SCIENTIFIC AND TECHNICAL PROGRESS AND ENGINEERING EDUCATION*

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1. The rapid development of natural sciences during the past 25 years, — particularly during the last decade — resulted in extensive changes in technology and production. In most of the developed and semideveloped countries, this enormous progress brought about new branches of production, while other branches, or processes, became outdated as a result of the "revolutionary" development of science and technology.

In this process, which is typical of our age, the most important index from the socio-economic and industrial view-point is the rise in productivity. Today, it is a generally acknowledged principle that science and technology belong to the forces of production, and represent the fastest developing and most mobile element among them. Consequently, in our era, qualification and the constant enhancement of the acquired qualification is a factor of utmost importance within the development of the forces of production; a basic factor of productivity.

The rapidly expanding national economy, the ever more complex technology which has to ensure the rapid increase of productivity, and basic research as its scientific foundation, have led to the formation of a wide spectrum of experts. In order to ensure specialists for permanently changing and rapidly developing production within the framework of a training system, based on relatively stable fundamental principles, a thorough analysis of this broad spectrum of experts is necessary. The range of action of the individual categories of specialists also has to be examined from the angle of expectations (as to activity and content), as well as the relative proportion of the groups within the spectrum. It is obvious that to create an educational structure of a relatively durable validity, the most assistance has to be acquired from the change mechanism (if its trends are recognized and adequately described) of this proportion. Parallel with this analysis, education for economy also has to be investigated. Although we know that the analysis of the spectrum of specialists

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will inevitably produce both gaps and overlaps, we cannot give up such examinations, for the initially quoted productivity factor in the national economy could only be efficient in case of optimum proportions in the training and post-graduate training of specialists.

2. These introductory statements with respect to the educational system lead to some important conclusions. The four or five years of college or university education, based on "classic" conventional primary and secondary level education, qualifies graduates to "freely practise" their profession. The current development of science and technology indispensably requires the revision of this classic educational system: it has to be extended far beyond the completion of university studies, with the continuous acquisition and supplementation of knowledge.

In other words, the accelerated increase of knowledge in new scientific and technical fields necessitates the continuous addition of new facts to the acquired scientific knowledge, the discovery of new connections within the old knowledge, and the rapid exchange or revision of obsolete knowledge. By its very quantity and quality, the increasing field of knowledge protracts the time of acquisition to a degree where permanent study and post-graduate education seem an imperative realistic requirement. The impact of this phenomenon on the education of specialists should be examined from two different aspects:

a) All essential factors of this expanding revolutionary transformation (the so-called scientific-technical revolution) have to be surveyed in a relatively short period of time. This survey will permit the formulation of the principles of an "ideal" educational system of a completely *new structure* — valid for at least 15 to 20 years — ranging from primary to highest level education, co-ordinated with the trend of the developing scientific-technical revolution. The emphasis has to be placed explicitly on the unavoidable reshaping of *structure.* This refers to the questions of purport and methodology, and to the selection of students according to their aptitude for a given profession and their receptivity to new ideas.

b) With consideration to the present realities of purport and methodology of the heavily inertia-laden educational system — developed as modern during the past 50 years — possibilities have to be elaborated for a *gradual transition* between the *actual* education of natural sciences and engineering, and the *projected* educational system on absolutely new foundations, as outlined under *a).*

Both of these aspects are of equal importance; if handled in any other manner, higher education would be confronted with heavy conflicts, from the side of the rapid development of scientific methods of production and research, changed as a consequence of the scientific-technical revolution, likely to clash with the rigid, traditional, unchanged forms of higher educational institutions.

Consequently, the *modern* training of young people, studying scientific or engineering professions, to comply with the scientific-technical revolution, is concomitant to the revision of the entire educational system, from the aspect of purport and methodology (and particularly, the secondary educational courses prior to higher education).

There are several important steps on the path to provide specialists through higher education for the year 2000; education for independent thinking, acquainting young children — according to some teachers, at the age of 6 to 9 — with the concepts of mathematics, physics, chemistry and biology; education for a scientific approach and abstracting abilities during the most susceptible years (12 to 18), generalization of methods, taking the versatility of the individual into consideration; the introduction and extension of mechanical (audio-visual etc.) teaching aids, which reduce the routine study time, and many others. Serious attention has to be paid to the development of various types of broadcast university courses to increase the technical and scientific knowledge of broad masses.

3. With regard to the structure of natural scientific and technical higher education, an integration of sciences, the reinforcement of interactions, the amplification of the phenomenon of "interdisciplinarity" as a result of the multiplication of marginal sciences have to be reckoned with, as well as with the tendency — contradictory or at least seemingly contradictory to the above — which requires specialized knowledge in a narrow field, for the perfection of the actual production.

In our opinion, this is an existing and relevant, but not irreconciliable contradiction. However, the solution has no universal formula to cover every sphere, and valid for a long period of time. The number and qualifications of theoreticians — primarily in marginal sciences — or of highly qualified technologists in a narrow field, can only be decided — as required by the two tendencies (integration — differentiation) in a given stage of development — according to each branch and in the various stages of technical development, for a relatively short period of time.

4. Recently, a multitude of reform endeavours, requirement surveys and exigency revaluation were launched throughout the world, entraining organizational dispositions in the technical education of a secondary, higher secondary, and higher (university) level. In the following, an attempt is made to contribute to the discussions on the development of education, particularly at *university level.*

It should be said in advance that most of the work done by technical intellectuals in industry, production, design, operation, technical conservation, and even in certain (non-managerial) positions of scientific research work, will continue to be done by specialists of differentiated qualifications. Obviously, however, this broad pedestal of the "pyramid" of technical intellectuals needs a much more thorough education in fundamental knowledge and in natural scientific approach than the present one, imposed by inherent conditions of the scientific-technical revolution.

5. Keeping this in mind, let us speak of the type of specialists educated at the universities of the future — needed in a relatively lower number — who are selected for their aptitudes, particularly for research and development work; they have to be imparted a different kind of knowledge — more accurately, a scientific-professional receptivity — which enables their knowledge to be converted for new requirements by means of serial recyclings of low periodicity.

If we accept this idea, then we can assume the following advantages of higher educational structure, built on such a basis:

a) The conditions of admission to higher education in natural sciences and engineering have to impose increased requirements. Candidates complying with these increased requirements have to be imparted profound fundamental knowledge in their basic speciality, and the essentials of applied science, during a study time of 3 to 4 years.

b) The work of universities and high schools does not end with graduation. After a few initial years of work, graduates have to be encouraged to specialize, through post-graduate education, in the narrow sphere around their actual work, range of interest, and professional problems. These post-graduate courses of an infinite variety of duration and character are naturally to be sponsored by the universities. By this, the obsolete ideal of polarization to a technologist or a researcher has been sublimed into multiple post-university specializations.

Recycling (in periodical series) would engage the majority of specialists throughout their professional life; this would make their scientific and engineering abilities adaptable, convertible and versatile, to cope with actual requirements — among others, the ever growing number of totally new fields of the so-called interdisciplinary or "borderline" sciences.

From the psychological point of view, such a development would eliminate many of the break-downs arising from a premature specialization, which reduce many technical specialists with otherwise adequate abilities to jobs far below their unrevealed qualities, after the age of 30.

c) The future shaping of the higher educational structure according to the lines above would induce the three — equally important — scientific-technical factors of a modern society to a closer co-operation than the present one. These three factors are the system of higher educational tuition, the research institutions, and the industry. In future, a closer co-operation could be established between the institutions of higher education and research.

d) All this strives to prove that today the "closed" training system, in general developed about the turn of the century, is untenable. The "closed" tuition system is not suitable for supplying the actually required specialists for the actual employment structure. A solution can only be found with a wider range of education involving more comprehensive fields, and completed by post-graduate training based on this. This post-graduate education system can be built on the "closed" fundamental education in two ways:

- multidirectional education corresponding to fundamental education (horizontal specialization); or
- periodically superimposed (vertical) post-graduate education, providing a more thorough knowledge in a restricted field, and granting higher qualifications.

The above statements — more or less closely outlining the involved categories — lead to the conclusion that while the organization of our high school and university educational system has to be improved, the main means of "higher education" in the field of technical professions should be the constantly mobile and — as earlier mentioned — dynamic post-graduate system.

e) We cannot ignore the fact that an important percentage of actual and future specialists to be appointed to leading posts in social production (managers on various levels), will come from the ranks of technicians with basic technical qualifications. This circumstance obliges planners and organizers of a higher education, and of the entire education system, not only to graft scientific social knowledge on future specialists at an early age, and to educate them to think and act accordingly, but also to introduce the essentials of management into technical higher education. A differentiated post-graduate education system — as mentioned in several instances in this study — will ensure that the higher scientific-engineering and scientific management knowledge will be utilized in the optimum ratio as required by the actual job.

f) Such specialist education and post-graduate training, pointing towards the integration of education, higher education, research and industry — undoubtedly laden with risky extrapolations — would also provide the possibility to resist the current fashionable views attempting to utilize the scientific-technical revolution to prove that "the bulk of scientific knowledge, outdated and to be replaced every five years, prevents people from doing full-valued work for a long period of time, if engaged in sciences and technology". These often superficial views raise scientific panic and a spirit of defeatism; they are likely to develop scientific anarchy among university students, and encourage them to demand the overthrow and replacement of traditionally developed institutions. In our opinion, both types of panic are avoidable! Even for *a five-year period* of outdating and reproducing knowledge, the knowledge of trainees at universities and high schools, *based on fundamentals, with a thinking in scientific categories, is always adaptable and convertible.*

Present difficulties must not be allowed to lead higher education onto a methodological and organizational no-man's land between what is obsolete and undeveloped.

Summary

i. Scientific-technical development has brought about a crisis in traditional higher education. The necessity of preparing and introducing important, far-reaching, methodological, organizational and conceptual variations into the training of specialists of natural sciences and engineering, to cope with the problems raised by the demands of society and rapidly developing industry, has to come to the foreground.

ii. The proficiency of the required variations depends on projecting the entire structure of the educational system for at least two decades, and on developing the transition varieties by taking prognosticizable trends of scientific and industrial development into consideration.

iii. Much care has to be spent — in addition to the quantitative and qualitative development of university training — to the perspective development of a new basic system from among the various tendencies of specialist education, replacing the present extensive specialization:

— A uniform education divided according to the main branches (mechanical engineering, construction, electronics, electrical engineering, chemistry, etc.) essentially based on priming subjects, training for independent thinking and work, followed by a series of post-graduate courses of defined, various periodicities and directions, throughout one's professional life.

— This consecution of post-graduate education may induce specialization of well-founded basic knowledge, adaptable to actual demands and convertible to new knowledge.

iv. At the same time, such a unity of education and post-graduate education demands a closer co-ordination between universities, research institutes and industry.

v. No synchronism can be expected between the scientific-technical revolution and the "revolution of specialist education". A radical change, without the realisation of this fact, in the long-term perspective, ignoring the activity of specialists far beyond study years, affecting only higher educational institutions,is likely to produce a condition of failure to reach the desired maximum — either for the individual or the society.

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