GRADUATE EDUCATION IN SCIENCE—THE LAST FORMAL RAMPART?

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A quarter of a century ago, Whitehead (1929) observed that "The expansion of universities is one marked feature of the social life in the present age. All countries have shared in this movement, but more especially America, which thereby occupies a position of honor. It is, however, possible to be overwhelmed even by the gift of good fortune; and this growth of universities, in number of institutions, in size, and in internal complexity of organization, discloses some danger of destroying the very sources of their usefulness, in the absence of a wide-spread understanding of the primary functions which universities should perform in the service of a nation. These remarks, as to the necessity for reconsideration of the function of universities, apply to all the more developed countries. They are only more especially applicable to America, because this country has taken the lead in a development which, under wise guidance, may prove to be one of the most fortunate forward steps which civilization has yet taken."

"The function of a University," he declares, "is to enable you to shed details in favor of principles," or " . . . the proper function of a university, is the imaginative acquisition of knowledge;" or again: "The whole point of a university, on its educational side, is to bring the young under the intellectual influence of a band of imaginative scholars."

Today we are being told, sometimes in tones of considerable alarm, that our nation is not producing the number of scientists it needs. The situation generally is regarded as one of crisis. For example, according to Science (123:928): "The Soviet Union is graduating 120,000 engineers and scientists every year to this country's 70,000. In a later issue (Science 124:821), comparative data for the graduating classes of engineers [only]* for 1954 show that Great Britain graduated 57 engineers per million of population; the United States graduated 136 per million of population; and the U. S. S. R. graduated 280 engineers per million of population. This situation is viewed with alarm from the standpoint of national defense, which has become intensely technologic in character. Is the American university failing to provide a sufficient technologic personnel in the interest of our national security?

Returning again to Science (123:928), it is reported: "The number of qualified teachers of science and mathematics in United States high schools has dropped 53 percent in the last 5 years, while high school enrollment has increased 16 percent.

"Fifty-three percent of all high schools in the United States do not teach physics and only half of the high schools teach chemistry. In addition, a recent survey indicates that between 250,000 and 400,000 United States high-school students are taking their mathematics and scientific training from teachers who are not qualified to teach these subjects."

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* Brackets mine.

Is the American university, in view of this information, failing our national interest? It would be presumptuous for me to attempt an answer to this question or to the one above. In the first place, I do not know the actual needs of our nation for technologic personnel either in terms of kinds of technologic skill or in terms of quantity of each. In the second place, national defense constitutes only one of our national interests.

We are concerned, too, with enhancing our standard of living, enriching our lives. This entails release from poverty and drudgery, increased leisure and literacy, and freedom to choose and pursue the way of life we desire; in short, directing our energies to socially constructive ends. National defense, therefore, is not the only measure of national security. The state of the national well-being also is such a measure. There is, however, critical opinion, which views the university as having "lost its intellectual and spiritual leadership" (Rogers, 1950). Does this destine us to a national mediocrity? A kind of automatism?

One result of having our attention directed to the kind of national dilemma reviewed above has been the development of an increased, or perhaps better, a renewed interest in the process of public education, particularly at the level of the secondary school. In our state, for example, "There has recently been organized in Oklahoma City a 'Frontiers of Science Foundation' composed principally of business and professional men whose aim is to mobilize a state-wide—and eventually a nation-wide— effort aimed at the junior-high-school student, his parents and his teachers, to bring home the needs, the opportunities, the requirements, and the rewards of a scientific or engineering career," (De Bridge, 1956).

The American Association for the Advancement of Science, and the National Science Foundation, among others, have developed programs aimed at the improvement of high school science teaching quality. Last year the National Science Foundation established a pilot program centered at the University of Wisconsin, and at Oklahoma State University. In this program, the National Science Teacher's Institute, superior high school science teachers are granted a stipend from the National Science Foundation to support them in a year of refresher and advanced work. Increased effectiveness in science teaching is the program's goal. This program has been extended an additional year at the two pilot institutions, and now also has been extended to several other academic institutions as well.

Government as well as private business thus is seen to be sponsoring and contributing to programs having for their objectives: 1) the development of an increased interest in the choice of a career in science, and 2) the improvement of high school science teaching. Would it be an affront to suggest that these two objectives might be worthy of some attention at academic levels of education?

It is by no means too late in life for a college undergraduate to choose a career in a field of science. There are instances, however, where advisors reportedly are shunting undergraduates away from such a choice. Imagine, if you will, students being advised away from science on the ground that it is too technical, too vocational, or just too "hard"! Aren't advisors supposed to counsel on the basis of the recognized interests, inclinations, or aptitudes of their advisees? On the basis of this information from Du Bridge (1956), college administrators might want to screen with the utmost care the competency of advisors apointed to counsel students.

While attention might profitably be directed to the improvement of science teaching programs at the undergraduate level, I wish here to restrict myself to a consideration of the graduate level of performance. I recognise that my background is in biology, and that my remarks will be about the educational process in science generally. I hope, therefore, that I shall outrage no single field of science.

The amount of formal participation in graduate study, already is increasing. The outlook seems to be for continued increase indefinitely. High school enrollment reportedly has increased 16% in the last five years. There seems to be no abatement in the number of marriages on the one hand, and on the other hand the present trend is toward a larger family size, that is, more children per couple. We might, therefore, expect considerable increase in graduate school enrollments. Increasing financial support, moreover, will probably encourage a greater number of students to undertake graduate study.

Among students of the usual age group pursuing graduate study, this experience can be an extremely important transitional period in their lives. It can be the period during which they metamorphose from the passive state of absorbing or "soaking up" what learning for which they have an affinity or a noticeable valence to the active state where they are engaged in searching out knowledge not only new to them, but new also to science. This is a metamorphosis from the role of the consumer to that of the producer. It is an important transformation because for the rest of his working life he will be expected to produce. What more congenial and sympathetic atmosphere is there within which to negotiate this transition than in the academic environment?

Lest there be misunderstanding at this point, allow me to explain that this transformation is not achieved solely through the discovery of facts. It can also be achieved through a reassessment of an existing body of facts in the interest of new interpretations or an extension of presently recognized implications.

The big problem is how to achieve this metamorphosis, assuming it is a desirable academic objective. Before attempting to answer this question, first let us inquire as to the aims of graduate education. One practical objective has just been offered, but what about academic aims? It was Wheeler's (1923) opinion that the young graduate biologist " . . . may be expected to adopt an independent, adventurous and creative attitude toward his science." It is probably safe to generalize this statement to cover all graduate endeavor in science. In their catalogs, many graduate schools recognize the development of capacity for independent and creative scholarly activity as a requisite for the doctorate. For present purposes, at least, let us accept as the aim of graduate study in science the development of a spirit embracing independence, adventure, creativeness, and also perceptive depth. This should be reasonable because these qualities characterize the very heartland of scientific endeavor. This activity is highly personal, and the individual is motivated largely through the pleasure stemming from the adventure of discovery. The scholar, in addition, is immensely motivated by the opportunity discovery provides for creativeness. Scholarly perception is satisfied not with the discovery of a fact, but with the interpretation to which it leads. The result of this is new gereralization, interpretation, or the recognition of implications not hitherto appreciated.

This brings us to the all-important question of how to achieve such a goal. What are the requisites? In the first place there must be discipline, discipline in an area of knowledge, and discipline of the emotions. Whitehead (1929) declared: "Education is discipline for the adventure of life . . ." Care must be taken not to confuse discipline in this sense with academic authoritarianism. Discipline in an area of knowledge is systematic intellectual exercise in that area, the pursuit of a systematic process of learning. The usual course is from the simple to the complex, from the concrete to the abstract. Discipline of the emotions we usually consider as the development of mature behavior. These kinds of discipline are achieved in varying degrees, and they are more than unlikely ever to be absolute.

Careful attention to detail is requisite to the cultivation of discipline. We learn early to be attentive to detail, for example, in arithmetic and in spelling. In these subjects the need for accuracy is obvious, and this accuracy rests upon proper attention to pertinent detail.

Sometimes a teacher is criticized for insisting upon attention to "too many" details. Before such criticism is valid, however, the allegedly superfluous detail must be evaluated in terms of the questions: Is it relevant to the subject? What is its relative importance? We must remember, too, that there is also the human variable attached to the evaluation of detail. Depending upon point of view, opposite positions concerning a particular detail may at times be equally defendable so far as a present state of knowledge is concerned. Even though the screening of detail may become more or less burdensome, we have no right to discard any arbitrarily.

Then there must be freedom—freedom to imagine, to explore the world of ideas, and to reflect purposely. There must likewise be freedom from restraint, and from harassment. Freedom, of course, is relative, and it is an ideal. It is something toward which we reach! There is probably, in the living world, no such thing as absolute freedom. A cell can't spread all over. It is restricted by its membrane. An animal homestead doesn't extend to infinity. It, too, is limited by a boundary. Our behavior is to a greater or lesser extent restricted by the law, if not by comfort or convenience.

Yet there seems to be some tendency to regiment the graduate student increasingly with more and more credit hours of required classroom work. This tendency, moreover, often seems not to take into consideration the relative state of preparation or the capacity of the student. With undergraduate science major programs as highly specialized as they, in general, have come to be, it is not to be unexpected that students often are able to approach their graduate study rather well prepared in their major. In prescribing a heavy load of formal class work for him, there not only is a risk of redundancy, or laying out a schedule of "busy work" but the development of his creative productiveness also may be impeded.

To the extent that further classroom work emphasizes the continued learning of facts rather than principles, its worth is questionable. Such a procedure can be likened to learning statistically, word lists from a dictionary rather than learning to combine words dynamically to convey ideas. By the time the graduate level of education is reached, it is high time to emphaize the study of principles to explains relationships or processes. The concern for factual information now can be limited to those facts which are helpful for exemplification.

At other times, there seems to be some doubt, at least implicitly, as to the real worth of a graduate research program as an edifying educational experience. Sometimes this program seems to be regarded in much the same light as an undergraduate term project. The interest seems to be centered about the execution of an exercise, rather than upon the discovery of information new to science, or whether or not the student is making any contribution to the body of principle upon which his field of science is structured. Research nevertheless was considered an intellectual adventure by Whitehead (1929). Well conceived research adds depth as well as breadth to the student's developing sense of appreciation. It has vitality, it stimulates the imagination and it satisfies the questing motivated by way of intellectual curiosity. Research cultivates a doer, a producer, a virtuoso!

Does curricular regimentation lead to intellectual suffocation? Is the imagination enkindled by way of this avenue? Does it satisfy the haunting desire for the adventure of exploration and discovery whether for facts or for ideas? To what extent does curricular regimentation based upon extended formal classroom work stimulate creativeness?

Is it possible that in promulgating heavy curricular regimentation, we are at least tacitly admitting a confusion between the aim or program of a technological and/or professional education in contradistinction to the liberal academic education? To qualify as a technologic or professional practitioner, and to pass state board examinations, it is manifest that the technological and/or professional student acquire a sufficient quantity of appropriate kinds of training. In such training, much emphasis is of necessity placed upon the cultivation of desirable technique as well as the accumulation of an appropriate body of facts. One yardstick applied to measure these proficiencies is the credit hour of classroom work. Another is the result of his state board examination. Are these yardsticks wholly satisfactory measures of proficiency in scientific endeavor?

Is this kind of requirement consistent with the spirit of freedom characteristic of scientific research pursued in the liberal tradition? Does a graduate curriculum in science, which is heavy on the side of credit hour accumulation of classroom work rather than on research endeavor satisfy the needs basic to the development of scientific research scholarship? Does it facilitate the cultivation of a scientist in the traditional sense? Is the balance between class work and independent research necessarily the same for both the life and the physical sciences? It may behoove us to give thoughtful attention to preserving that unshackling of man's mind from authoritarianism, which was achieved during the Renaissance! For according to the record of history, it was this which led to the development of modern science.

The development of communicative skill is another requisite to the achievement of the aim of graduate education in science, which we are accepting for present purposes. There can be little sympathy for anyone who may research diligently for no more than mere personal gratification, and who communicates little or nothing. Such a person is like a miser, and is about as valuable to society. The importance of communication has for long been recognized. One of the most beautiful as well as meaningful statements in this regard is that of Christ in His "Sermon On The Mount," when He declared: "Neither do men light a candle, and put it under a bushel, but on a candlestick: and it giveth light unto all that are in the house" (Matt. V:15).

Essential as communication is, there are limits to its effectiveness. One of these is lack of sufficient ability to read. Some critics of science charge that its language is too high-brow, or that it is largely an unintelligible jargon. They argue that scientists should use language understandable to all. Sometimes they even insist that to reach the public, desirable as this may be, all communication needs to be at the eighth grade level of language proficiency.

Criticism along these lines is fallacious. In the first place, scientists use language to communicate their work to their colleagues. To do this, each scientific realm has its own vocabulary, that is, its own language, which simplifies, makes less cumbersome and more precise the exchange of work and ideas. Some scientists do endeavor, however, to communicate with the serious public at large. Notably successful among these, to name only several present day scientists for the sake of example, are Theodosius Dobzhansky, Julian Huxley, Margaret Mead, and Paul B. Sears.

People generally can be expected, moreover, to concern themselves mainly about their own personal interests. They usually are not inclined to be interested in everything, and if they were, they would not have the time to explore or follow any interest very far. It does need to be recognized here, moreover, that all persons are not seriously inclined. Many are fickle or trivial in their interests. To expect any more of human nature than what now characterizes it so far as our present interest is concerned is to engage in wishful thinking.

Lastly, it is unreasonable to expect there can be an easy meeting of minds far apart in their degrees or directions of education. It would be unreasonable to undertake doctoral programs at the primary school level! Were it possible, such a short-cut would make for great economy.

The fallacy of this kind of thinking generally is the subject of a worthwhile editorial discussion in Endeavor (58:59-60), which later was reprinted in Science (124:207-208).

Related to the problem of communication and to the exploratory and discovery aims of graduate study in science, is the matter of foreign language study. The practice of requiring the cultivation of a reading proficiency at least, in one or more foreign languages is questioned with some frequency. Some departments among several leading American universities, according to the October 1956 issue of "Higher Education," are being permitted to liberalize the traditional foreign language requirement. At Michigan, for example, certain departments are being permitted to substitute an integrated program of at least nine hours of graduate course work for one language. To become a technological and/or professional practitioner, foreign language study may not be necessary. But in scholarly research endeavor, no reason is apparent to regard facility in the use of foreign language any less important today than it has been in the past.

Foreign literature attests the fact that research is active in the several realms of science abroad as well as at home. Foreign language citations in our domestic literature is further proof of this. It is a matter of comment every once in a while that certain extended or critical American treatments had been pursued apparently without the benefit of pertinent foreign work. This is to say that American science and education have their isolationists just as does government. Foreign language proficiency, therefore, is more than a mere asset, it is an essential.

Not the least of the values of foreign language study is the increased skill it can give us in the effective use of our own language. While it is sometimes averred that the best way to develop a mastery of one's own native tongue is to study it, not some other, it usually is helpful also to consider our own from the facet of one or more foreign languages. Insight and appreciation can thereby be developed that is difficult to achieve without this benefit.

Foreign language study, moreover, can be helpful also in the cultivation of ordered and disciplined thinking. This contribution certainly is of benefit to scientific endeavor.

With reasonable freedom from the continuing demands of the classroom, and with some foreign language reading facility, more time becomes available for study in the library. Here an increased opportunity now is opened for exploration and discovery. The thinking of the ages becomes increasingly accessible. Does this not contribute to the cultivation of imaginative thinking? Does this not lead to a satisfying of the aims of graduate education in science we have here recognized?

There is another fallacy associated with communication. It is that the measure of a scientist is the volume of his published output. When this measure is used alone, there is risk of failing to discriminate between what is contribution and what may be little more than patter. Whitehead (1929) challenged this position with his recognition that: "Mankind is as individual in its mode of output as in the substance of its thoughts. For some of the most fertile minds composition in writing, or in form reducible to writing, seems to be an impossibility. In every faculty you will find that some of the more brilliant teachers are not among those who publish. Their originality requires for its expression direct intercourse with their pupils in the form of lectures, or of personal discussion. Such men exercise an immense influence; and yet after the generation of their pupils has passed away, they sleep among the innumerable unthanked benefactors of humanity. Fortunately, one of them is immortal—Socrates."

The final requisite of graduate study in science to be considered here is that of quality of performance. Our law, which opens the door of educational opportunity to all who may wish to enter, and the fact that we live in a production-conditioned economy may tend to encourage quantity at the expense of quality at the graduate level of education as it seems to have at other levels. For scholars there is but one approach to this problem, and that is to strive ever for quality. As someone has said, "We do want to offer opportunity, but do we want to cultivate mediocrity?" Our last hope against quantity at the expense of quality, perhaps, is at the level of the graduate school!

Some views have been aired here, and some questions raised. I hope they are worthy of your attention. Graduate education in science seems destined to become, in some measure, a big business too. Let us not administer this endeavor as though it were a commercial or an industrial enterprise. Instead, let us always cultivate and encourage imaginative scholarship and understanding!

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