privilege of censorial restriction beyond 56 years.

Copyright restriction can be a serious roadblock in scientific writing and research. Anyone who has attempted to obtain permission for reproducing work that is more than 30 years old knows how difficult and time-consuming it can be to locate the copyright holder, and how frequently the quest is unsuccessful. If scientists and educators are interested in disseminating knowledge, they certainly should not favor a law that makes such dissemination difficult, if not impossible.

Folsom presents a false picture of pricing methods in publishing—a not uncommon error of people who don't fully understand trade practice. Royalty is a cost which almost always increases the retail price by three times the amount of the royalty payable. If you take a book in the public domain that is usually priced at $2.25 and add a 10 percent royalty of 22½ cents per book, the retail price will have to be increased to $3, not to $2.50. This factor of 3 is necessary to take care of booksellers' discounts and overhead. In the same way, a saving of 25 cents in binding cost can lower the price of a book by $1.

Having a large body of literature in the public domain makes it possible to publish cheaper editions of this literature, and the availability of these cheap editions tends to limit the price for all books which are still protected by copyright. It is very difficult to price a paperback at $5 when others are available from 25 cents to $2. As the source of books in the public domain becomes smaller, the price of books protected by copyright will increase. There is no law or regulatory body which limits the pricing of copyrighted literature, even though the prices may be exorbitant and restrictive.

If the public is willing to pay considerably higher prices for thousands of books, records, and musical scores, it has the privilege of supporting the bill for copyright revision. However, I do object to statements that create the false impression that there will be little or no increase in price, and that these miniscule sums will aid hard-working, somewhat indigent authors. The increase in price will be substantial, and most of the money will go to a small group of publishers and authors who have already greatly profited from 56 years of copyright protection. I have never seen the present copyright law inflict a hardship on any long-lived author, and I challenge proponents of the bill to present more than an occasional and unusual case where it has done so. On the remote possibility that this legislation may benefit these very few individuals, isn't it rather foolish to support legislation that contributes to monopolistic growth, further limits the circulation of ideas, and asks the public to pay additional millions of dollars to private interests?

The bill for copyright revision may pass because, as in the case of so many special-interest bills, minority property interests are strongly represented and no one is speaking for the public—a public that does not realize that the proposed bill is not calling just for a longer copyright period for new works but is granting an additional 20 years for all works copyrighted during the past 56 years. Except for the Department of Justice and a very few private citizens such as myself, no one has made any effort to inform congressmen of the full implications of the bill. The bill can be defeated if there is some resistance to it by an informed citizenry. Congress does not generally give public property to private interests, but it may very well do so unless the public asserts its rights and indicates that it objects to this usurpation of public property. I hope that, as scientists and educators become aware of all the implications of the bill, they will speak out against it, and that Congress will then be less susceptible to the pressures and blandishments of the special-interest groups that are pressing for this unfortunate piece of legislation.

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University Education and Applied Science

In approaching the subject of education in a university engineering department, I propose to take quite a broad view, for what I have to say is applicable to almost any university department and is not special to departments of engineering.

What is the objective of a university? As I see it, the preeminent objective of a university is developing students' minds: to take in good brains from high school and make them work as well as possible.

What is the objective of a particular department of a university? A particular department is concerned with a particular field of knowledge, but the department is nevertheless pursuing the common university objective: to exploit the potentialities of a particular field of knowledge for the purpose of developing students' minds as well as possible. Notice that the objective has nothing directly to do with training the students for a particular job.

What is the objective of a particular university engineering department, such as the department of electrical engineering? It is not to train students for a particular job. It is to develop the students' minds. Thus, the objective of an electrical engineering department is to exploit the potentialities of electrical engineering for the purpose of developing students' minds as fully as possible. Notice that electrical engineering is only the means whereby this can be done.

Unfortunately, there are people in engineering departments, both faculty and students, who do not distinguish clearly between the means and the objective of the educational process in which they are involved. For example, it is not uncommon for someone in an engineering department to recommend a particular professional specialty in the following words: "Students should not graduate in such-and-such engineering from this university without knowing so-and-so."

Such an individual can usually be tagged as a man who has allowed a misguided loyalty to the profession of engineering to supersede his loyalty to the profession of education—a man who talks about the means available for the educational process as though they were themselves the objective of the educational process; a man who has forgotten that, even in an engineering department, the objective of the operation is mental development.

Many people in engineering departments have had the experience at some time or other of being looked down upon by someone in the humanities as a person involved in an inferior brand of intellectual activity. While there is no foundation for the assumed intellectual superiority of the humanist, it is nevertheless true that he does have a significant point. Put yourself in the position of a man engaged in teaching the classics. What does a professor of the classics regard as the objective of the educational process in which he is engaged? The classics professor is in the fortunate position of being almost unable to conceive any primary educational objective other than that of developing students' minds. He cannot be trapped into imagining that he is training "classicists" for industry! But he notices that many engineering educators do fall into just this type of trap, and he likes to poke fun at the consequences. However, it is not intellectual superiority that keeps the classics professor straight about educational objectives!

It is true that many students who have had their minds developed by mastering the physical concepts and mental skills upon which, say, the electrical engineering industry is based find it appropriate to pursue a subsequent career in electrical engineering. Unlike many university departments, engineering departments are aware of the probable future career of their students, at least on a short-term basis. Awareness of the probable future career of a student is, however, no basis for making a change in the fundamental objective of the educational process.

Most of the statements I have made concerning the objectives of the educational process are true for all university departments, and the same is true for most of the statements still to be made. Let us now begin to distinguish between the objectives of undergraduate and graduate education.

What is the objective of undergraduate education? Its characteristic feature is that it is principally concerned with what is well known. Its objective therefore, is to develop students' minds as fully as possible by having them study what is well known.

There is a common fallacy that brings out quite well the confusion between means and objectives in engineering education. The fallacy pertains to the exponential increase in knowledge. It is argued that students must be taught more now than they were 50 years ago, and that they will have to be taught much more 50 years from now. The fallacy is immediately seen as soon as we remember that the objective is mental development. Students' minds today are the same as they were 50 years ago, and they will be the same 50 years from now. What the exponential increase in knowledge does is this: it gives universities more material from which to choose in producing the same degree of mental development. Even this is less true than is sometimes supposed, because the advancing front of knowl-

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edge is followed by a less-well-defined advancing front of oblivion.

What sets a limit to the undergraduate educational process? In a qualitative way this can be specified for an individual student, and if desired, one can take the risk of extending the statement to a hypothetical average student. The mental development of an individual proceeds rapidly through the years of early childhood and those of elementary and high school education. When a student becomes an undergraduate, his mind is still developing rapidly. Indeed, in countries with weak school systems, the rate of mental development may even increase at this time. As the undergraduate continues to develop his mind by studying what is well known, he reaches a point of diminishing returns. There is still a great deal that he does not know, some of which he may subsequently need to know. But the undergraduate educational process comes to an end when it is no longer worth the student's while to study what is well known merely for the purpose of developing his mind. In many universities the limit of undergraduate education defined in this way is not at the level of the bachelor's degree but somewhat above the level of the master's degree.

What is the objective of graduate education? At the conclusion of an ideal undergraduate education, a man's brain works well. He is convinced, not that he knows everything or even that he knows everything in a particular field, but that he stands a reasonable chance of understanding anything that someone else has already understood. Any subject that he can look up in a book he feels that he too can probably understand. On the other hand, if he cannot look it up in a book, he is uncertain what to do next. This is where graduate education comes in. Unlike the recipient of a bachelor's degree, the recipient of a doctor's degree should have reasonable confidence in his ability to face what is novel and to continue doing so throughout life.

There is a need to have the most intelligent members of society capable of facing novel situations with confidence. I do not mean only in the technical fields of science and engineering. The successful business man must continually face such situations with confidence and correctly evaluate them. So must the politician. The two K's are constantly confronted with novel situations upon which our very future depends. We can all point to major blunders that have been made in world affairs because a politician, or group of politicians, met with such a situation and bungled it. We are still keenly aware of the one that had to be faced in the 1962 Cuban crisis. Facing novel situations and mastering them is one of the most challenging tasks with which mankind is confronted.

There are, of course, many ways of learning to face such situations with confidence. If this is done in a university, what is the principal technique available? The answer, of course, is research. There is a contrast between research in a university and research in industry or government. In industry or government, research is itself the objective, or is the immediate objective in a series of objectives. On a university campus, research is the principal means for developing the minds of doctoral students.

Members of university departments associated with professional engineering activities sometimes try to claim exemptions from the general university educational objectives that I have outlined. The argument is that engineers have to take responsibility for the construction of reliable equipment, products, and installations for the benefit of mankind; that this requires practical training and experience that is not incorporated in university education aimed at developing students' minds; and that the engineering departments must therefore be permitted to depart from the broad educational objectives of the university in order to provide the necessary practical training for a professional career. As a civil engineer put it to me recently: "I will take any bet that you will refuse to have an appendectomy performed on you by a Ph.D. in medical science, no matter how well his mind has been developed."

It is interesting to compare the means of acquiring practical training and experience in engineering and in medicine. A man intending to practice medicine obtains practical training and experience by working in teaching hospitals which are frequently located on university campuses. The procedure is highly effective and yet can be made to fit in with academic life. Doctors-in-training assist with real operations on real people who can die (and sometimes do!). There is nothing artificial about a teaching hospital. It is genuine doctor-

ing business, and yet it can be conducted on a university campus.

To use a corresponding technique in engineering, it would be necessary to conduct genuine engineering business on university campuses. Real bridges would have to be designed, their erection would be supervised from university campuses, and real people would risk their necks crossing them. Imagine the howl that would go up from the local automobile dealers if, in order to provide practical experience for engineering students, the department of mechanical engineering went into a full-scale business of automobile servicing! The plain fact is that practical training corresponding to that in the teaching hospital is impractical in engineering.

An engineer receives his practical training and experience in industry after obtaining a university education, or sometimes concurrently with it. The vast business activity involved in the practical training of engineers has to be conducted within industry; no other arrangement is feasible or, probably, even desirable. Important, therefore, as the practical training of engineers is to mankind, it is not achieved by exempting university engineering departments from the preeminent educational objective of a university—the development of students' minds (*1*).

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Note

1. This material was presented during a symposium at the University of California, Berkeley, May 1963, and was based on a paper presented before the International Conference on Electrical Engineering Education, Syracuse University, September 1961. The author is IBM Professor of Engineering and Applied Mathematics at Cornell University, Ithaca, N.Y. He is temporarily at the Stanford Research Institute, Menlo Park, California.

Research in China

As agricultural research workers in mainland China several years before 1948, we can hardly agree with the statement made by Cheng in the first paragraph of his article "Insect control in mainland China" [*Science* **140**, 269 (19 April 1963)] that ". . . Before 1948, no organized research . . . in any field of science existed [in mainland China]. Insect control was practically unknown to the average farmer, who in his lifetime never saw a sprayer or a duster . . .".

Universities (for example, the University of Nanking since 1888) and