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THE NEED OF SCIENTIFIC TRAINING FOR ENGINEERS:
PROBLEMS AND PROSPECTS IN BRAZIL*

by

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ABSTRACT

This paper discusses the demand of university-level engineers in Brazil. Information is given on the schools of Engineering in Brazil, on the yearly output of engineers, in each field of specialization, on their industrial demand and on the measures taken to increase the output.

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The need for the training of engineers in the basic sciences is emphasized and claimed to be important for the developing countries as well as for the advanced countries. The difficulty offered by the obsolete structure of traditional universities can be provisionally circumvented by the creation of modern institutes, where research work is intimately associated to the teaching function, which will give an example to the older ones on how to change.

An example is described in the field of physics, in Rio de Janeiro, where the Brazilian Centre for Physics Research spontaneously became a national centre of training of assistants of physics and graduate students of Engineering Schools of other regions of the country.

Another initiative which it is hoped to influence favourably the quality of the scientific and technological education of technicians, engineers and scientists required to maintain and expand that development in the frame of the national interest. The first problem is the affair of economics and engineering specialists. The second problem has usually been discussed by these experts and by educators. I believe that the scientists of such countries should have a great interest in the problem since they have something to say about the education of scientists and engineers.

First of all a remark must be made concerning the transfer of industries to less developed countries. They immediately require a certain number of specialized workers and technicians. But if the technological and industrial problems which occur are not to be investigated only abroad and their solutions exported to the less developed countries - if they are to be investigated and solved locally, as it must be - there will be a growing need of university-level engineers and scientists.

In Brazil, such a need starts being felt. There was, in this country, in the last 20 years, an industrial growth which was not accompanied by a corresponding output of intermediate-level technicians and university-level engineers. Of great significance - to summarize the situation in this respect - is the fact that,

according to the 1950 census, only 1.15% of the personnel working in industry had a technical education. This index expresses the low technological level of the industry in this country ¹.

The number of university-level engineers evaluated in Brazil in the 1950 census was 25 532, corresponding to an index of 1 engineer per 2 000 inhabitants. This index, however, includes engineers who do not exercise their profession or who have administrative functions only. Less than 50% of the university-educated engineers work in industry: the figure is 44.5% ². One obtains, therefore, an index of the order of 1 engineer working in industry per 4 000 inhabitants in this country.

In the United States, in 1957, there were 528 000 engineers, 152 000 scientists and 58 000 administrators of scientific and engineering activities employed by industry, of which about one third were engaged in research and development activities ³.

This problem has been the subject of discussion and studies in Brazil and is leading to the organization of new Engineering Schools and new Universities in this country. The Table I gives the number of university-level schools of Engineering in Brazil ⁴ since 1940. From 1940 to 1950 only three new schools were created while from 1950 to 1962 sixteen new schools were organized. The Table II gives the number of engineers graduated in Brazil ⁴ yearly since 1940 and by specialized fields. The numbers are exceedingly small. It must be pointed out that the new schools have not all been created as a result of a pre-established program. And in fact the organization of such Schools have not been accompanied by the required intensive program of training of professors and assistants for the new positions, in spite of the important effort of the Brazilian National Research Council (created in 1951) and of the Commission for the Training of University-level Personnel (CAPES) (created also in 1951), which have had a very limited budget for this purpose. The Table III gives the number of fellowships granted for studies abroad by the first of these organizations ⁵ from 1956 to 1961; Table IV gives the number of fellowships granted by CAPES ⁶ in the period from 1953 to 1961.

They illustrate the highly unsatisfactory situation concerning the training program.

It is not enough to increase only the number of universities. It is indispensable to improve the quality of the teaching and research staff. In the Engineering Schools, the Assistant and Full Professors must be competent not only in the case of the disciplines which have an applied character but also in the basic sciences and they must be dedicated to their jobs in the university. And a national effort has to be called for a change in the structure of the Brazilian Universities to make this possible and to change them into modern institutions corresponding to the actual needs of the country.

How does one change the structure and the mentality of old and obsolete universities in countries in a stage of development? If one sets aside the intervention by force or the reforms which follow from revolutionary movements, an efficient way to induce such a change is, in the opinion of the writer, the creation of a new institute or a new university with a good and modern structure and a competent staff, which will in the long run provide an example for the other, traditional, ones to change.

Two examples are now available in Brazil.

In 1949, an institute was founded in Rio de Janeiro in a special field, the Brazilian Center for Physics Research (Centro Brasileiro de Pesquisas Físicas). It had the support of scientists, engineers and men of social and political representation and its aims were to promote and stimulate research in physics and to offer courses on those branches of this science which might be regarded as a complement to the university courses in the Schools of Engineering and of Sciences in the country. The structure of this Centre was chosen to be that of a private institution to allow for more flexibility in its expansion.

One of the great problems which have faced the universities in Brazil has been the structure of their professorship career. The Universities are divided in Schools and each one of these has a given number of disciplines called chairs. Each chair is occupied by a Full Professor (called "professor catedrático") who is ap-

pointed after a competition takes place in which the candidates present a thesis, give classes and submit to practical and written examinations before a Committee. In such a system, the scientific production and life of the candidates are considered with a relatively small weight if at all.

In the Brazilian Centre for Physics Research this system was abolished. The career starts with the position of Instructor and follows through the positions of Third Assistant, Second Assistant, First Assistant to Associate Professor and Full Professor. Scientific and teaching experience, with strong emphasis on original scientific work carried out, are the fundamental criteria for admission and promotion of the scientific staff of the Centre. From the beginning, young graduates were admitted for post-graduate training and sent abroad with fellowships after they had already carried out research work in the Centre. Several of these young men occupy a research position in this Centre and elsewhere after having completed their doctoral work abroad.

As a result of the work thus developed, young assistants and graduate students were sent to the Brazilian Centre for Physics Research by the Schools of Engineering of other regions, of Brazil, such as Pará, Ceará, Pernambuco, Bahia, Minas Gerais, Paraná and Rio Grande do Sul States for initiation in research work.

Training has been offered in two levels: in an elementary level, as a review to unsatisfactory courses obtained elsewhere, the Centre has offered a course with laboratory experiments in General Physics and practice in glass work, machine shop, electronics, precision optics and mechanics. Graduate and post-graduate courses have also been offered in experimental atomic physics, structure of matter, nuclear physics, solid state physics, electronics, quantum mechanics, electromagnetic theory and several topics of advanced theoretical physics. Research work has been carried out and published, mostly in journals of international circulation, on cosmic radiation physics, nuclear chemistry, nuclear emulsion studies of low and high energy events, elementary particle and quantum field theory, nuclear theory, problems of propagation and diffraction of electromagnetic waves, solid state physics⁷.

The modernization of Engineering education in the universities of countries in phase of development will hardly be successful - let me emphasize it again - if basic research work is not stimulated at the same time. It was the reputation obtained in Brazil and in the other Latin American countries by the research effort employed by the Brazilian Centre for Physics Research that attracted graduate students and Assistants from the Engineering Schools of universities of other cities of Brazil to the Centre for an intensive training period in physics. This work has offered a conspicuous example of the fundamental importance of an intimate association of research and teaching work in the basic sciences. And it proved that it was feasible in this country. Moreover, it spread and brought a concrete support, to the idea that the Physics professorial staff in any university-school - including Engineering Schools - must be first of all good physicists engaged in active research in one of the fields of pure or applied physics. This idea is not accepted without a strong resistance. The Engineers would prefer them to be the professors of any speciality in an Engineering School, even if they only know the special field superficially. And indeed, the by-laws of the Schools of Engineering in Brazil, require that the candidates for the Physics professorship carry an Engineer diploma. If they do not have such a degree their applications for the professorship competition will hardly be accepted.

Obviously, the action of the Brazilian Centre for Physics Research has been limited to physics; and research work has been conducted only in the field of this science in which its scientists are specialized. Its catalitic action has however, been felt through the years in other institutions of the country. Together with other research institutes, the Brazilian Centre for Physics Research has been invited by the federal university of Rio de Janeiro - the University of Brazil - to offer this university's post-graduate courses and training in Physics.

The fundamental problem still remains, however, that the scientists of these research institutes do not have access to the university students - including the Engineering students - to teach and train them while they still are in the undergraduate level. For in Brazil, many research institutes and many first-rate scientists

are outside of the universities not because they do not want to teach; but because the universities have been closed to them and have presented obstacles to their incorporation into the university.

The other important initiative which it is hoped to significantly contribute to the improvement of the education of engineers in Brazil was the creation in December, 1961 of the University of Brasilia. Since about four years ago, a group of Brazilian scientists and educators strongly defended the idea that if the new Capital of Brazil were to have a university, this must be different from the traditional universities in the country. A rare opportunity was offered to build a modern university which would abolish the system of appointing catedráticos and would invite competent men to start each department. Moreover, it was suggested that the University were formed of Institutes of basic sciences such as mathematics, physics, chemistry, biology and geological sciences, and Institutes of Arts, Letters and Social Sciences. These Institutes would offer the basic and advanced courses for students who wanted a degree in that special field. But such institutes would also give the basic courses for students who after two or three years would go into a professional school of the University such as Medicine, Technology (comprising the several branches of Engineering) and others. The structure of the university has been outlined elsewhere⁸. The plan is progressively being made into reality.

Physicists from the Brazilian Centre for Physics Research have been invited to organize the Institute of Pure and Applied Physics for that University. A detailed program for this institute is under study which will include a substantial amount of basic and modern physics and physical techniques needed for the modern engineer as well as for physicists and chemists. It is hoped, furthermore, that there will be strong interaction between the staff of the Physics Institute and that of the Technology School in the choice and contents of subject matters for regular and special courses and in research work.

If this work is allowed to proceed according to the plans and recommendations of the experts and if the best scientists and specialists in other fields of knowledge are finally appointed to the staff, this University will have accomplished a peaceful revolution in the Brazilian University system.

Already, the University of Brasilia, its aims and its intended organization, is affecting the older universities - which take the first steps to review their present structure.

These are some of our problems and expectations in Brazil. In the advanced countries, the scientific training of engineers is almost automatically offered in good universities which have science departments working side by side with the engineering departments.

In a country like Brazil, the need of a greater output of university - level engineers and of intermediate technicians is presently recognized by industrialists and Government authorities.

There is, however, presented before us the problem of changing the universities, their system of selection and appointment of professors, the problem of attracting competent young men to scientific and teaching positions in our universities, of creating these positions and opening them to such young men, of surmounting the traditional obstacles which are opposed to modernization.

Local initiatives, as the ones described in this paper, need, however, aid and cooperation. It is very important that international organizations which have as their program to stimulate technological education and industrial development, have a full realization of the special problems of each country and of the region it belongs to. An organization, like the United Nations Special Fund, which considers requests of aid to improve Engineering education in developing countries, must understand that basic science and scientific research are also important in modern times, for engineers, for electronic engineers, metallurgical engineers, nuclear engineers, among others.

A failure to stimulate the proper interaction between science and technology, a pressure to separate and isolate the Engineering Schools from the Schools and Institutes of Sciences represent a step backwards and a threat to make the economically smaller countries developed only to the stage when they can import ideas and assemble mechanisms invented abroad.

Table I

Number of University-Schools of
Engineering in Brazil

Year	1940	1941	1942	1943	1944	1945	1946
Schools	13	13	13	13	13	13	14
Year	1947	1948	1949	1950	1951	1952	1953
Schools	14	15	15	16	16	18	19
Year	1954	1955	1956	1957	1958	1959	1960
Schools	21	22	25	26	26	26	28
Year	1961	1962					
Schools	30	32					

Table II
Number of students who completed university courses in engineering

Fields	Years																				
	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
Total	273	303	245	356	413	585	685	667	896	968	961	1036	870	1132	1259	1176	1323	1123	1239	1418	1446
CIVIL	178	205	202	243	328	426	527	503	637	713	696	751	590	855	933	787	993	785	765	866	731
Others	95	98	43	113	85	159	158	164	259	255	265	285	280	277	326	389	330	338	474	552	715
Aeronautics	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	39	35	45	39	31
Civil, Mines and Metallurgy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	26	11	21
Civil and Mines	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	57	-	5
Civil and Electrical	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	58	13	68	102
Civil and Industrial	13	8	8	11	16	12	23	28	19	49	28	30	27	21	19	30	16	1	23	2	9
Mines	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	12	10	74	17	15
Petroleum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	9	17	27	28	25
Electronics	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	111	93	61	-	102	121
Electrical	44	55	11	43	16	34	60	50	125	99	100	111	125	88	88	111	93	61	-	-	33
Geology	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	32
Industrial	18	17	10	33	44	74	36	29	40	26	29	30	59	10	28	5	8	11	32	32	1
Mechanical	-	-	-	-	-	-	-	-	-	-	-	-	-	-	37	37	69	29	60	73	163
Mechanical and Electrical	13	10	8	18	7	27	20	28	47	46	42	62	45	92	71	67	35	69	67	72	32
Mechanical and Metallurgical	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Metallurgical	-	-	-	-	-	-	-	-	-	-	-	-	1	3	9	3	5	-	4	13	34
Metallurgical and Mines	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	2	6	15
Navy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11
Chemical	7	8	6	8	2	12	19	29	28	35	66	52	23	63	74	80	45	24	42	59	65
Industrial Chemistry	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	10	6

Table IIIFellowships granted by the Brazilian National Research Council

Field	Years					
	1956	1957	1958	1959	1960	1961
Agronomy	10(52)	12(75)	9(81)	(92)	(82)	(67)
Biology	24(142)	25(148)	21(154)	13(152)	4(170)	3(190)
Chemistry	7(52)	14(65)	12(73)	7(73)	2(76)	6(103)
Geology	1(40)	(41)	(39)	(59)	(27)	(25)
Mathematics	5(18)	6(24)	7(27)	3(31)	6(26)	7(37)
Physics	19(44)	17(44)	18(46)	16(31)	10(17)	8(32)
Technology	20(4)	16(9)	9(23)	5(27)	4(28)	6(20)

Numbers outside brackets refer to fellowships for study abroad.

Numbers inside brackets refer to fellowships for work in the country.

Table IVFellowships granted by CAPES
in the period 1953-1961

Agronomy and Veterinary	151
Biology, Medicine and related	1159*
Physics and Mathematics	253
Engineering, Architecture and Urbanism	510

* Including 201 fellowships granted in cooperation with the Rockefeller Foundation.

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