The design of engineering curricula

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Studies in engineering education

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Preface

The effectiveness of recently graduated engineers and technicians is profoundly affected by the curricula followed during their education and training. Among the many factors to be considered in designing engineering curricula, it is important to take into account the content of the secondary stage of the educational system in the particular country, and also the role that the new graduate will be expected to play on completion of his training. This role differs markedly between the highly industrialized countries on one hand and the developing countries on the other. Whereas in the advanced countries the new graduate will enter a formal or informal training period in his first place of employment, in the developing countries he will often have to assume the full responsibility of a professional post immediately.

Within the framework of Resolution 2.23 adopted by the General Conference at its sixteenth session, Unesco convened a meeting of experts on New Trends in Curriculum Design in Engineering Education in Tbilisi (U.S.S.R.) in December 1972. The International Working Group on Curricula Design was established by Unesco as a direct response to a recommendation made at that meeting. The Working Group held its first meeting in Warsaw (Poland) in May 1974, and a second meeting in Paris (France) in December 1975. In addition, several members of the Group participated in the sessions on curriculum design at the International Conference on the Education and Training of Engineers and Technicians held in New Delhi (India) in April 1976.

The Working Group is in an intermediate stage of its activities. It has developed a series of background papers on various aspects of curriculum design, but has not yet finalized its study into a conclusive report. In a sense, the present publication may be treated as a summary of the deliberations of the Working Group to date.

Unesco wishes to express its gratitude to the members of the Working Group who contributed much of the information required for the sections on engineering education in their respective countries. Thanks are expressed also to Dr. Grayson, who integrated the information, in consultation with the Unesco Secretariat, and who co-operated with the Secretariat in the editorial preparation of the manuscript. The facts and ideas are expressed in complete independence of the Organization and the opinions given are not necessarily those of Unesco.

Contents

Foreword

This book is an outgrowth of the activities of the Unesco International Working Group on Curricula Design in Engineering Education.[1] It draws heavily, but not exclusively on the documents[2] produced by the Group, and attempts to summarize and expand upon the work of the Group in developing a methodology for curriculum design. In order to be of value to people in many countries, operating under a variety of social, economic and organizational arrangements, a general approach to design is presented and a framework is described within which a curriculum can be developed. The approach is broad and, I believe, can be applied in a global manner to most situations; yet, the approach can be expanded to add as much detail and precision as required.

The book begins with a series of descriptions of the engineering educational systems in various countries in order to illustrate the variety of philosophical and institutional structures within which curricula must be designed. These descriptions are not case studies; they are not complete enough, nor is there uniformity in what they cover. They are presented as vignettes, in order to highlight certain aspects of engineering education in each country. On the whole, they are meant to show more of the differences than the similarities among educational systems.

The second part of the book presents a generalized approach to curriculum design. The methodology consists of three stages: problem definition, which requires developing an information base, identifying the need for engineers, and setting goals for the curriculum; structuring the curriculum, which includes selecting and organizing the content and teaching approaches to be used, with consideration given to the resources and constraints that exist; and the implementation and evaluation of the final curriculum. The book includes the recommendations that resulted from the meetings of the group (Appendix C) and a series of references for further reading (Appendix D).

I am grateful to my fellow members of the Working Group for the stimulating and enlightening discussions which have developed at our meetings, and to the Unesco Secretariat for guidance and support in the writing of the manuscript. Although this book draws liberally from the documents produced by the Working Group, I have used an author's prerogative to

1. Members of the group are listed in Appendix A.
2. See Appendix B.

edit, delete, modify and re-write material as I believed necessary. I refer to the documents listed in Appendix B as the primary sources for this manuscript, but have made no attempt to reference individual items. While this document reports on the activities of the Working Group, I take full responsibility for the content, focus and shortcomings that exist.

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1 Introduction

Throughout the world, engineering is constantly changing. Technological advances, increases in knowledge, changes in national priorities and funding patterns, and altering social conditions, as well as changes in the profession itself, combine to affect the demand and requirements for engineering services. This in turn has direct implications for the type of education that engineers receive.

It is generally recognized that the wealth of a nation is based upon its power to develop and to effectively utilize the innate capacity of its people. The economic development of any country is ultimately the result of human effort. It takes skilled human agents to discover and exploit natural resources, mobilize capital, develop technology, produce goods and distribute them among the people for the welfare of the nation. In this task of social development, scientific and technical personnel have rendered significant contributions. Engineers and technologists, in particular, have responded to the needs of society and, through their professional activities, have induced events or developed technologies which at all stages have affected human welfare.

Engineering curricula have changed and will continue to change in direct response to the present and anticipated future need for engineering manpower. In a nation such as the United States, for instance, engineering schools began in the early 1800s, when the nation was in its infancy. In the intervening years the United States developed from an agrarian, pioneering country to one with a high degree of mechanization and industrialization, to a country whose technological advances were heavily based on science, to a nation that presently is seeking to apply engineering and technology to the social problems of the nation. Engineering curricula kept pace, first emphasizing the mechanic and practical arts necessary for land development, then the skills necessary for creating and operating a mechanized industry. Still later, the emphasis of the curricula changed to include the mathematics and science necessary for developments in electronics, high-speed production, automation, and space exploration. Today, curricula are beginning to include substantial amounts of the humanities and social sciences, as engineering is being applied to health, education, urban development, pollution control, the development and location of new sources of energy, and other socially related problems.

The social relevance of the engineering profession has assumed more importance than ever before because of the wider impact of the engineers' activities in shaping the social and economic conditions of countries, both developing and developed, throughout the world. Solutions to the problems which confront engineers today must take into account not only technical considerations but also the cost, practical adaptability and, above all, the direct and indirect consequences they will have on the nation's economic and social systems.

The design of a curriculum is not an easy task, particularly for a developing country which lacks a basis of existing curricula designed to meet its past local needs and conditions. Often, it is unsatisfactory to copy exactly a curriculum that exists in another country. Religion, language, history, tradition, culture and philosophy of life and government are important factors in the development of any educational system. Curriculum design is often more difficult for educators in developing countries, as many of them have been educated in developed countries and tend naturally to repeat the curricula under which they have studied. Many of them also have the underlying concern that drastic departures from the curricula of developed countries may result in ineffectual education for the transmission of knowledge. They must balance the advantages of proven curricula against the needs and special requirements of their own country.

Developing countries have other problems that set them apart from the more developed nations. A student in a developing country, for instance, is often poorly prepared to begin the study of engineering, even after he graduates from secondary school. Such a student has less familiarity with mechanical and electrical equipment and their applications than his counterpart in a developed country. In his surroundings, mechanical toys and objects are not commonplace, hence he is deprived of the acquaintance and knowledge possessed by students in technologically advanced nations. The student's lack of familiarity often makes it difficult for him to relate mathematical analyses to the realities which they describe, or even to visualize and draw simple mechanical objects.

Part of the difficulty arises from the fact that advanced technologies are introduced into developing countries at a complete, functional stage. The people in these countries have been introduced, for example, to power systems, airplanes, modern construction techniques and the like, in their present forms, but have not had the opportunity to participate in the growth and development of these technologies, from initial concept to present state. These and other difficulties must be taken into account as curricula are designed.

In this discussion, the term "curriculum" is taken to mean the organized set of content and activities that a school uses as the basis for educating students. The changes in engineering programmes that have occurred to date have been largely due to perceptive individuals who could anticipate the changing needs for engineering services and who were in a position

to modify the curricula. The changes, for the most part, have been in content, e.g. a course in atomic physics replaces a course in electrical machines, although there have been a few notable changes in the types of activities in which a student is engaged, such as the introduction and subsequent de-emphasis of shop-floor training, the development of laboratory work, and the introduction of project-based activities. These modifications have not been based on any scientific, methodological approach to curriculum design, but have come about by traditional, empirical and intuitive methods.

A study of engineering curriculum design practice shows that there are certain common logical steps that can be followed, the identification and analysis of which leads to a methodology of design. The steps in this methodology include an analysis of needs for technical manpower; the setting of specifications which identify qualification profiles or specify desired characteristics in skills, training, and knowledge that the graduate is to possess; the selection and structuring of the content; and the validation and evaluation of the curriculum as it is used.

It is axiomatic that the planning of a curriculum should begin with an analysis of technical manpower needs and an identification of education-occupation linkages, in order to develop engineering personnel with the desired attributes and abilities. This requires an analysis of engineering positions in various sectors of the economy to provide information regarding the skill, knowledge and competencies needed for the range of engineering occupations. This analysis provides the basis for setting the goals and objectives upon which the curriculum is structured.

In the past, curriculum developers have focused on what a student is to know, to the exclusion of how he learns. This was because our knowledge of the human learning process was insufficient. Recent advances, however, in the teaching-learning sciences are providing a basis for changing curricula to account for the learning process, as well as the content. Certain principles have evolved which, if followed, will increase the amount a student learns and remembers. We now know, at least partially, how to organize curricula so that learning is reinforced and becomes easier and more meaningful for the student. This does not mean that we are at a point where a model or recipe can be presented which, if assiduously followed, will provide an optimum curriculum. This is not the case. Rather, certain principles are known which, if applied in the development of a curriculum, will increase the knowledge and skills of a student in the content area. The methodology of design that is presented will show how these advances can be taken into consideration.

Part I. Engineering Education in Selected Countries