TECHNOLOGICAL EDUCATION AS PART OF THE EDUCATIONAL SYSTEM*

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Technological education has become an engrossing subject for scientific, industrial and political figures in all countries. The large-scale development of the natural sciences and, subsequently, of technology, is producing structural changes in industrial production in many respects, leading to a change in the tasks confronting specialists. An extensive differentiation is taking place in certain scientific fields. At the same time, there is a strong tendency towards integration in high standard technical management, as most modern manufacturing processes require the complex application of a number of basic sciences.

This development of science and technology has made urgent the training of technical experts for the near and distant future. We may say that technical training and post-graduate training have become a major problem, and perhaps the most important one, of industrial production in our time.

Immediately following the second world war, the first step towards solving this problem appeared to be a substantial increase in the number of technical experts trained on the intermediate and higher level. (Data in this sphere concerning the U. S. S. R., the United States, Great Britain and France are a matter of public knowledge and are not quoted here.) The fundamental contradiction just mentioned has not been solved by a substantial increase in the number of students attending educational institutes on the intermediate and higher level, or by the manyfold increase in their numbers in certain instances and specialized fields. This contradiction has developed from the revolutionary change which has taken place in the natural and technical sciences. The necessity of fundamental changes in technical training, despite the great numerical increase and the establishment of many specialized educational institutions, has been stressed by notable personalities in all important industrial countries. In short, the relation between theoretical and practical training appears to be unsolved at this time.

Modern technology requires that the specialist shall possess extensive

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and new theoretical knowledge. This knowledge may be acquired by the students only at colleges and universities. At the same time, modern technology requires engineers who possess an extensive fund of practical know-how, which may be acquired only in their receptive youth through work in large-scale modern factories. No nation in the world would be willing to have its young intellectuals remain totally ignorant of history, literature and the arts, while they prepare for careers in the natural sciences and technology. A thorough knowledge of political economy likewise is an urgent requirement for the majority of engineers. If we also take into consideration the quantity of technical literature increasing in accord with an almost exponential function, every scientific and technical worker must have a competent command of two world languages; this makes it imperative for even the young intellectuals of the largest countries to study at least one foreign language.

If we were mechanically to align all these requirements, then an undergraduate engineer would require a minimum of ten to fifteen years of technical education over and above primary school to be able to acquire all the knowledge demanded of him during his career. This would be simply absurd: there are natural limits to extending the period of training (age, capacity for study, rational proportion of life span spent at study and work etc.). In addition, science and industry, which are making rapid strides forward, continue to advance with leaps and bounds during the period of training, irrespective of how well that training has been selected. Therefore, should we endeavour to solve the problem mechanically, we may easily arrive at Zeno's paradox of Achilles and the tortoise.

But, it may be pointed out that these problems are due to the basic contradiction existing at present between the structure of production which is developing by leaps and bounds and undergoing a qualitative transformation, and the present categories of technical instruction. This contradiction is extremely sharp. While industry is going over to completely new methods of production, the fundamentals, structure and standards of technical instruction are extremely rigid and, apart from the introduction of certain new subjects and branches, correspond in general to the educational system of half a century ago. In other words, while the content of an engineer's work and the demands made on technical experts are radically different from what they were a few decades ago, the forms and methods of preparing engineers have progressed very little. It seems unavoidable, therefore, to re-examine, re-assess and make radical structural changes in the system which was evolved in essence in the latter half of the last century.

Attempts have been made in all large industrial countries, especially during the past five or six years, to re-examine the structure of technical education and to introduce structural changes. Many scientific institutions, like the Engineers Council for Professional Development ,U. S. A., the National

Council for Technological Awards, Great Britain, the Institute of Engineering Pedagogy at the Technical University of Dresden, German Democratic Republic, and others, are engaged in working on these problems.*

The vast project presented by U. S. S. R. Prime Minister Mr. Khrushchov last year, and which has already been launched on the basis of the Soviet Government's resolution following comprehensive debate, may be regarded as a major initiative towards a radical solution of the problem outlined here. The extensive reform of the educational system now in progress in the Chinese People's Republic, and the experiences accruing from the measures introduced in Czechoslovakia and the German Democratic Republic, are all worthy of careful study. Attention should be given to the practical steps taken in Great Britain in the sphere of the "sandwich" system of technological instruction.

These examples illustrate how structural change in the system of technical training is being considered in every important industrial country. However, the change ought not to be limited solely to transforming technical instruction as such. The problem of modernizing technical education will only be solved by transforming the entire educational system. Education specialists in all countries attribute great importance to the extensive educational reform in progress in the Soviet Union, precisely because it is aimed at a radical transformation of the entire educational system, based on prolonged preparatory work.

Undoubtedly, the history of a given country, its educational traditions and industrial development, the world economic situation and trends in economic development, will affect the method by which these problems are solved. There is not doubt either that the methods for resolving the problems will vary widely in countries with different social systems. However, the objective is modern scientific and technical development in all industrial countries, and it is appropriate for scientific workers — and those engaged in education in particular — to give special attention to each other's activity, and to exchange views at international conferences as well as through exchange visits and on-the-spot study of systems and methods of training.

I shall attempt to outline here a few of the problems, based on the wealth of international technical literature specifically referred to previously, which exist in the educational systems of all advanced industrial countries, and which should be examined with special attention in our attempts aimed at reforming technical education.

* *The Proceedings of the Institution of Mechanical Engineers*, 1957, Vol. 171, Nos. 6 and 12, present data and debates which are extremely interesting. Of the many articles published on this subject by leading scientific and technical journals, I would like to mention the valuable studies which appeared in *Engineering*, a British journal, from 1954 to 1959. The material presented at the Symposium held at the time of the Fifth General Assembly of the World Federation of Scientific Workers in Helsinki, September 1957, likewise made a valuable contribution to technical and scientific and cultural co-operation among the nations.

1. Problem of a universal and uniform basic education

All advanced industrial countries are striving to raise the low limits of education for all citizens to the highest possible plane. We may call this stage of schooling and education, basic education. This first stage of schooling varies in the advanced industrial countries from seven to ten years. If we accept that the modern development of technical education can be solved only within the development of the entire system of education and in correlation with it, then this has a twofold influence on basic education.

At school, students preparing for a technical career should get an adequate general education (language, literature, history etc.). At the same time, it is necessary to ensure that those students, whose future career will not be in industry, technology and science, shall acquire an understanding of modern science and technology. We may say, therefore, that the crucial problem of developing the entire educational system and, within it, technical education, is the constant development of basic education and the optimum satisfaction of this twofold requirement within a uniform system. We should grant high recognition to the efforts of countries which, in addition to satisfying these twofold requirements, are also pursuing a third objective: that during the final years of the uniform basic education, the students shall participate in some form or other of productive work. Endeavours aimed at developing a universal and uniform system of basic education, are justified by the fact that the majority of 13/14-year olds of to-day are unable to decide on their future careers. In my opinion, this phenomenon is becoming ever more general in the epoch of the radio, T. V. and high-speed aviation. With the elimination of the ancient barriers on time and space, the growing child is becoming acquainted with an ever broader sphere of the world and of life; he has a growing opportunity to "choose" from among the professions offered to him. Therefore, the period of choosing a career is shifting increasingly towards a higher age group (16—18 years). This circumstance urgently requires a far more diversified period of primary school education.*

To sum up: the tendency of expanding basic education tends at present towards establishing a uniform basic school, a type of school with the task, on the one hand, of assuring a solid foundation for basic knowledge in science and technology, and, on the other, in the humanities, linking it according to possibilities with the objectives of the "work school".

* At the beginning of the century, the school system in Central Europe which existed in certain countries up to the second world war, and the most shocking example of which was that of the Austro-Hungarian Monarchy, placed children at the age of ten before a final choice by compelling them, after four years of elementary school, to enter entirely divergent educational institutions, which from the outset decided the later choice of a career. I do not wish to dwell here on the political considerations and objectives of that school system.

2. Basic technical education

Following the basic education discussed under Point 1, we must proceed to the question of choice of a profession, breaking down the trend in training according to the ability, aptitude and interests of the students.

I share the opinion of those who insist that two or three years spent in productive work should be a condition for acquiring highly skilled training, irrespective of the chosen profession. Consequently, this phase of training would be fitted in between completion of the period of general basic education and the more restricted period of professional training on a higher level, not only for future engineers, bur for those preparing for other intellectual pursuits.

It would appear that the tendency to direct youth towards productive work after they complete their general basic education and before entering technical training at the intermediate or higher level, is an indispensable part of the education of youth preparing for a technical career. This solution is a paramount link in resolving the contradiction between theoretical and practical technical education.

In an educational system of this nature, young men and women, who have acquired a general basic knowledge and are preparing to enter the engineering profession, have to choose an industrial occupation, master it and become skilled workers. To-day we should take as our point of departure the fact that the formerly sharp differentiation between the worker and technician, or the technician and engineer, is becoming obliterated. Modern industry requires skilled workers with a far greater knowledge of science and technology than their counterparts of ten or twenty years ago. Consequently, modern training of skilled workers during the period apprenticeship, does not exclude but rather makes indispensable a solution of apprentice training in which the time spent by the student in the factory (4—5 hours daily) should be planned so that after work, or as a part of it, he may be obliged to acquire, with appropriate assistance (evening schools etc.), a knowledge of mathematics, physics, chemistry etc. These subjects are necessary for a skilled worker's training, on the one hand, and, on the other, should be on a plane which meet the requirements for admission to college.

A system of training skilled workers over a period of from two to three years, varying from trade to trade, would give industrial workers qualifications which are higher than the present ones. In addition, it would equip youth in the 18—19 age group, who wish to go on to college or the university, with extensive industrial know-how — skill and experience — by the time they enrol in college. The educational reform in the Soviet Union mentioned previously, is based consistently on a similar principle. Similar endeavours may be noted in other countries, even though they may not constitute a permanent system (Great Britain, for instance).

Thus, a system of general, universal basic education and of vocational training offering high standard qualifications and fitted in between institutions providing intermediate and high level technical training, would be a substantial contribution to raising technical standards, for two reasons. Firstly, besides the training acquired in manual labour, the general skill of industrial workers would be augmented considerably by an obligatory knowledge of science and technology; secondly, qualified undergraduate engineers who desire to continue their studies at technical universities, would possess considerable factory experience on entering their university studies. Only those students who have been selected through a rigorous "competition" would enter the universities.

3. College and university training

Articles taking higher institutions of technical education to task generally approach the problem by examining the two tendencies observable in the types of schools within the various countries or within a single country — that is, the tendencies apparent primarily in technological training, or theoretical and scientific education in particular. For instance, Professor H. S. ARMS notes in his article "The American System of Education and Training of Mechanical Engineers," that in Great Britain the tendency in improving the training of engineers is to increase the quantity of technological education and provide education on new technological processes, while in the U. S. A., the emphasis is placed on more intensive education on fundamental sciences and theoretical-technical subjects. In my opinion, both tendencies are proper and justified in large countries. There does not necessarily have to be a contradiction between the two tendencies if the aim is to solve the problem in the entire structure of the educational system.

If, following the preliminary training outlined in Point 2, the undergraduate engineer does enter college or the university, then it would appear necessary for two types of institutions training engineers to be maintained in the large industrial countries. The first, which would enrol far more students numerically speaking, would have to be a type of college providing training of a technological nature in particular. These colleges would offer specialization in a more restricted field to meet the technical requirements which are rapidly becoming differentiated. The second type of college, or rather technical university, which would enrol far less students numerically, would offer fundamental scientific training of a wider scope. Students possessing outstanding theoretical aptitude would enter these universities. Three or four years would be required to complete the first type of college training, while five or six would be required for the university. I wish to stress that the point at issue here is educating the students to fulfil two different types of engineering functions.

The two types of colleges (the core of which exists in the system of the German *Fachschule*, or *Technische Hochschule)*, should not be separated rigidly from each other of course. If we intend to solve the development of technical education, and to do it well, in the school system as a whole, then our aim must be to establish an educational system from the elementary school to training on the highest level — which will enable experts graduating from all types of schools to acquire the ensuing higher level of training, if he has the ability to do so. Therefore, we must see that the student may acquire dissimilar training by studying subjects which are essentially different, without having to go through all the subjects (including those well-known by him) of the institution offering higher education. This would serve the interests of both the individual and the economy of the country concerned, while providing an incentive for experts to aim at higher-level qualifications.

As far as college training is concerned, I wish to mention two other problems:

(a) *Problem of production experience*

In a system of fundamental technical training as outlined under Point 2, the curricula of the colleges could include practical work in the factory, during which the students, instead of being mere "observers" could fill responsible technical posts for one or more months while they are securing practical experience in production. The level of responsibility of the assignment could depend on the number of years spent in college. In this way, undergraduate engineers would have active contact with industrial development during their college studies.

(b) *College education by way of evening classes, correspondence courses, and "sandwich" courses*

I believe that in the system sketched, increasing importance will have to be given to these forms of college training. A system of universal and uniform education would offer people of varying age groups, who wish to study at higher educational institutions for various reasons, more favourable conditions to select from among these diverse forms of continuing study which help to co-ordinate the entire system of education.

4. Post-graduate training, extension training, scientific degrees

The importance and problems of this topic require a special study, and I wish to mention it here only to the extent that it fits into the general educational system.

As I pointed out at the beginning of this paper, the dual tendency of differentiation and integration of technical development requires, at all levels of production, experts equipped with greater scientific qualifications. Similarly, I have shown the dual tendency of differentiation and integration in the stages of superimposed training.

School training

Universal basic education (7—10 years) — no differentiation.
Basic technical training (2—3 years) — differentiated

College training

Technological (3—4 years) — differentiated.
Basic scientific theory (5—6 years) — integrated.

The next rung on the ladder is specialized study, scientific qualification on a plane higher than the college level, in a narrow field sharply differentiated. A proportion of the engineers may meet the dual requirement by acquiring qualifications which are always on a higher level. Methods of obtaining scientific degrees vary widely from country to country. I believe that the system of "aspirants", developed in the Soviet Union and some of the People's Democracies, is well worth attention. This system, which provides a high degree of incentive, is constantly in the process of evolution. The system of candidates and doctors offers both moral and material encouragement to talented specialists.

Summary

Rather than presenting these issues as proposals, my intention has been to underline the tendencies apparent in all countries, to a greater or lesser extent, which have accrued from the rapid development of science and technology, by studying the important initiatives and efforts which have been made during past years in the advanced industrial countries.

The thoughts expressed in this paper are largely based on the reports made at the Symposium arranged at the Fifth General Assembly of the World Federation of Scientific Workers, held in 1957. I have drawn also on recently published international technical literature. I think it would be appropriate to hold a series of international conferences to deal with the problems of the educational system in general, and technical instruction in particular. I have in mind a type of conference at which experts would, through personal contact and debate, study the achievements of countries with different social systems. This would contribute to mutual understanding on one of mankind's major issues, in the interest of future generations.

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