GRADUATE EDUCATION AND RESEARCH

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GRADUATE EDUCATION AND RESEARCH

Graduate education and research is a matter of survival of the nation and a free society. A cursory examination of population statistics demonstrates that we must make up by a superior level of knowledge for our small proportion of the peoples of the world. If one considers that the free world includes the United States, the Americas, Oceania and Europe while the rest of the world is either uncommitted to a free society or is communist-oriented, the following population statistics (millions) emerge.

Population and Survival

	1960	1970	2000
Free World	836	950	1,500
Uncommitted or Communist	2,074	2,480	4,770

The importance of these figures cannot be overestimated when one realizes, as has the National Science Foundation (1), that all peoples have the capacity for intellectual achievements including science and all peoples desire the benefits of technology.

Perhaps of equal importance to the situation in regard to numbers is the matter of the existence in the nation of the talent which can be educated to a high level. The numbers are very small as illustrated by:

Limited Top Talent

1) Rosenhaupt (3) states that only a third of the 1957 class of college graduates had I.Q.'s above 123, about 35,000 had an I.Q. of 138 or above and only 20,000 rated above 143. Law, medicine and engineering alone demand over 20,000 such college brains each year.

2) Health, Education and Welfare (4) reports that our current level of productivity of Ph. D.'s is only one (1) per 20,000 of population -- a fantastically low productivity in relation to the need.

Graduate Education and Research Inseparable

In studying higher education in Colorado and in the nation the position is frequently taken that the programs of educational institutions may be divided into: 1) undergraduate instruction, 2) graduate instruction and 3) research. Others take the position that the three programs are so intermingled that no one can exist without the other two. In a very broad sense the second approach is much more justifiable; however, if one ignores secondary relationships such as the use of graduate students for teaching freshman courses it is possible to analyze higher education based upon a two-fold division: 1) undergraduate education and 2) graduate education and research. This inseparability of graduate education and research is a fundamental contention of the report, "Scientific Progress, the Universities, and the Federal Government," (2) by the President's Science Advisory Committee submitted to President Eisenhower. This paper is predicated on graduate education and research being inseparable.

Graduate Education Oriented to Individual

Nearly everyone will agree that higher education is very difficult to analyze when one is attempting to determine appropriate levels of budgetary support from state sources, appropriate faculty-student ratios and necessary levels of support in terms of facilities and equipment. This complexity is quite understandable when one considers that graduate education and research is organized so

that practically every individual has a program developed to suit his particular needs, which differ slightly from the program needs of any other individual participating in the system. This orientation of programs around the individual is an essential ingredient of graduate education. It does, however, add significantly to the difficulties of budgetary analysis.

Even though a graduate education and research program either at a single institution or on a state-wide level is a very complex structure, there are certain basic items which are essential to the development and sustenance of any quality program. These basic items are:

Features Basic to any Graduate Education and Research Program

1) A number of top professional faculty of national and international reputation who may well be employed at higher salary levels than the president of the institution or the governor of the state.
2) Extensive library holdings and facilities coupled with an acquisition program having a substantial emphasis on current periodicals and research papers in addition to more normal acquisition of books.
3) Students of superior ability, particularly those in the upper 25 per cent of their bachelor's level graduating class, provided with sufficient money to support themselves and their dependents at a better than an existence living.
4) Modern research and teaching equipment.
5) Substantial operating expense budgets for each faculty member.

6) In certain fields, particularly the biological and physical sciences and engineering, a large amount of laboratory space.

These several items required for a quality graduate education and research program are necessary whether the institution is a teacher-training institution, a land-grant university, a state university or a technical and professional college.

PURPOSES OF GRADUATE EDUCATION AND RESEARCH

The purposes or objectives of graduate education and research may be studied from three points of view: 1) the student, 2) the faculty, and 3) the institution, state and nation.

The Student

The purposes insofar as a student is concerned of pursuing a program that will take one to ten years of his life after the bachelor's degree could be any one of, or combination of, three objectives:

1) Education and training in preparation for a teaching career,
2) Education and training in preparation for an academic, industrial or government research career, or
3) A level of intellectual achievement preparatory to a management career in educational, industrial or governmental organizations.

The Faculty Member

For the faculty member of an educational institution there are several reasons why graduate education and research programs are important. These are:

1) Such programs are needed in order that the technical competence of the faculty will be at a sufficiently advanced level that students who work under the faculty will be prepared to adequately teach the new technology to the undergraduate students of the following decade,
2) Status in a particular professional field is frequently directly related to a recognition of achievement in

graduate education and research,

3) Teacher inspiration is assisted at all levels of higher education by participation in graduate teaching and research,

4) The value of the faculty member as a consultant to industry and government is enhanced,

5) The salary and rank of a faculty member within the institution frequently is directly related to his performance as a research scientist and only indirectly related to his teaching ability, and

6) The conservation, dissemination and accumulation of knowledge necessitates the existence of graduate programs.

For the institution, state and nation there are essentially three purposes of having strong graduate education and research programs. These are:

Institution, State and Nation

1) The status of an institution and its ability to draw and retain top quality students and faculty requires a strong graduate education and research program,

2) A development of national laboratories and research oriented industries within the state, and an associated widening of the tax base of the state, results from the fact that such concerns wish to be associated with nearby strong academic programs, and

3) National defense and national welfare rest on strong individualized institutional programs.

GRADUATE STUDENT NUMBERS, COSTS AND MARKET

Since graduate education and research is an individual-oriented matter, the number of students enrolled in any specific departmental program in an institution or in a total institution is not an adequate measure of either faculty or budgetary needs. The number of students that an individual faculty member can accommodate rests on the type of program that is involved. As an example, an individual faculty member can serve as an adviser for 20 to 30 non-degree graduate students while the professor working with five Ph. D. students in engineering or physics is probably overloaded.

Student-Teacher Ratio

One of the most critical problems associated with graduate education is the long period of time between the receipt of a bachelor's degree and the awarding of the Ph. D. A well-recognized graduate school dean recently presented, in a verbal report to the National Aeronautics and Space Agency (NASA), a figure of eight years as the median elapsed time. This figure is supported by Berelson (5). All those people who may work toward a degree only during the summer session while they carry on a full-time teaching or research obligation during the academic year are included. This duration of study must be shortened very substantially; according to a number of authorities it should be cut in half to four years. This duration of study or median elapsed time varies substantially by field -- low in the sciences, medium in the social sciences and humanities and high in the professional fields. The median elapsed time for all fields

Elapsed Time

8 Years Median Elapsed Time

has been shown by Berelson (5) to have remained essentially constant during the last 20 years for the total group of doctorates. That no significant progress has been made in 20 years and that a number of the nation's foremost science leaders, such as Dr. Lloyd V. Berkner, President of the Graduate Research Center of the Southwest, have expressed great concern emphasizes the attention that must be given to the support of graduate programs. This concern was stated by the President's Science Advisory Committee in these words: "Yet many (universities) do much too little, and none does all it should. The growth of science requires more places with superior faculties and outstanding groups of students. Existing institutions cannot fully meet the nation's future needs."

Another facet of the student numbers problem is associated with the very low productivity of the western states of doctorates. According to Berkner (6), the southwestern states produce only one-half as many doctorates per million of population as the national average. Since there has been demonstrated by Dr. L. V. Berkner to be a one-to-one correspondence between the number of doctoral graduates and the level of industrial development on a technological base by geographic area of the country, it is obvious that if we are to increase Colorado's relative industrial position it will call for a substantial increase in the productivity of doctorates. That this is possible is demonstrated by two facts: 1) in the entire United States less than a thousand graduate students annually at the doctoral level travel more than 500 miles from their homes for their education, and 2) since we have the students and they do not

Low Regional Doctorate Productivity

travel great distances for their education, the basic inadequacy in the region is in providing an educational opportunity or adequate motivation. This problem is a corollary to the one at the high school-college level of the qualified students who do not go on to college.

The low level of productivity of doctorates cannot be attributed to inadequate talent. An unpublished study submitted to the American Association for the Advancement of Science demonstrates that based on population the State of Colorado ranks fourth among all the states in the number of men who have attained the status of recognition of a listing in the American Men of Science since the time they were in Colorado in 1930. Utah, Idaho and Washington, D. C. rank ahead of Colorado.

Economies Due to Graduate Students

There are certain very immediate returns and economies to the institutions from having graduate students available in large number. These are basically two: 1) graduate assistants provide instruction at a very nominal cost since their salaries are low in comparison to the salary levels of full-time teachers, and 2) in the performance of research the graduate student as a low paid employee performs many tasks which in his absence would have to be done by some professor. The question of whether or not the quality of the educational program suffers when graduate students are used as teachers is very much debated by many people and there seems to be no definitive conclusion.

The problem of class size is frequently considered. In many respects statistics on class size are meaningless as a measure

of the financial investment necessary for the economical operation of a graduate program since about half of the time of a graduate student in the professional programs is devoted to a thesis, dissertation or foreign language. For this half-time he is not registered in any class but is using a large amount of professorial staff time. If a class is made up entirely of graduate students and it is a class in a relatively mature program, that is, one that has been developed to the point where there is a large number of graduate students in that particular department, then classes of 10, 15 or 25 will be fairly common. In the case of either a new program, or programs wherein the national demand for numbers of students is relatively small, such as astronomy or meteorology, then it should be anticipated that class size will not only be small but may well remain small even if the program is in existence for many years. In addition to classes which are made up entirely of graduate students, most graduate students take a substantial part of their total program from the upper division undergraduate program. In this case they frequently add to the economy in terms of cost per student credit hour, since they normally occupy vacant positions in the undergraduate class sections; thus the institution is not required in many cases to add additional sections of the same course offering.

Class Size

The costs of supervision of theses and dissertations in a program can easily make up fifty per cent of the faculty costs in a graduate program, particularly in the physical and biological sciences and engineering. This illustrates the

Costs Not Related to Student Credit Hrs.

necessity of studying graduate education costs at the individual departmental level. The converse situation to that indicated above is one in which a department is offering graduate programs which do not have a thesis or dissertation requirement. In this latter case the faculty costs can quite closely be directly related to the costs for the formal course offerings.

Obtaining Qualified Graduate Students

A major problem is that of inducing qualified graduate students actually to enter graduate school. While many studies have been conducted in recent years on the problem of the qualified high school student that does not go on to college, there has been very little study in a formal sense of the problem of the number of qualified graduate students with bachelor's degrees who do not go on for advanced degree education. The problem has now become so serious nationally that some educational institutions have entered into annual regional institutional visitation programs in the same manner that industrial concerns come to the institutions to recruit employees. The basic emphasis of the visitation program is to talk with all qualified students who are nearing completion of their bachelor's degree in an effort to talk them into going on for advanced education, whether it be at the institutional representative's institution or some other institution.

Admission Standards

The problem of admission standards does not appear to be substantial. The standards generally vary from department to department in single institutions, with the graduate school providing a general overall screening. Also, standards vary since in many cases each individual professor has the opportunity to accept or not accept

a student who may wish to study under him. Furthermore, many departments offer both degree and non-degree graduate work in an effort to afford an educational opportunity for graduate students working toward a degree and opportunities for non-degree graduate students whose qualifications are inadequate to permit them to even consider the possibility of acquiring a graduate degree.

An item of cost to operate a program that is frequently not given the attention that it should have is the very substantial cost of supporting the student and his dependents. This is an essential and well recognized item for which funds must be provided but little recognition has been given to considering it as a part of the operating cost of a graduate program. At the present time the Federal Government is much further advanced in its recognition of this necessary cost of a graduate program than are the majority of the states. It is equally true that institutions themselves frequently do not stop to consider the level of investment that they make in each graduate student. A basic fact of present-day and future graduate programs is that students will not participate in the programs unless they are provided directly or indirectly a comfortable living wage, not just an existence wage, for themselves and their families during the full period of their graduate study program. It is increasingly common to find part-time graduate students being paid three and four thousand dollars for half-time service. It is only a matter of time before it will be next to impossible to obtain the quality of graduate student required at salaries less than $5,000 or $6,000 per year. Furthermore,

Costs of Supporting Student

there are already in existence Federal programs that support graduate students up to levels of $6,000 and $7,000 per year. In addition, if one considers post-doctoral study personnel in the category of graduate students, then there are Federal programs in operation which will pay the student up to $15,000 per year to conduct research and study to his personal liking. Some fellowship data are given on page 14.

Duplication of Graduate Programs

Certain features of the cost of a graduate program might indicate that the concern about duplication of science or engineering oriented graduate programs at several institutions may not be warranted. The President's Science Advisory Committee reports that the institutional educational and general costs for each graduate student is conservatively about $3,500 per year. Since the student may well receive a stipend of at least a like amount, regardless of the institution he attends, it is clear that perhaps 50 per cent of the cost of a graduate program has no relation to whether or not each and every institution offers the same graduate program. This analysis assumes considerable importance when one studies the following quote from Berelson (5): "At one time or another, almost everyone who gets the doctorate has some support; only 12% had received no stipends while pursuing the degree, and only 8% in the arts and sciences."

Percent of Fellowship Support
Contributed by Various Sources, 1959-60

Major Academic Areas	University tuition fellowships	Other university fellowships	Government fellowships	Private foundation fellowships	All sources
Engineering fields	8.0	58.1	22.6	11.3	100.0
Physical sciences	8.8	48.8	32.5	9.9	100.0
Biological sciences	7.3	45.8	38.8	8.1	100.0
Social sciences	13.5	51.9	11.1	23.5	100.0
Humanities	16.2	44.2	17.2	22.4	100.0
Education	7.3	47.1	38.9	6.7	100.0
Other	8.5	64.8	11.3	15.4	100.0
TOTAL	10.3	49.3	26.5	13.9	100.0

Fellowship Support 1959-60
From all Sources by Academic Areas

Academic Areas	Percent of value of fellowships	Percent of total number of fellowships	Percent of earned doctorates 1958-59
Engineering fields	11.1	10.0	6.4
Physical sciences	27.2	24.0	21.2
Biological sciences	17.2	15.3	21.1
Social sciences	16.9	19.7	13.1
Humanities	13.7	17.7	14.4
Education	4.6	4.9	17.2
Other fields	.7	.8	.7
Total	91.4	92.4	94.1
Total "other"	8.6	7.6	5.9
GRAND TOTAL	100.0	100.0	100.0

Note: The above data taken from Chase, John L., Doctoral Study, U. S. Department of Health, Education and Welfare Circular No. 646, OE-54016 (1961) (4).

This excludes consideration of the cost of nuclear reactors and other such expensive equipment.

The question is frequently raised as to what happens to the doctoral holders once they have received their degree. Or to word it another way, does the investment in graduate education benefit primarily the institutions and the states by educating teachers or does it benefit primarily industry and government by providing employees to them? According to Berelson (5) it varies substantially by field. In the social sciences and humanities, over 70 per cent of the doctoral holders go into college or university employment. Some five per cent go into government and other educational employment. Of the order of ten per cent go into industry, and the remainder go into other occupations. In the biological sciences, some 60 per cent go into the universities; 19 per cent into government, and 12 per cent go into industry. In the physical sciences, one finds the greatest competition for doctorate holders between industry and the colleges and universities, with some 41 per cent going into colleges and universities, some nine per cent into government, and industry obtains the services of some 47 per cent. It is this last situation in the physical sciences area where the competition between industry and the college and universities makes it so difficult for educational institutions to recruit physicists, chemists, mathematicians and engineers on current academic salary schedules.

Who Hires Doctorates

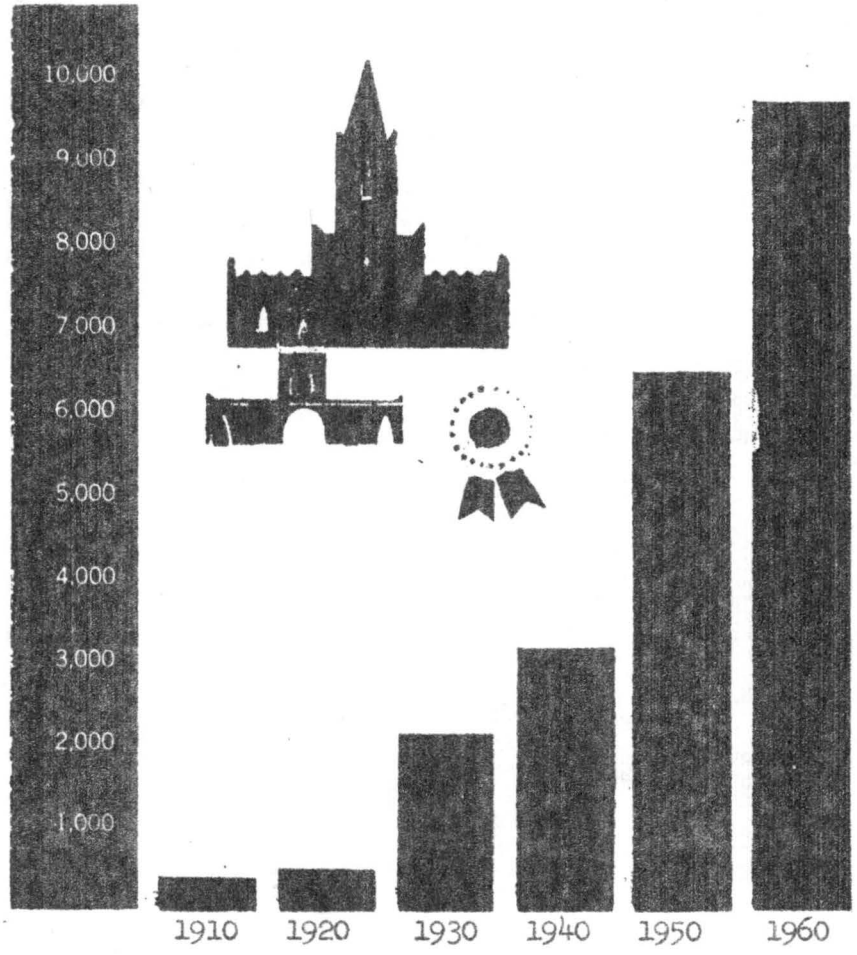
A problem of great importance to the nation is illustrated by the following taken from Chase (4): "The number of doctoral candidates, at the 139 responding institutions, who have recently

All But Dissertation Students

completed all formal requirements for the doctorate except the dissertation, and who would finish this dissertation in an additional year of full-time study, exceeds 4,000." This situation exists at a time when the nation is producing only 9,000 - 10,000 Ph. D.'s per year.

The rapid national rate of growth of graduate student numbers and the distribution among the Colorado public schools is illustrated by the following chart from Rosenhaupt (3) and the table from the U. S. Office of Education publication (8).

PH. D'S. CONFERRED BY U. S. UNIVERSITIES



Fall 1959 Advanced Degree Enrollments

	Total	Full Time
Adams State	119	34
Mines	83	73
CSC	419	244
CSU	289	184
CU	1,273	946
WS	33	23
Total Colorado Public Institutions	2,216	1,504
Total United States	304,831	115,292
Per Cent Colorado of Total United States	0.73	1.31

Fall 1959 Advanced Degree Enrollment in Basic and Applied Sciences and Mathematics Engineering Excluded

Adams State	--
Mines	--
CSC	37
CSU	193
CU	565
WS	--

FEDERAL, STATE AND PRIVATE FINANCIAL SUPPORT OF GRADUATE EDUCATION

Source of Support

Of the three major sources of support for graduate education and research - private donors, state appropriation, and Federal funds - the private donor source is relatively small in relation to public sources for public colleges and universities. There are several reasons for the private support being relatively small. The basic limitation, of course, is that the private support available is in total very small in relation to the total needs of all of the institutions of higher education in the United States. As a consequence, these private donors, whether they be industrial oriented foundations or private individuals, feel an obligation to give first priority to the support of private institutions. In addition, however, many companies consider that they pay taxes so they have no further obligation to public institutions of higher education. There is a noticeable change, however, in this attitude particularly by the larger corporations. It is also worth noting that in order to obtain support from foundations it is frequently necessary to maintain a continuing relation with a foundation over many years before the people in charge of the foundation are convinced that they should give money to the public institution involved. This maintenance of a continuing relationship is, of course, a substantial expense in itself.

The support by the Federal Government for graduate education and research is one of the largest and most influential

forces in higher education today. During the last few years the growth of Federal support, particularly for the physical and biological sciences, has been phenomenally rapid. It has only been during the last three or four years that increased recognition has been given to areas such as the social sciences, the humanities and certain applied research programs. That this influence, or role of the Federal Government in higher education will increase, not decrease, is again illustrated by a quote from the President's Science Advisory Committee report:

Role of Federal Government

> "Whether the quantity and quality of basic research and graduate education in the United States will be adequate or inadequate depends primarily upon the government of the United States. From this responsibility the Federal Government has no escape. Either it will find the policies - and the resources - which permit our universities to flourish and their duties to be adequately discharged - or no one will."

One of the most significant programs of the Federal Government has been its contract and grant activities supporting research. This rapid development of contract and grant activity has, as everyone is well aware, been a mixed blessing. On the one hand it has provided substantial sums of money for project oriented research activities, particularly in the physical and biological sciences. On the other hand, it has been an extremely difficult activity for the institutions to participate in by virtue of the fact that each project has a specified end objective and in addition the requirements of the Federal Government for financial reports of all types cost a large sum of money and time on both the part of the administration of the institution and its technical staff. Fortunately, during the last two years there has been an

Contracts and Grants

increasing willingness on the part of the Federal Government to provide institutional level research support by means of grants rather than contracts with an associated decrease in the volume of paper work required for the administration of the program. The very fundamental question involved for an educational institution, however, is whether or not its faculty members should have to participate in so-called programmed or end product oriented research versus the type of institutional research normally associated with and financially supported by a university - that of basic inquiry without a specified objective on the part of each faculty member.

Federal Support of Assistant-ships etc.

Another facet of Federal support is associated with research assistantship, fellowship, scholarship and scientific travel programs. Several years ago the National Science Foundation and the National Institutes of Health recognized the need to assist the states in the support of their graduate programs by providing financial support for graduate students which, as discussed earlier, represents a very substantial part of the cost of a graduate program. Fellowship programs were initiated, but again during the last two or three years it has become evident that these programs primarily provided money for the large institutions, particularly of the Ivy League, the Big Ten mid-western and the west-coast universities, while the rest of the institutions in the nation continued to go without support. Very specific plans are now under consideration to provide fellowship support through such administrative means that all institutions, regardless of size, will participate to some extent

in proportion to their interest and needs. There is no question but what we can look forward to increased Federal support of graduate fellowships and scholarships in order that no qualified student, if he has the motivation to continue to graduate school, will be prevented from doing so by lack of financial means.

In terms of the total support for basic research, the trend is for the Federal Government to support an increasing proportion of the total investment in basic research. According to the National Science Foundation Report NSF 61-27 (1), at the present time the colleges and universities through income from state appropriations, fees and tuition, and other sources provide 12 per cent of the budget for basic research. While these same colleges and universities expend 50 per cent of the nation's budget for basic research, the Federal Government provides 60 per cent of the total financial support but actually performs only 18 per cent of the research within its own laboratories.

Fiscal Support by Source and Preformer

Per Cent Distribution of Funds
for Basic Research According to Sectors
F.Y. 1961

Sector	By Source	By Performer
Colleges and Universities	12%	50%
Other Non-profit Institutions	6	7
Industry	22	25
Federal Government	60	18
Total	100%	100%

Even if this relative proportion of support were not changed, the expenditures required for research will obviously increase very

rapidly. According to the National Science Foundation, basic research in colleges and universities now occupies 45,000 full-time equivalent professional scientists and engineers, including graduate students and post-doctoral fellows supported by 35,000 non-professional personnel, with this total rising to 150,000 or nearly 100 per cent increase before the end of the current decade.

Influence of Federal Support on Direction of Programs

A critical question which is frequently raised in regard to this Federal support is that of the influence and direction of a state institution's program by the Federal Government. There is little question that the project type of Federal support of research in the institutions has at times led the institution into re-orientation of its program which it did not really want. However, with the current trend being for increased Federal support with decreasing Federal control for each program, there seems to be little reason to be unduly concerned about the Federal Government attempting to control the individual institutional programs. The pro and con arguments were summarized by a report, "Sponsored Research Policy," (7) as follows:

Pro and Con of Federal Support

> "The Committee recognizes many advantages which sponsored research has provided. It has expanded the volume of research in the colleges and universities. It has made a large contribution toward the advanced education of students, particularly in science. Many of our graduate schools could not have maintained their current enrollment and output had not sponsored research increased their capacities and provided employment opportunities for able but financially needy potential graduate students. In addition, sponsored research has in many instances improved the quality of advanced education by providing large-scale equipment otherwise not available to the institution. It has increased the scientific productivity of our leading scholars by furnishing them with academic assistance and equipment. Sponsored research has provided enlarged thesis opportunities,

which have given new dimensions to graduate training. The larger-scale projects afforded by government have enabled young men and women to acquire research techniques which can be learned only by participation in organized team research. The result is that our institutions are turning out qualified research men and women who are more immediately useful to industry and to the government research laboratories than they would have been under older training methods.

"Despite these obvious advantages of sponsored research, colleges and universities must recognize its hazards. They have a heavy obligation to minimize these hazards, whether the research is supported by government, industry, or foundations. Among the more important are the following:

a) Such research may seem so attractive financially as dangerously to divert the scholars in our universities from research which extends the boundaries of knowledge and to bend their interest too much toward matters of immediacy, thus drying up the principal wellspring of fundamental knowledge.

b) The attractiveness of sponsored research may divert an improper amount of attention and interest from the academic program, thereby affecting the quality of our education.

c) Such research may emphasize certain fields of knowledge at the expense of others, with the result that important areas of scholarship and research may be neglected simply because funds are available more readily in those fields in which sponsors are interested--a danger which becomes more serious when institutions use a substantial part of their own unrestricted funds in the sharing of the direct or indirect costs of sponsored project research.

d) The control and accounting procedures required by the government may subtly change the character of educational institutions, thereby reducing the value of their special type of environment for creative work, which includes independence of the investigator, relative simplicity in management, and sympathetic understanding between administrative and academic personnel.

e) Cancellation of contracts may leave the institution with long-term commitments to the graduate student program, to the staff, and for facilities, that may be financially embarrassing or disastrous."

One of the most difficult problems that any institution faces in its efforts to get outside Federal money for the support of its graduate programs is that of qualified faculty. Most Federal agencies state as a matter of policy that they will support any fundamentally sound research investigation for which they have the fiscal resource irrespective of the past performance of the individual scientist requesting support as to whether he is a new Ph. D. or a national or international figure in his field. In actual practice, however, no institution has much opportunity to get substantial Federal support under contract or grant auspices without having each project associated with a man whose reputation is national or international in character. This then means that each institution, if it is to assist in the support of its graduate program by its own efforts so that its state does not have to carry the full burden, must have the ability to employ the services of nationally or internationally known scientists. The market for these people is very rigid. At the present time, salaries of $25,000 and $30,000 per year are quite frequently quoted. At the university level it is essential to be in a position to offer $15,000 to $25,000 for nine months' employment to top full professors if one is to stand any chance at all of getting their services.

Qualified Faculty

A prevailing characteristic of Federal support is that unless the institution is willing to take on Department of Defense developmental work of a quite routine character, Federal support can only be achieved for basic research. Certainly not all faculty members are suited to or interested in conducting only basic research. The result is that there is a substantial part of

Support for Applied Research

graduate program support that must be achieved at the state level in the applied fields. In the context of several of our funding agencies, engineering is considered to be an applied field, particularly such areas as agricultural and civil engineering. Forestry and agriculture are also frequently considered as applied programs; hence, can obtain support only through the Agricultural Experiment Stations.

State appropriation support must then be provided for not only applied research but for all of the staff time for teaching and such staff time as goes into undirected inquiry. The maximum level of state support for graduate education and research is essential if we are to improve the effectiveness of our faculties. There is a great loss of creativity under the Federal type of research support which requires each project leader to devote a substantial period of his time to routine paper work, frequently away from the campus and his students, so that he cannot do creative thinking. This is a net loss to the state involved.

Loss of Creativity

While programs differ greatly and each institution in the state must develop its own figures on faculty needs for graduate education and research, it is worthwhile noting that in 1961 the National Science Foundation (1) reported that there are about 100,000 professional scientists and engineers teaching 645,000 students enrolled for degrees in science and engineering in colleges and universities. These same teachers, of course, teach many students specializing in other fields so that it becomes evident that a figure of approximately six to one student-faculty ratio on a national average represents the current situation. The Colorado ratio, unfortunately, is no where near this low.

Student-Faculty Ratio

SALARIES, OPERATING BUDGETS, CAPITAL OUTLAY AND CAPITAL CONSTRUCTION

Salary costs for graduate programs, irrespective of the measure used as a basis, will be much higher than the salary costs for undergraduate education. They can easily be three to five times higher. This is due to graduate education being an individualized matter, the fact that graduate programs use a higher proportion of the time of full professors and only a small amount of time of people in the assistant professor rank, the numbers of students who can be accommodated in any one class are usually less than in undergraduate programs, and the fact that many people involved in graduate programs are the national and international figures who demand much higher than normal salaries. In view of the national need and state need for rapid growth of graduate programs at all levels, there is little question but that state budget allocations for graduate programs should triple or quadruple during this decade. It is probable that Federal budgetary allocations will more than quadruple in this decade when one combines the support for graduate students with the other support given to the institutions by the Federal Government.

Salary Costs

Operating budgets are always a topic of much discussion. A few points are very clear. The magnitude of an expense budget for a graduate program must be several orders of magnitude larger than expense budgets for undergraduate programs. The research scientist who does not attend at least three national meetings per year is neither keeping up with his colleagues nor maintaining the acquaintances essential to the acquisition of new faculty. In

Operating Budgets

addition, he must make many trips during each year in order to maintain the inflow of Federal support to the graduate program for students, faculty, equipment and operating expense costs. The costs of utilities, plant maintenance and operation, and costs of modern instrumentation are very large whether they be for a biology experiment requiring high intensity light sources or a cyclotron or a wind tunnel with a several hundred horse-power motor driving it.

Capital Outlay

Capital outlay is an area of state budgeting that seems to have received some recognition across the country for support at three per cent of educational and general expenditures. This figure is reasonably adequate to meet the normal recurring cost for equipment such as desks, chairs, typewriters, duplicators, minor teaching aids, and equipment of this nature. It is grossly inadequate, however, for the acquisition and replacement of research equipment, such as electron microscopes, which cost from $20,000 to $40,000 each and are now considered as essential standard equipment.

Estimate of Colorado-National Support

Using the average cost to an institution mentioned earlier of $3,500 for educational and general costs per graduate student and the conservatively low figure of 2,000 students for Colorado, one has an annual cost of $7,000,000 if Colorado was providing a level of support equal to the national average.

Capital Construction

Capital construction of adequate research space is always a chronic problem for research programs. Again the National Science Foundation (1) provides some useful figures indicating the seriousness of the problem. The provision of adequate research space for science and engineering in colleges and universities requires

approximately 300 square feet per full-time-equivalent person. This is gross floor space. The cost of this research space is now approximately $40 per square foot and is expected to rise to $60 per square foot by 1970. These figures include the cost of fixed equipment and up-to-date facilities. It is considered that provision must be made for obsolescence and depreciation at the rate of six per cent per year.

Matching Funds

Fortunately, there is an increasing trend for Federal programs to match state programs for the construction of research and graduate education facilities. These programs vary greatly. Some provide, from Federal sources, 100 per cent of cost; others provide as low as 25 per cent of the cost. It is quite common for the participation on the part of the Federal Government to differ substantially in regard to the fixed equipment to go into the building. In some cases the Federal Government will provide no support of the fixed equipment; in other cases there are programs which provide only fixed equipment, sometimes on a 50-50 matching formula.

Space Standards

Standards in regard to space utilization and the size of individual laboratories cannot be derived. Each individual laboratory must be designed on the basis of the specific purpose which it is to fulfill.

The table reproduced on the next page is from NSF 61-31, June 1961 showing the distribution of capital expenditures in the United States by field for the fiscal year 1958.

(Thousands of dollars)

Organizational Unit	Total	Field of Science			
		Life	Physical	Engr.	Social
Total	$153,539	$76,153	$50,027	$23,250	$4,109
Colleges and universities proper	110,688	61,599	29,088	16,873	3,128
Engineering schools	19,896	84	3,969	15,842	1
Medical schools	42,371	42,344	23	--	4
All other units	48,421	19,171	25,096	1,031	3,123
Agricultural experiment stations (including schools of agriculture)	15,454	13,632	59	798	965
Federal contract research centers	27,397	922	20,880	5,579	16

LIBRARIES

Library Inadequate

Very substantial library facilities and holdings are basic to any graduate or research program. There is no public institution library in the State of Colorado at the present time that is anywhere near adequate to the current programs let alone the responsibilities for education which must be provided in the next very few years.

Current Research Reports

One of the greatest difficulties which the libraries face in providing adequate support for graduate education and research is associated with the continuing purchase of an adequate number of periodicals and reports. The research scientist and teacher thrives on, and must have available to him, periodicals and reports. By the time information is sufficiently mature that it is published in book form, it is already many years behind time as far as the research man is concerned. This creates a great burden for the libraries since the number of periodicals is increasing at a fantastic rate. The problem of information storage and retrieval appears to be nearly insurmountable. It is so serious that several Federal agencies are allocating many tens of millions of dollars to attempt to find means to resolve the problem.

State-wide Library Coordination

Every effort is being made on a state-wide basis to provide a means for each institutional library to complement the holdings of every other library in such a way as to provide a minimum of duplicate acquisitions. Even so, the costs of acquiring and maintaining a library are very substantial when one recognizes that it takes from $9 to $11 per volume to acquire and put on the shelf an individual book.

SUMMARY

Graduate education and research is of vital importance to the state, the nation and the world and must be expanded at an ever increasing rate at all institutions of higher education in Colorado if each student who is qualified and motivated is to have an opportunity to achieve the highest level of education of which he is capable. This will require large sums of money. These sums invested in the development of human capital will be small, however, in proportion to the value of the human capital generated.

Summary General

The U. S. Office of Education (4) summarizes the situation as follows:

> "The long-term trend in total student enrollments shows a more rapid growth of graduate, as compared with undergraduate, enrollments. This trend reinforces the national need for a growing supply of teachers and scholars with the doctorate who are qualified for the most advanced teaching and research positions in industry and agriculture, in Government, and especially in higher education.
>
> "The most serious barrier to expansion of the graduate schools, in all academic areas, is the lack of financial aid for graduate students. Following in order of importance are the lack of academic facilities, the lack of qualified students, the lack of adequate housing, and ... the lack of qualified faculty."

Summary HEW

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