterozygosity in the hybrid. Overdominance would thus preclude the establishment of pure-breeding lines as vigorous as the hybrids. If dominant interaction is the mechanism, however, the possibility of obtaining such lines would be raised, although linkage between favorable dominants and unfavorable recessives may make the formation of homozygous lines as vigorous as the hybrids difficult to obtain and hence impractical for agricultural use.

These theories can be tested by a breeding method called convergent improvement, by means of which various inbred lines can be produced that differ from each other only in the proportion of germplasm which they possess in common. Thus, when these inbreds are crossed, their hybrids will have varying degrees of heterozygosity. Using the fruit fly *Drosophila melanogaster* as the experimental animal, and egg productivity as the quantitative characteristic measured, such lines were produced in the laboratory. When these lines were crossed, their hybrids had 12.5%, 75.0%, and 87.5% of their germplasm in common (considering the original F_1, hybrids as 0%). All crosses showed heterotic increases in egg productivity when compared to the parental lines, and all were equal or superior to the original hybrid. Since no correlation between productivity and expected degree of heterozygosity was found to exist, overdominance was rejected as an explanation of the observed hybrid vigor.