CONFERENCE BOARD OF THE MATHEMATICAL SCIENCES

REPORT OF THE SURVEY COMMITTEE

VOLUME V

UNDERGRADUATE MATHEMATICAL SCIENCES IN UNIVERSITIES, FOUR-YEAR COLLEGES, AND TWO-YEAR COLLEGES, 1975-76

JAMES T. FEY
DONALD J. ALBERS
and
JOHN JEWETT
with the technical assistance of
CLARENCE B. LINDQUIST

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PREFACE

This volume is a repetition, with some modifications, of two earlier surveys conducted by the Conference Board of the Mathematical Sciences in 1965 and 1970. The 1965 survey was an expansion of a study done by Clarence B. Lindquist five years eariler for the U. S. Office of Education in 1960. Thus, with the publication of the present volume, we now have available a record of undergraduate education in the mathematical sciences based on four successive major surveys conducted at five year intervals.

All of these surveys have sought to gain information on curricular trends by collecting data on enrollments in undergraduate mathematical science courses. Beginning with the 1965 survey, we have presented data on the number, qualifications, and distribution of mathematical science faculty. In succeeding surveys, we have placed greater emphasis on faculty characteristics, mobility patterns, and other information relating to manpower considerations. Volume I, based on the 1965 survey, also included information from a separate survey (actually conducted in 1966) of the mathematical sciences in two-year colleges, and the two subsequent surveys have incorporated data from two-year colleges as an integral part of the total picture. The present survey presents for the first time data on age, race, and sex of mathematical science faculty.

The fundamental nature and purpose of these surveys has largely been determined by the nature of our sponsoring organization. The Conference Board of the Mathematical Sciences is an organization whose members are organizations; the membership in fact includes virtually all of the principal professional societies in the mathematical sciences.[1] Such sponsorship has had

[1]American Mathematical Society, American Statistical Association, Association for Computing Machinery, Association for Symbolic Logic, Association for Women in Mathematics, Institute of Mathematical Statistics, Mathematical Association of America, National Council of Teachers of Mathematics, Operations Research Society of America, Society of Actuaries, Society for Industrial and Applied Mathematics, The Institute of Management Sciences.

several advantages. It has helped to make possible the objectivity which we have always sought to have as the principal characteristic of our work. The Conference Board has also made it possible to obtain a broad coverage of the mathematical sciences which was feasible only because we have been able to draw freely on the expertise and experience of prominent individuals from all areas represented by the member organizations. On the other hand, restricting our investigations to the mathematical sciences has provided a certain unity and coherence which would have been lacking had the surveys been aimed at a wider range of disciplines.

The Conference Board surveys, representing a long term effort to provide a comprehensive background of information about the mathematical sciences, serve several distinct purposes. First, they provide a backdrop against which the results of ad hoc surveys can be viewed in proper perspective. Second, the prior availability of certain data can on occasion obviate the need for hurried surveys done on a crash basis. Finally, the continuous monitoring of trends by successive surveys is the only way in which the actual existence of suspected changes can effectively be confirmed or denied. For example, the 1965 survey gave the first concrete evidence that the shortage of mathematicians was coming to an end; the 1970 survey provided the first measurements of the then explosive growth of statistics and computer science; the present survey shows that the two-year college segment of the system has become by some measures comparable in size to that portion included in four-year institutions, and also has documented the first demonstrable increase in teaching loads.

There are still, however, important gaps in our knowledge about the mathematical sciences. Since the present survey has been restricted to undergraduate programs, we have been unable to provide needed data bearing directly on graduate education and research. This has the effect of limiting our understanding of important aspects of the professional life of those teaching in universities as well as making it impossible to provide the factual data needed in connection with manpower questions. Especially at a time when there are basic issues in graduate education needing to be resolved, it would be extremely helpful to have from some source a study of graduate education in the mathematical sciences of the same comprehensive nature as the survey done by the Conference Board in 1966, a survey that we have failed to repeat only because of our inability to secure the necessary funding.

Because the process of graduate education in the mathematical sciences is structurally different from the customary patterns in the natural sciences, it is essential that such a study be done on a disciplinary basis.

A second major deficiency in our understanding is our virtually complete lack of knowledge about the subsequent careers of mathematical science graduates at all degree levels. The only subclass about which there is anything approaching adequate understanding is composed of those going into college teaching. The collection of such information has been a very difficult problem. Despite the obvious relevence of such questions to the formulation of educational policy, the promising beginning represented by Volume III of the Survey Committee's report has not been followed up. As far as we can discover, information is no more complete for other scientific disciplines than for ours. Because of the proclivity of scientists, even at the doctoral level, to switch fields after graduation, a study of career patterns is one which might be done most effectively if conducted for a group of related disciplines.

The present survey has depended on the efforts of many people, not the least among whom were the many department chairmen who undertook to complete our lengthy questionnaire. We were fortunate in securing the services of Dr. Clarence B. Lindquist of the U. S. Office of Education, who supervised the editing of questionnaires and the tabulation of data, and especially of Professor James T. Fey of the University of Maryland, who was the executive secretary for the project. Dr. Fey is the principal author of most of the present volume and deserves the main credit for shaping a vast amount of data into an orderly whole. We are grateful to Professor Donald J. Albers of Menlo College who, in addition to providing insight and advice regarding two-year colleges, wrote much of the material in Chapters 5 and 6. We are indebted to Dr. Truman Botts, the Executive Director of the Conference Board, for his tact, patience, and administrative skill. We have profited greatly from his comments and advice in connection with the conduct of the survey as well as the interpretation of the data. Mrs. Patricia Hughes deserves our special thanks for her careful typing of the entire report. Finally, we are especially grateful to the National Science Foundation for its support of the present project and for its foresight in realizing that the information developed will have not only immediate value but longer term value as well.

December 1976 John Jewett

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INTRODUCTION

The Survey Committee, in publishing the results of its investigations, has always felt its fundamental responsibility to be the neutral presentation of a factual background for use by those in education and government who make decisions about the mathematical sciences, the fundamental premise being that informed decisions are likely to be superior to decisions based merely on hearsay or wishful thinking. Beginning with Chapter 1, the present volume maintains that posture, attempting to describe only what our data say without assuming the more interpretive role of making subjective assertions about what the data mean. In this short introductory chapter, we will try to suggest something of the significance of our most salient results without, however, presuming to offer any recommendations for specific actions which the mathematical community should take.

Anyone engaged in planning regarding mathematical sciences in higher education must make assumptions as to the numbers of enrollments to be expected in mathematical science courses. One of the most suggestive findings of our surveys is the relatively constant relationship between college enrollments and enrollments in mathematical science courses. If we compute the ratio of the number of enrollments in undergraduate mathematical science courses to the number of full-time-equivalent students in four year institutions, we obtain .32 in 1960, .31 in 1965, .30 in 1970 and .30 in 1975. For two-year colleges, the corresponding ratios are .37 for 1966, .38 for 1970, and .36 for 1975. The constancy of this ratio over a period which saw profound changes in all aspects of education in the mathematical sciences suggests that future mathematical science enrollments may well be more closely tied to general college enrollments than is commonly believed.

The percentage of high school graduates continuing to college, after rising steadily over a long period of time, has recently ceased to increase and has begun to oscillate gently about what may be a new equilibrium value. Therefore, the prime determinant of future mathematical science enrollments, especially in four-year institutions, may be the size of the 18-21 year age group. But the 18-21 year age group, which numbered 16.2 million in 1974 (up 40 percent from ten years earlier), will fall to 15.8 million in 1984 and to slightly over 14 million in 1988. These figures

represent people who have already been born and do not, therefore, involve any prediction of the birth rate. It is perhaps worth noting in this connection that a preliminary report from the U. S. Office of Education shows that enrollments for the fall of 1976 (including part-time and non-degree students) increased less than one percent over the preceding year.

The periodic nature of the Conference Board surveys together with their consistent methodology makes them particularly suited to the observation of trends in the data. The most conspicuous trend was not unexpected -- an abrupt halt to the exuberant growth of the sixties. The mathematical science faculties in four-year institutions remained constant in size from 1970 to 1975; overall mathematical science enrollments for the first term increased only eight percent -- from 1,386,000 to 1,497,000. Even in those segments of the community where growth continued, growth from 1970 to 1975 was at a slower pace than in preceding years.

First we single out for special consideration four broad trends, not direct corollaries of the above, and all to a certain extent unanticipated in 1970.

1. Changes in student-faculty ratios. From data of our survey, we can compute the ratio of undergraduate mathematical science enrollments to full-time-equivalent faculty. For four-year institutions this ratio increased from 79 in 1970 to 86 in 1976. In two-year colleges the increase was from 104 to 123. This is corroborated by somewhat less solid data about teaching loads reported below, and is consistent with data from the National Center for Educational Statistics indicating that (for all fields) the ratio of full-time-equivalent students to full-time-equivalent faculty increased from 14.9 to 16.3 between 1970 and 1975, ending a long period of stability of this ratio.

2. Decline in upper division mathematics enrollments. Our data indicate that, after increasing 29 percent from 1965 to 1970, enrollments in upper division mathematics fell from 229,000 in 1970 to 155,000 in 1975, a decline of 32 percent. Among the subjects whose 1975 enrollments were less than half of their 1970 enrollments were theory of numbers, courses in history, logic and foundations, advanced geometry courses, topology, real variables, and complex variables. The fact that courses in differential equations, advanced calculus, and linear and matrix algebra did not fare as badly

suggests that the enrollment decline was not primarily due to a decrease in enrollments by engineers and scientists. Upper level courses enrollments increased by 10,000 in computer science and by 7,000 in statistics, but these increases taken together are smaller than the 19,000 student decrease in courses in linear and matrix algebra. This argues against the decrease in upper mathematics courses being attributable primarily to a shift of interest from mathematics to other areas within the mathematical sciences.

We can only conclude that the enrollment decline is due to a drastic decrease in the number of students majoring in mathematics (including prospective high school teachers). This conclusion is confirmed by U.S.O.E. data showing that the number of bachelor's degrees granted in mathematics and statistics fell from 25,000 in 1970-71 to 20,000 in 1975-76. That worse may be in store is suggested by the American Council of Education survey of entering freshmen which shows that the number of entering freshmen who consider themselves probable majors in mathematics and statistics fell from 52,000 in 1970 to 19,000 in 1975.

What is described above refers only to the fairly recent past and to the immediate future. It may well be that mathematics will follow the physical science which have experienced a period of stability following an earlier period of decline. It can be argued, probably with some justification, that the decline in mathematics majors has been caused in large measure by students' (false) perceptions of declining job opportunities for bachelor's level graduates. If this is true, a natural correction can be expected, as has actually happened in engineering.

3. Declines in graduate programs. Since this subject is not within the scope of our survey, we can present no new data. However, we can observe that data from the American Mathematical Society [S,T] have shown a slight decline in number of Ph.D.'s granted in the mathematical sciences and a substantial decline for pure mathematics both in numbers of Ph.D.'s and in graduate enrollments. These trends can be expected to continue during the next five years and may well lead to a precarious balance between decreased supply and decreased demand for new Ph.D.'s for a short period about 1980. There may be some hope that changes being discussed in graduate education leading to broader relevance of doctoral programs and to greater emphasis on the master's degree might serve to extend this equilibrium somewhat beyond 1980.

Unfortunately, our lack of detailed quantitative knowledge about graduate education in the mathematical science precludes any more detailed analysis.

4. Growth of the Mathematical Sciences in Two-Year Colleges. Over the last five years, not only the rate of growth but also the total amount of growth in two-year colleges has exceeded that in the four-year segment. Mathematical science enrollments increased by 290,000 in two-year colleges compared to an increase of only 111,000 in four-year institutions. Since the four-year mathematical science faculty did not increase in size from 1970 to 1975, the increase of approximately 1,500 full-time-equivalent faculty members in two-year institutions represented the only growth in the system except for a significant increase in computer science faculty. Moreover, the data from the present survey show that at least for the mathematical sciences the two-year colleges have become comparable in size to four-year institutions. In 1975 there were 874,000 course enrollments in undergraduate mathematical science courses in two-year colleges compared to 1,497,000 in four-year institutions. In mathematics courses at the level of calculus and below, there were approximately 830,000 course enrollments in two-year colleges compared to 1,090,000 in four-year institutions. In terms of full-time-equivalent faculty slightly over 7,000 were in two-year institutions and 18,000 in four-year institutions.

In addition to these four trends, it seems worthwhile to mention our results on faculty age distributions and on tenure and faculty mobility prior to discussing some of the trends that were mainly confined to certain types of institutions. The age distributions of mathematical science faculty in four-year institutions give some clue as to the number of vacancies to be created by deaths and retirements. We estimate that only five percent of the mathematical science faculty are 60 or over, another five percent are between 55 and 59, and eight percent between 50 and 54. This indicates that in the critical period between 1980 and 1985, the number of retirements from the faculty of four-year institutions will be less than 200 per year with under 300 retirements per year to be expected from 1985 to 1990. During the eighties, few if any additional new positions can be expected to be added as a result of enrollment increases.

The median age of mathematical science faculty in four-year institutions was approximately 39 years with 54 percent of the

faculty under 40. It is perhaps surprising that the age distribution for faculty members in statistics departments, which have been growing more rapidly, is virtually identical to that for all mathematical science faculty. The computer science faculty is not much younger, its lower median age of 37 occurring primarily because the age distribution is somewhat truncated above, with only three percent of faculty being 55 or over. It is also surprising that the junior college faculty is slightly older than the faculty in four-year institutions. Our data indicate that the percentage of four-year faculty with tenure has risen to 72 percent with five percent of the total 1975 faculty having been granted tenure in the preceding year, at an average age of 35. This corresponds roughly to every sixth non-tenured faculty member being granted tenure, which suggests fairly rapid change in the direction of an almost completely tenured faculty. In this connection, it is interesting to note that 71 percent of the 3,364 non-doctorates on four-year college faculties have tenure, a percentage essentially equal to that of doctorate faculty. This means that the replacement of non-doctorate faculty by doctorate holders, a process that provided over 500 jobs a year for young Ph.D.'s between 1970 and 1975, cannot be expected to continue at anything like the former rate since there now appear to be fewer than 1,000 non-tenured non-doctorate faculty members left in four-year institutions.

Our data on faculty mobility in four-year institutions for the single year 1975 confirm a death and retirement rate of approximately one percent. Of those who left for other reasons during this year, about two-thirds or 540 went to positions in other four-year institutions. This represents an internal mobility rate of only three percent, which is surprisingly low. Approximately 200 left for non-academic positions. The sources of new faculty were preponderantly the traditional ones of graduate schools and other colleges and universities. Perhaps the most interesting results of our mobility data involve the small magnitude of some other flows. From our data we can conclude that the number of doctorate faculty who left four-year colleges and universities for two-year colleges in 1975 is almost certainly smaller than 100 and probably less than 50; the flow in the opposite direction appears to be even smaller. In contrast to 1970, we could find very little evidence of faculty members returning to graduate study.

We now turn our attention to trends characteristic only of particular types of institutions or particular types of departments,

and consider in turn universities, public four-year colleges, private four-year colleges, and two-year colleges.

Universities. Declining upper division mathematics enrollments were most pronounced in universities, where such enrollments declined 41 percent (from 114,000 to 67,000) between 1970 and 1975. This more than offset modest increases in calculus and precalculus courses so that the total undergraduate mathematics enrollments in universities actually declined by about four percent. Our data indicate that the full-time mathematics faculty in universities declined from about 6,200 to about 5,400. There were also declines in part-time faculty and in numbers of graduate assistants. This decrease in faculty size must imply a gradually aging and presumably less innovative faculty as well as a dearth of tenure opportunities for younger scholars. The faculty appeared to have slightly higher teaching loads; expected teaching loads of six hours or less were reported by only 26 percent of responding departments in 1975 as compared to 48 percent in 1970. The most typical teaching load seems to have crept upwards from six hours to seven or eight hours.

As commonly conceived, the distinguishing characteristic of a university among the totality of educational institutions is its concern for expanding the frontiers of knowledge and for transmitting specialized knowledge at an advanced level. If graduate programs in mathematics are contracting, advanced course enrollments declining, and teaching loads increasing, then university mathematics departments must to a certain extent be losing their special character.

University statistics and computer science departments showed more vigorous growth. The faculty of computer science departments increased by 299 full-time professors from 688 to 987, while part-time faculty decreased from 300 to 133. It seems reasonable to assume that many of the part-time faculty who were in effect replaced by full-time professors held joint appointments with other departments. Curiously enough, our data indicate that enrollments in elementary computer science courses[1] taught by university mathematical science departments showed little if any increase from 1970 to 1975, although advanced undergraduate courses in computer science increased from 15,000 course enrollments in 1970 to 25,000

[1]Specifically, courses 51, 52 and 53 of Appendix E.

in 1975. Although enrollment in undergraduate statistics courses increased from 49,000 in 1970 to 67,000 in 1975, the faculty of university statistics departments appears to have remained essentially constant in size.

Public Colleges. Between 1970 and 1975, a dramatic change has occurred in the formal qualifications of mathematical science faculty in public four-year colleges. The number of full-time faculty with doctorates increased from 2,866 to 4,536 while the number of faculty without doctorates decreased from 3,114 to 1,609. Thus in the five year period, the percentage of doctorate holding faculty increased from 47 percent to 74 percent. Expectations of research have also increased; the percentage of departments stating some expectation of research increased from 38 percent in 1970 to 64 percent in 1975. Moreover, among those willing to state an expected rate of publication, the average expected rate increased from two papers every five years to four.

While faculty qualifications and research expectations in public colleges have been becoming more like those in universities, other aspects have been moving in the opposite direction. The number of mathematical science enrollments per full-time-equivalent faculty member increased from 78 in 1970 to 87 in 1975; the percentage of departments reporting expected teaching loads of 12 hours or more increased from 53 percent in 1970 to 78 percent in 1975. Moreover, as we indicate below, this increased load has become increasingly composed of courses of a lower, even remedial, level and courses whose orientation is determined more by student needs and demands than by mathematical structure. Increases in computer science and statistics enrollments were more striking in public colleges than in universities or in private colleges. Computer science enrollments in public colleges increased from 17,000 in 1970 to 31,000 in 1975 and statistics enrollments more than doubled from 22,000 to 45,000. The bulk of these increases was in introductory courses. The decline in upper division mathematics courses was 23 percent, not as sharp a decrease as in universities.

The most interesting curricular trends in public four-year colleges, as reflected by enrollments, could be observed in courses below the level of calculus. Courses in intermediate algebra and courses below this level can be thought of, at least for the moment, as "remedial courses". Enrollment in such courses in public colleges increased from 68,000 in 1970 to 97,000 in 1975 or 43

percent, this increase lending support to the frequently expressed opinion that the mathematical preparation of freshmen has been declining. Courses in college algebra, trigonometry and combinations of these subjects (such as elementary functions) can similarly be lumped together as "precalculus courses". In public colleges enrollments in these courses declined by 39 percent from 126,000 in 1970 to only 77,000 in 1975. Finally one can define a category of "elementary service courses" comprised of courses oriented more or less to major interests of the students in fields other than mathematics. Among such courses we include mathematics for liberal arts, finite mathematics, mathematics of finance, business mathematics, and mathematics for elementary school teachers. Enrollments in such courses increased by 55 percent from 94,000 to 146,000. Put another way, the percentage of all undergraduate enrollments which were in precalculus courses decreased from 26 percent to 14 percent between 1970 and 1975 while the percentage in remedial courses increased from 14 percent 17 percent and the percentage in elementary service courses went up from 19 percent to 26 percent.

It is interesting and important that none of these three large scale trends was evident either in universities or in private colleges. It is difficult to tell whether the public colleges were acted on by forces which did not affect either universities or private colleges or whether they were more responsive to forces which acted more universally.

Private Colleges. The percentage of private four-year college faculty who held doctorates increased from 42 percent in 1970 to 69 percent in 1975. Otherwise, the private colleges showed fewer signs of change than did other types of institutions. A modest increase in faculty size almost covered a modest enrollment increase. Teaching loads, typically 12 hours although smaller at most prestigious colleges, did not appear to rise. Declines in upper class mathematics enrollments (24 percent) were not as great as in universities, and increases in computer science and statistics enrollments, although larger than in universities, were not as great as in public colleges.

Two-Year Colleges. We have already identified the continued growth of the mathematical sciences in two-year colleges as one of four particularly noteworthy trends. It remains to trace the characteristics of that growth. The data presented in Chapter 5 show

that from 1970 to 1975 part-time enrollment grew much faster than full-time enrollment. It is also known that occupational and technical programs experienced especially rapid growth as compared with programs which parallel those offered in four-year institutions. These trends are reflected in the data we have collected concerning mathematical science faculty as well as mathematical science enrollments. The full-time mathematical science faculty in two-year colleges increased 22 percent from 4,879 in 1970 to 5,944 in 1975 while the part-time faculty increased 54 percent from 2,213 to 3,411. The formal qualifications of full-time faculty improved. It now appears that approximately 11 percent of full-time faculty hold doctorates, about half of these being in mathematics education. The qualifications of part-time faculty declined, probably as a result of the necessity of hiring 54 percent more part-time faculty from a pool that had not greatly enlarged.

Mathematical science enrollments in two-year colleges increased by 50 percent to 874,000 between 1970 and 1975. The pattern of this growth is interesting in its overall resemblance to the change in lower division enrollments already observed in public four-year colleges. Remedial courses increased from 33 to 40 percent of all mathematical science enrollments; precalculus courses went from 21 percent to 17 percent; while elementary service courses levelled off at around 30 percent of the total load. Enrollments in statistics courses went up significantly from 16,000 to 27,000 from 1970 to 1975. However, computer science enrollments declined from 13,000 to 10,000. This indicated decline is mysterious in view of the substantial increase in the availability of computers and the general increase in enrollments in elementary computer science courses in four-year colleges during the same period. What is perhaps more noteworthy is that statistics courses account for only three percent and computer science courses only about one percent of the total junior college mathematical science enrollments. Since explanations of these phenomena in terms of offerings by non-mathematical science departments, lack of faculty expertise or the nature of two-year college students are not convincing, it is reasonable to surmise that the next five years may see tremendous growth in these areas in two-year colleges.