Strengthening co-operation between engineering schools and industry

Wilfred Fishwick
Studies in engineering education 8
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The importance of satisfactory education-industry relationships, long recognized in the industrialized countries, has often been perceived more slowly in the newly industrializing countries.

From its foundation in 1946 Unesco has been involved with the applications of science—particularly, but not exclusively, in the newly independent countries. In 1960 this area of Unesco's activities was given high priority, and in 1970 education-industry co-operation became part of the regular programme of the Organization, along with complementary subjects such as curriculum development and continuing education for engineers and higher technicians.

Unesco has organized, alone or jointly, many meetings at which a main topic was education-industry co-operation. Within the framework of Resolution 2.221, adopted by the General Conference at its fifteenth session, Unesco organized a meeting of internationally recognized experts on engineering education and training, held in Paris in July 1970, which urged that 'future activities (in education-industry co-operation) should be on a larger scale'.

Unesco-sponsored regional meetings on this topic were held in Nairobi, Kenya (December 1972), Córdoba, Argentina (May 1973) and Manila, Philippines (October 1973). The International Working Group on Education-Industry Co-operation was formed, and met first in Paris (May 1974), again in Paris (September 1976), and then in Cairo (September 1978). The author of this study attended the Cairo meeting.

Other meetings on the education and training of engineers and technicians have been organized wholly or partly by Unesco and some of their deliberations and conclusions are relevant to this study. In particular, the International Conference of Education and Training of Engineers and Technicians, held in New Delhi (April 1976), produced much important material.

The working group has concerned itself mostly with the education and training of engineers, but did give some attention to the equally
important subject of technician education and training. The group has produced several background papers but has not yet issued a final report, and may continue its work.

Unesco is grateful to the author, Professor Wilfred Fishwick, for having successfully completed this study, and also thanks the working group members who have contributed much information on technological education in their respective countries.

The author is responsible for the choice and the presentation of the facts contained in this book and for the opinions expressed therein, which are not necessarily those of Unesco and do not commit the Organization.
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References
Introduction: The benefits of co-operation

This study is concerned with the various possible types of co-operation between engineering educational institutions and industry which can improve the education and training of engineers and engineering technicians. Such co-operation can also lead to a more useful flow of information from the institutions to industry, because information, as well as appropriately educated people, is an important output of educational institutions. Other volumes in this series have described curriculum design [1] and continuing education [2] for engineers, and these are topics that are also concerned with institution-industry relations. This study will, as far as possible, restrict itself to those mechanisms that will enable engineering educational institutions to perform their main tasks satisfactorily, and will exclude the methodology of curriculum design and the means of updating the knowledge of working engineers and technicians.

The mechanisms to be dealt with will be those that result in the bilateral flow of useful information, equipment, manpower and perhaps finance between industry and educational institutions. The educational institutions will be considered as two groups: 'engineering colleges' (producing engineers) and 'technical colleges' (producing engineering technicians). This simplification is not an attempt to impose a standardized nomenclature but is used for the sake of brevity. In practice, of course, institutions have a vast variety of names [3].

Institutions and industry should be partners

Technology is the systematic organization of knowledge for practical ends, and engineers and technicians are technologists' working in public

1. Figures in brackets correspond to the references at the end of this book.
2. The unqualified word 'technologist' will be used to include engineers and engineering technicians, and must not be confused with 'engineering technologist', as used in North America to denote a technician-engineer.
or private industry. Industry is the chain of activities whereby raw materials are processed and used to produce goods designed to provide services to people.

Ever since technical operations in industry became based on scientific and technological principles it has been considered that engineers and technicians should be educated and trained partly in educational institutions and partly in industry. Each partner in the process should attend to those activities for which it is best fitted. The precise division of responsibilities has always been the subject of discussion and even argument, particularly in English-speaking countries where a sharp distinction is sometimes made between education and training. In this study, it will be assumed that education implies an open-ended process leading to minds capable of further development, and training implies a closed process with the specific goal of acquiring certain technical skills and knowledge. An educational process also implies training in many skills, although it should go far beyond this. Thus, defining exactly what industry should do needs continuing and friendly co-operation between engineering colleges and technical institutes on the one hand and industry on the other.

Another function of the educational institutions is research and it is not unknown for industrialists to be somewhat scornful of this activity and its results. Co-operation can improve both the quality of the research and industry's understanding of it.

There is also a supplier-consumer relationship

Although educational institutions and industry have been described as partners, it is also true that their relationship has similarities to that between a supplier of goods and his customers. A satisfactory relationship is fostered when a supplier understands fully the needs of his customers and when the buyers are aware of the constraints within which the supplier has to operate. This mutual understanding can arise only following amicable exchanges of requirements and experiences by both sides. Furthermore, these exchanges must be continuous and keep up with technology. The fact that engineering colleges and technical colleges exist only because industry exists, while the reverse is not true, sometimes leads to pressure on institutions to try to do things which, in fact, they cannot. The institutions are equipped and staffed to provide a theoretical and practical education but they cannot provide a practical training in the special technology used in every enterprise. That sort of practical training is the duty of industry and in many countries it is carried out in an admirable manner; industry often realizes that investment in training is profitable. However, in some areas of industry, and in some countries, industry expects technologists, and particularly engi-
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We shall see, the education sector can help industry to organize adequate training even if it cannot do it itself.

Co-operation continues when self-interest is satisfied

Co-operation between technologists in industry and educators must be rewarding to the participants in that the self-interest of people must be satisfied in some way. If this is not so, the co-operation diminishes and becomes sporadic and formal. There are many impediments to successful co-operation which can arise from historical decisions, social organization, political decisions and so on. Even the fact that industrialists are themselves products of a past educational process can be a hindrance to co-operation. In subsequent chapters the possible benefits of co-operation to people and organizations are outlined, as well as some of the impediments that have to be overcome.

Technologists in the necessary quantity

The number of educational institutions is much smaller than the number of industrial enterprises or units they serve. Any relationship between the two sides is inevitably multifaceted and complex. Neither side normally speaks at the working level with a single voice, although the educational institutions usually function in more or less the same way. Industry, however, comprises many enterprises and departments with diverse technical operations and objectives, and with a corresponding multiplicity of needs. Only close co-operation can ensure that the education sector educates and trains people to desirable levels and in the right numbers.

Getting the numbers right, including the ratio of engineers to technicians, is not easy. In some countries a reasonable balance between engineers and technicians has not yet been achieved, with suitable technicians always being in short supply [13-15]. The shortage of technicians can be accompanied by an apparent surplus of engineers, many of whom will then be employed as technicians. This situation can lead to resentment and frustration and to inadequate technical assistance in the enterprises. Of course, any government or public policies in existence must be taken into account when the distribution of students between technological institutions is under discussion; co-operation is then a three-way affair between industry, institutions and policy-making bodies [16, and all references preceded by an asterisk].
The education and training of technicians has its own difficulties

The quality of technician education and training varies enormously from country to country [17-19]. In the older industrialized countries, industrial enterprises originally had to train all their own craftsmen and technicians, a tradition that continues to this day. In newly industrialized countries, higher technical colleges may have been set up but the complementary responsibilities of industries not recognized. This is particularly true of smaller enterprises with regard to higher technicians. These engineering technicians (as opposed to craftsmen/technicians) often enter technical colleges from secondary school, having failed to get into universities. The practical education they receive is often the weakest part of their education so that they are not immediately useful when they enter industry. Practical training in industry is usually supposed to be an integral part of such courses but in these countries it is not always easy to place college-based students in industry for short periods. It becomes easier if the students have already worked in industry as craftsmen or lower technicians, and work-based students normally return to their parent enterprises for practical training. These matters will be further discussed in the chapters in Part Two on co-operation between technical colleges and industry.

Technologists must know how to use information

Technologists of all kinds, including engineers and technicians, meet a continually widening range of problems. There is now an increased awareness of the bad as well as the good effects of industrial technologies, especially in highly industrialized countries. There is also, somewhat suddenly and none too soon, an awareness of the finite resources of the globe. Technologists have always had to deal with ideas, things and people but today people means society at large and not merely the traders who buy from or sell to industry.

The four components that enable a technology to function and progress are energy, information, materials and educated people and the training of a technologist must be more and more directed towards coping with information [20-22]. Indeed, the central task of technological education is training to use information systematically to produce solutions to practical problems. The upsurge in the science and art of modelling complex devices and systems is one aspect of the attempts to deal with the immense flow of available information.

Industry is where the problems have to be solved but educational institutions are sources of some novel concepts and procedures. It is essential both for industry and the institutions that there is the closest
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innumerably scientific and technological facts. At any given time a technologist will be able to memorize only a small fraction of available knowledge, and with time this stock will have to be changed by discarding some methods and facts and learning new ones. Education has to be built around principles, and on the skills needed to use them, and to select and use currently available information.

The information acquired in a technological education will probably be of importance during, say, the first ten years or so of employment, that is, during the 'first career' of a young technologist, whether engineer or technician. At this stage both engineers and technicians are concerned mainly with technical matters. Many engineers and some technicians move into a second career involving increasing management responsibilities or public administration. The background or non-technical part of the education of a technologist then assumes greater importance, and it is to be hoped that there will be opportunities for continuing education as discussed in Study 6 of this series [2].

The humane technologist

The role of the technologist in a society—for good or for evil—has been much discussed recently. The main theme has been that a technologist needs to know something of human systems, or societies, as well as of technological systems. The technologist ought to understand his society and be aware of any effects on it that a potential technological development might have. This implies a capability for rather close study, observation and sophisticated judgement. It is necessary for educators to know the way in which decision making is carried out in various enterprises and public bodies, if the humanistic side of an education is to be shown to be relevant to the activities of technologists. The education of an engineer should be based on a realistic and humane view of industry and society and, as in other forms of higher education, should be motivated not only by career prospects but by a desire to get at the truth whenever possible [23-28].

Engineering colleges can learn from other university institutions

The relationship between engineering colleges and industry is part of a wider involvement of the institutes of higher education with all aspects of the life of a nation. Cardinal Newman's concept of a university in which by the study of 'liberal knowledge', i.e. non-useful knowledge, a man could be prepared 'to fill any post with credit, or to master any subject with facility' [29], is dead, if it was ever really alive. Universities
today are much more in tune with the ideas of Francis Bacon, who wrote that the acquisition and transmission of knowledge 'should not be as a courtesan for pleasure and vanity only, or as a bond-woman to acquire and gain to her master's use; but as a spouse for generation, fruit, and comfort' [30].

A modern university often not only instructs undergraduates, but also carries out extensive research and serves the community and nation in a host of ways [31]. It is interesting that when large universities are more or less free to control their own activities, they involve themselves with more and more aspects of their society. Through research consulting and advisory services, joint endeavours, continuing education, part-time teaching, and so on, they relate to all types of public and private activity and need. The University of California is the archetypal example of such a university, but there are many others. From an engineering point of view the lesson is that a purely teaching-oriented institution will never have the intimate relationship with industry that can arise when an institution is so equipped with physical facilities, variety and quality of staff, research and development activities, and education extension services as well as ordinary college-based teaching that it can relate to every industrial activity in some way or other. In practice, resources are nearly always limited and constraints on the freedom of operation of institutions are often imposed by governments. Nevertheless, there are many ways in which education-industry relationships can be fostered to the benefit of both sides.
Part One

Engineering college–industry co-operation
1. The channels of co-operation

People, resources and information

As already stated, the phrase 'engineering college' will be used here as a name for any kind of higher educational institution that educates engineers. It therefore includes specialized technological universities, faculties and departments of multidisciplinary universities, and other engineering institutions of university standard. The graduate engineer will have a qualification that identifies him as someone who has received a theoretical and practical education enabling him to begin practising an engineering technology at an advanced level.

Engineers are normally employed by public or private industrial organizations that provide services to the members of a society by making consumer and capital goods, and by providing and operating systems of goods. It is in industry that technologies are practised in order to solve practical problems. The inputs to industry are raw materials, finance, information and people. Engineering colleges are today, in all countries, the most important source of engineers. They also supply information to industry. In return, the colleges receive, or should receive, information, equipment and financial support; they should also recruit some of their educators from industrial enterprises. It is a fact that industry, in general, considers graduate engineers as the most important output of engineering colleges. The information arising from the research and development activities of the colleges merges with information from many other sources and is thus harder to identify as originating in educational institutions. This knowledge is also only a fraction of the new knowledge accumulating all the time.

Nevertheless, a flow of information in one direction can stimulate a useful flow in the opposite direction, with ultimate benefit to the education and training of engineers. Indeed it is only through an adequate exchange of information with industry that engineering colleges can design satisfactory curricula. A simplified block diagram of
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these flows between colleges, industry and 'governments' is shown in Figure 1. Governments include public and private bodies that control the input of resources, and perhaps instructions, to the colleges.

Fig. 1.

We shall not be directly concerned here with the relationship between engineering colleges and their 'governments'. Whether the latter are state or other public bodies, or even private bodies as is the case in some countries, these sources of finance, land, buildings, and so on can obviously exert pressure on an engineering college and change its activities. They may act because of direct or indirect pressure from industry, but in such a situation the views of industry will undoubtedly be known in the colleges. Such pressure usually implies that co-operation between industry and the colleges has ceased to be effective. This can happen, but it is the thesis of this study that engineering education should change as a result of a continuing dialogue between the two parties. Scarce resources are then more likely to be allocated for
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activities approved by both educators and industrialists than they would if only one side pressed for changes and increased resources.

Figure 1 also shows a flow of resources in both directions between the colleges and industry. In most countries, engineering teachers and researchers are an important proportion of those engineers who are primarily concerned with technical matters. Furthermore, in less industrialized countries this group often includes most of the highly qualified engineers. The college laboratories are usually well equipped and include computing facilities. This expertise and these physical resources can be of great value to industry, just as industry can make some of its resources, especially equipment, available for use by college staff or even students.

Information is also subject to a two-way flow, not only as written material and films but also through personal contact between educators and industrialists. Indeed, it can be argued that the most valuable result of education-industry co-operation is the continuing education of the educators. Technologies can change so quickly that if a teacher does not keep himself up to date with current knowledge, he will be faced by what seem to be giant steps in technological development. Assimilating this new knowledge, and discarding other knowledge, becomes harder as time goes on. Teachers then take refuge in teaching well-established 'disciplines' that are not subject to rapid change. Engineering educators are not usually expected to teach all the latest technological practices to students, but they should be aware of important new practices in their own spheres of interest. Such an awareness is necessary if they are to teach material that their graduates are likely to use in the first ten years of their professional life. Without a knowledge of current technology, it would seem almost impossible to discern technological trends of real importance.

Co-operation starts in the colleges

Engineering colleges exist because industry exists and it needs well-educated and well-trained engineers. Engineering colleges should therefore attend to the important functions of industry such as research, design and production and possibly even to management and operations. However, while many engineers become managers, it is true in general that during their 'first careers' most engineers are concerned mainly with technical matters [5]. Thus while the organization of industry and management techniques can be discussed with undergraduates (and even more profitably with Ph.D. students), deeper studies of management are probably best left until the young engineer has some industrial experience. Not all educators or industrialists would agree with this view, especially in developing countries where young engineers are often
placed in managerial positions almost immediately after graduation. What should be done in a particular engineering college must be the result of discussions with industry, and will depend on the foresight of the professors who try to predict how industry will change.

It is only by being closely connected with industry and its practical problems that teachers will recognize that the primary value of an engineering theory or method is its utilitarian value in solving problems. It may also be an elegant or complex theory but these characteristics are of secondary importance. Furthermore, only teachers who have been involved in problem-solving or have studied the process of solution can appreciate fully that any chosen solution is a compromise between alternatives and has been adopted because it satisfied a set of constraints. These constraints may have been economic, technological, environmental, and so on, and relative to the constraints the solution will have been the 'best' one. If the problem had been one of design then an essential part of good engineering would have been a consideration of the interface between an artefact and man and his environment [2, 13].

The solution of engineering problems, including design problems, necessitates what has been called a systems approach in which an engineer sets out to find some optimal solution with respect to constraints set up by the social and physical environment. The problem has first to be defined, then the creative process of producing solutions carried out, and then mathematical or other models made and analysed. If the original specifications can be satisfied instructions are issued whereby a product can be made, or a system assembled, or an organization changed, taking into account such things as physical facilities, manpower, finance and materials available. It would seem therefore that an engineering education should include study of a systems approach to the functions of an engineer in industry. This is not easy to do without a knowledge of industry.

The ways in which engineering teachers can co-operate with industry, and get to know it, are not always easy to develop quickly. Even in highly industrialized countries co-operation is not easy, whereas in a less developed country, where perhaps industry is based on imported technology, it can be difficult or elusive. Nowhere in the world are engineering colleges part of industry, for they do not produce goods or operate systems of goods. Engineering teachers, therefore, quite often consider themselves first as teachers and only secondarily as engineers. They often prefer to teach subjects that are part of the intellectual stock of an engineer in the sense that they are used to analyse devices and systems. These subjects are certain physical theories and mathematical methods which are of importance to engineers, but which are not engineering. Current practices in a technology are hardly touched upon, the excuse being that the chosen topics are in some way fundamental to technology.
Obviously engineers do need this kind of knowledge but engineering colleges—to live up to their name—must go further. If they do not they might as well distribute their students to other departments or colleges and leave the teaching of mathematics, physics, materials, and so on to the appropriate experts. In fact, most engineering colleges make an attempt to educate engineers in theory and practice which has some relevance to the needs of local or regional industry.

Not all colleges are equally successful in educating engineers who can quickly assimilate the practices of an industrial enterprise that might employ them. It is not possible to educate and train engineers for a particular enterprise, except in very special cases. For example in some countries a Ministry of Power, which controls all generation and supply of electricity, has its own school for engineers who are to take up employment with the ministry. This is not very usual and indeed would not seem to be a very good educational practice. Today few industries in any country train and educate their own engineers, for this practice began to die out in the oldest industrialized countries, such as the United Kingdom, about a century ago. Training in particular practices associated with an enterprise is still the duty of the enterprise, but theoretical and practical education is usually the province of educational institutions.

**Educators should get to know industry**

It would probably be ideal if all engineering teachers were recruited after working in industry, and also returned to industry from time to time. In most countries only some of the teachers have worked in industry. Of those who have not, some have acquired knowledge of technological practice and industrial organization through co-operation with industry, but there are always some who have avoided much contact with industry. To have a few teachers of this kind is not disastrous provided their skills are balanced by other teachers with industrial experience.

In some colleges, and particularly in some less industrialized and developing countries, very few of the teachers have ever practised engineering in industry. In other words, they have never been involved in the solution of practical problems with all their accompanying constraints. However well-read, they are thus in a weak position from which to educate engineers for industry and it is not surprising that they tend to teach well-established subjects and avoid open-ended projects and problems. A lack of contact with industry leads teachers to feel incompetent to examine the state of a current technology in their own and other countries. Thus they avoid serious discussions with students on possible solutions to local or national practical problems. This is a situation that
can be largely corrected by well-organized co-operation with industry (see Part Three for examples).

**Education sector or industrial sector—where are the colleges?**

Another fact that sometimes militates against full co-operation with industry is that engineering colleges are usually considered part of the education sector of a country. They are supported by funds that do not come directly from industry, and colleges claim with some justification that their functions are not completely determined by the needs of industry. Engineering colleges share some of the aims of other university faculties, as well as having some of their own. Thus the colleges both serve industry and criticize it; they pursue new knowledge and apply it to solve problems; they educate and train men to practise a profession and to go on learning. They often claim to instil in their students an understanding of the industrial society in which they will work and live.

Almost unconsciously some teachers try to stand back and examine industry with an impartial if critical eye and extract from the very diverse practices of industry those activities that are in some sense fundamental. This scrutiny should also include technological trends that are important, and would lead to changes in educational curricula. Such practices seem unexceptionable if carried out thoroughly, and thoroughness implies a first-hand knowledge of industry. For example, the question of what is an important fundamental subject to be taught now does not really depend on what has been useful in the past. It depends on whether the young graduate is likely to use that knowledge or technique in the first five to ten years of his professional work. To be competent at guessing the way a technology will develop is not easy, and not all professors have the necessary sensitivity to the technological Zeitgeist, but systematic study should help to improve this ability.
Industry, public or private, manufacturing or service, would probably claim that it pays for the products it obtains from colleges by the compulsory taxes it makes to the public purse, but enlightened industry realizes that more can and should be done, and so provides aid voluntarily in many forms. This chapter deals with various types of voluntary aid given by industry to colleges because it is in industry's interest to do so.

Curriculum design

In most countries and especially in the developing ones engineers enter industry with a first degree only. The scheme of studies leading up to graduation is therefore of immense importance. Once the objectives of a course have been clearly stated then most educators can design a reasonable curriculum within the financial and other constraints of the college or educational system [32]. There is no finality in a curriculum and what is 'best' today will have to be modified tomorrow. As Lawrence P. Grayson has made clear [1], the first step of finding realistic objectives is difficult. Co-operation with industry is essential and yet many educators set up new schemes of study without consulting industry. In fact industrial engineers are usually very willing to help. Indeed they often have their own ideas of curricula [33] which do not always correspond with the cherished beliefs of the college authorities.

Nevertheless, it is good practice to invite a few industrial engineers to meet with departmental or faculty staff to exchange ideas on curricula. Indeed a committee can be formed which might meet two or three times per year, perhaps with equal, but small, numbers of teachers and practising engineers. This is common in some countries but apparently unknown in others.

In the United States, degree courses are accredited or recognized as being of a sufficient standard by the autonomous Accreditation Board
for Engineering and Technology (ABET), using the criteria set up by its predecessor, the Engineers’ Council for Professional Development (ECPD). In the United Kingdom, the major professional engineering societies which are members of the Council of Engineering Institutions (CEI) also recognize degree courses as being of a sufficient standard, or not, to exempt a graduate from sitting CEI examinations if he is aiming to be a Chartered Engineer (C. Eng.). These accreditation procedures must not be confused with curriculum design. The comments of these inspecting bodies can be very useful in that regard, but they do not really replace discussion between working engineers and academic teachers. For that purpose, industrial engineers usually donate their services or at most ask for travel expenses.

College councils and advisory boards

Engineering colleges, whether governed by college councils or boards of faculty, lose nothing by co-opting industrial representatives on to these governing committees. Well-chosen industrialists will bring in new ideas or new views on many topics ranging from finance to examinations. They can also be extremely useful members of those committees that make new appointments to college staff, for they often have much more experience in selection and appointment of staff than do professors [34].

Industrial representatives on these committees soon become aware of the needs of the college. It often follows that the organizations with which they are associated will help the college or a department in some of the ways described below. Colleges in many developing countries, for example, are completely dependent on the government as the only source of finance and other resources. The colleges tend to become part of the bureaucracy and so rather separated from industry. Industrial representation in a college is at least a step towards a closer relationship with industry and the opening up of a new resource.

Part-time teaching staff

The use of practising engineers as part-time teachers is common in some countries, such as France, but uncommon elsewhere. Joint appointments, agreed to by an engineer and by authorities in an industrial enterprise and a college, are another matter and are discussed in Chapter 4. However, ad hoc arrangements whereby an engineer gives a short course of lectures or supervises one or more projects (and is usually paid for his time in addition to his industrial salary) can be useful. These engineers can lecture on real industrial problems, industrial organization, management, up-to-date technology and similar topics. Not too
much should be expected of them, however, for their industrial work and their careers will be their first priority. Hence, the college must co-operate fully with part-time teachers if the maximum benefit is to be obtained. For example, it is good policy to arrange a lecture timetable to suit the lecturer. Project supervision in the form of discussions with students can take place in the evenings, at the enterprise that employs the lecturer or even at his home if this is desired. Dissatisfaction with part-time assistance often arises simply because the college authorities, and maybe academic staff, have not done as much as they could to minimize the difficulties and upsets faced by part-time staff who are also fully employed elsewhere.

Part-time teaching staff drawn from industry make the best contribution when they lecture on matters related to their industrial activities or supervise projects in fields where they have expertise. They give less valuable assistance if they are expected to teach the more academic courses accompanied by examinations, homework and tutorials. Few part-time teachers want to, or indeed should, be involved in marking homework or examinations [35, 36].

Advice on research topics

Engineers and scientists in industry are often involved in solving a range of research and development problems. They are usually quite willing to discuss with college staff any proposed programme of research in the college. They will be particularly interested if they think the research has some relevance to the problems of industry. Indeed, they may point out areas where progress or new knowledge is needed, but which are being neglected by the college [37].

College academic staff should not be afraid of discussing research topics with practising engineers. It is always worth while to explain a project to other engineers practised in research or development. Pertinent comments may help to crystallize a vague idea or uncover an unsuspected difficulty. Completely new research projects may be suggested, and minor ones, suitable for student projects, recommended.

Loans and use of equipment

Discussions of college-based research can lead to offers of a loan of equipment or of the use of equipment in industry. Direct requests can also be made if suitable equipment is known to exist in an industrial laboratory or works. Gifts of unused equipment are also sometimes made by industry. Even if the equipment is outdated from the point of view of an industrial engineer or scientist, it may well be of use in a college. Sometimes industry does not know that an apparatus, now not
needed, would be of value in a college laboratory, so that visits to industry by college staff should be encouraged even from this rather narrow standpoint. Such visits obviously have other rewards as well.

Technical advice about equipment can often be obtained from engineers in industry. This can be especially useful when the purchase of expensive measuring equipment is contemplated. Even in the developing countries government laboratories and the larger industrial enterprises may be extremely well equipped with measuring apparatus of all kinds. It should be a duty of college teachers to find out just what is being used in the industry of a region or country. The college might even become a centre of information on these matters, doing a job sometimes done, as in the United Kingdom, by official organizations.

Visits to industrial enterprises

It is common practice to send or encourage students to visit industrial factories and laboratories during their studies. Some colleges leave this to student engineering societies while in others it is organized by college staff. If the full educational value of these visits is to be realized, then at least one teacher should be involved with each visit. He should go to the establishment before the visit is finally arranged to meet the engineers and technicians involved and to investigate what might be seen by students. When the visit has been arranged he should give a short account of the place to be visited before the visit takes place. This is valuable even if someone in the enterprise will also talk to the students before they begin their tour.

If possible, before the visit ends, there should be an opportunity to ask questions so that more information can be produced or misconceptions clarified. Visits made to industry without suitable preparation often leave students with impressions that are of little value or are even incorrect. In many colleges, where industrial vacation work is not compulsory, or where co-operative sandwich courses are not practised, these visits may be the only views of industry that students get before graduation. This is all the more reason for extracting the most from such visits. Another reason, of course, is that the enterprise or laboratory will have its work disturbed by such a visit and is allowing the visit because it believes in its value to students. If students do not benefit from the visit then everybody has wasted their time.

Acceptance by industry of students for industrial training

In some countries, for example the Federal Republic of Germany, students are supposed to have worked in industry before entering
Engineering college–industry co-operation

...
two parts of the course, especially in degree courses at polytechnics and colleges of further education which are approved by the Council for National Academic Awards, who also award the degrees. The approved sandwich courses are complete in themselves, with industrial training being just as much a part of the course as academic studies. Integration is effected not through regulations but by agreed programmes and visits by college tutors.

Students placed in industry for six months or more in a year almost always receive wages from the employer. The employer therefore expects some useful work in return, and experience indicates that he usually gets it. Of course, wages will vary from employer to employer but this matter ought to be settled before college-based students enter a firm. The salary should not be the major criterion as to whether an offer of training employment is accepted, but it is an important factor and one which varies from country to country. As indicated in the section on Sri Lanka in Part Three, a living wage is needed if students are expected to spend a year away from college in industry [42]. In the United Kingdom, for example, students receive grants for university education from the government which can suffice for the whole calendar year. Even so, most sandwich-course students in industry are paid. Payment ensures some loyalty and facilitates industrial discipline. Unsatisfactory student employees can be dismissed and will lose their wages. Wages will also depend on the experience and maturity of students. Placing first-year (non-sponsored) students in industry is more difficult than placing students who have completed two or more years in college, with some vacation employment perhaps as a bonus. This is so even in the United Kingdom where many colleges have ‘thin sandwich’ courses and employers are used to inexperienced student employees. Thus some new sandwich courses are of the ‘thick sandwich’ type, with a whole year in industry after two or three years in college. Programmes of industrial training for each student still have to be agreed, however.

**Undergraduate and postgraduate project work**

Most undergraduate and many postgraduate programmes now include one or more projects to be completed by the students. A project, in the sense used here, is an open-ended assignment; the outcome is not known at inception, and progress depends mostly on the intelligence, skills, creativity and energy of the students. Projects are usually meant to introduce students to non-artificial problems and to the procedures used to reach acceptable solutions.

Some so-called project assignments require a report which is an exposition of some topic not covered, or only introduced, in normal classroom and laboratory periods. A lecture to other students and staff
is also sometimes required. Expository projects of this type usually require literature searches and they have a particular value to students who are going on to research in the field of their project studies. But they are also sometimes a last resort in a situation where research activities are almost non-existent and the relationship with industry is weak, and some kind of project assignments have to be produced for final-year students.

Where research is involved staff often suggest projects arising from their own studies. Sometimes the design of an experiment is required, followed by an analysis of the results, or an instrument is to be designed and perhaps constructed. An element of creativity is usually required of the students. Similar types of project may sometimes be obtained from industry and will often involve design studies but such projects may have little commercial importance, valuable though they may be as educational tools. As discussed below, suitably chosen projects from industry can be of value to both parties.

Industry-based projects

Engineering students will, of course, benefit from the types of projects mentioned above but many colleges now prefer projects that aim to introduce authentic engineering experience to the students. This almost always requires that the projects originate in industry and are of real importance to the sponsors [43-46]. The sponsors may include private industry, public industry and government organizations, private hospitals and public health services and so on, or any organization that uses engineering technology at a reasonably sophisticated level, or which is anxious to do so for the first time. The latter situation arises in developing countries more often than in highly industrialized countries.

In real engineering situations young engineers usually work as members of a team. The ability to work with others, to divide or share responsibilities and to communicate orally and in writing with colleagues are all valuable skills of an engineer. Solutions to problems have many constraints, such as final cost, limited facilities and manpower, ceilings on the weight or size of the product and, more and more commonly now, the economical use of energy. Ease of maintenance is also an important factor. Suitable projects arising from industry will be associated with some or all of these constraints, and because of the need to produce a solution within a certain time it is advisable to use small teams of students. A staff member is also usually necessary as an adviser but the team leader should be a student selected by the students. Team leaders can be changed from time to time, by previously agreed procedure or at specific times if the students wish. Sometimes a project leader may be a postgraduate student who might then lead the project...
work over a period longer than one year. In that case the composition of the undergraduates in the team will change from year to year (see the section on the United States in Part Three, for example).

Project work sponsored by industry falls into two classes: that which is financially supported and that which is not.

**Unsupported sponsored projects**

Sponsored but unsupported projects often involve problems which are not of immediate importance, or are of a speculative nature, or are ventures into a new field by someone with limited financial resources. This type of project must then be supported by a college's own resources or any other resources the college may be able to call upon. Furthermore, if the problem is solved, or the task carried through, it does not necessarily follow that there will be any financial reward to the college by the originators of the project. There may, however, be rewards in the form of a published paper, or suggestions for further project work which might then have much more support. Alternatively, when, as for example in Ghana (see Part Three), a university project leads to the setting up of a small business, there may be a financial return from some kind of royalty.

Another type of sponsored project which does not lead to direct support at the college occurs when the project is carried out in industry. Many projects undertaken by students on sandwich or co-operative courses take place at the site of employment of a sponsored student. The work and the report are assessed by the college but any useful results are naturally the property of the enterprise. In some countries, it is possible for students to carry out project work in industry as the final phase of degree or diploma studies. After successfully completing oral and written examinations a student then works in a previously arranged location in industry for up to six months or so on a project jointly agreed by the college and the industrial enterprise. This arrangement usually ensures good supervision by engineers in industry, and provision of all apparatus and materials. The problem will almost always be of genuine interest to the industry, as the student will be a junior member of some team of experts in industry. His work will be closely controlled by others. Nevertheless, this arrangement does provide authentic engineering experience within a scheme of studies.

**Supported sponsored projects**

In many colleges, for example in the United States and France (see Part Three), students undertake projects that are sponsored and supported,
even though they are not on sandwich courses or are not compelled to work in industry [44-46]. Because an industry is financially involved in the project work at more than a trivial level, its interest in the progress of the project will be serious, leading to rather close co-operation. The greater the amount of financial support the greater will be the concern, but it is not possible, as a rule, to arrange a completely commercial contract. The best that can be done is to get an industry to pay for materials, new instruments and overhead costs. Even so this may amount to the equivalent of several thousand US dollars in any one year. An industry or organization offering this kind of support will expect results, perhaps within an agreed time. If there are no acceptable results then an industry may withhold a final payment but it is far better if the college writes in the agreement its willingness to forgo this payment (or even the whole of the support) if there is a lack of success.

Supported and sponsored projects usually require that new ideas or solutions are brought to the stage of a complete design specification, or a prototype device or apparatus, or a feasibility or marketing study. Projects may also involve the design of experiments and analysis of results, preferably as part of the work leading up to an engineering result of some kind.

Students benefit from differing projects

Some colleges give undergraduate engineers two different kinds of projects. One will be a project, most probably originating in the college from staff or student, which is carried through by one person. This could be attempted in the penultimate year of a course. A major project in the final year would then be undertaken by two or more students. Some colleges include a project assignment which is not of an engineering nature, although it might be related to the impact of technology on the community [43].

Freshmen design projects

Engineering design projects for first-year students were probably first pioneered at Arizona State University in the United States in about 1965-66. It turned out that groups of first-year students, with guidance, could produce successful designs for many kinds of device [47-50]. Other engineering colleges have followed this practice, finding considerable innovative talent to be developed even at first-year level. There are various ways of introducing projects to freshmen but the one used in Arizona State University is worth describing. If students are asked to identify some physical need that has not been met, or satisfactorily met,
they produce many suggestions. These, which are in effect design proposals, are assessed and the best are taken and developed by groups of five or six students. These groups can be termed 'companies or enterprises' with the student originating the proposal acting as team leader or 'chief engineer'. Guidance must be given, perhaps by weekly lecture or discussion sessions, but the groups also need some individual guidance. It can be provided by engineers in public and private industry, possibly contacted through professional engineering societies or their local sections; or in any other convenient way. This leads to many links between industries and the college but at a level of engineering practice that does not take up too much of the industry's time.

The level of technology used to develop engineered products varies enormously although most products do not use very advanced technologies. First-year engineering projects may produce very useful devices, even though their development does not need advanced mathematics or deep theoretical knowledge. Suitable guidance from the 'consultants' to the groups, in fact, can make up for some lack of knowledge without suppressing creativity.

Freshmen projects, like other engineering college projects, are normally examined in some way. A report and oral presentation, perhaps accompanied by a working model or prototype device, may be made to an examination jury, for example. Fairly senior engineers from industry have been used most successfully on such juries. These engineers have thus participated in college activities and their interest has been aroused. Engineers who acted as 'consultants' to the student groups will also have enhanced college-industry interaction and ultimately more co-operation should result between the college and local industries.

**Engineering case-studies or feedback from industry**

An engineering case-study is a written record of an engineering process from beginning to end [51-57]. It is not just a technical report of an investigation or an example of a design that is accepted, but it is an account of how an engineering activity was actually carried out. It will therefore include examples of successful and unsuccessful encounters with problems and constraints. A good case-study is usually told chronologically and may include calculations, drawings, facts and opinions. It should also include false starts or blind alleys that set back the work. Schedules and budgets affecting the scale of the work, feasibility or market studies preceding the work, and any other data affecting the final outcome should be included. Obviously a case-study is also about the people writing the case as well as about engineering problems, in that their mistakes and decisions are important to the reader [53].
Case-studies can be used in engineering education in several ways. They can be used by teachers to broaden their own knowledge of real engineering, and as a source of examples for classroom use [54, 55]. Case-studies can also be read by students who will find out just how theoretical knowledge and practical skills are applied [56].

Case-studies can often be used as the basis for design projects to be carried out by students. The students can then redesign the devices described in the case-study [57]. Laboratory-type investigations can sometimes be the outcome of studying a case, and a case-study can be used as the subject of discussion at a student engineering seminar on design.

Reading and discussing case-studies might be the preliminary to asking a small group of students to write a case-study using material extracted from a co-operative industrial engineer [58]. Sometimes, as a result of the internal policy of a company, something similar to a case-study is prepared by engineers in the course of writing reports. These reports will never be quite what is needed but can be filled out into proper case-studies without too much effort. Although engineers rarely bother to write case-studies unless they are particularly interested in describing engineering as it actually happens, or are interested in engineering education, they are often prepared to help students to do so.

In the United States, several colleges have made collections of case-studies of which copies are available for a small fee. An important collection is the Stanford Case Study Library at Stanford University, California, now partly supported by the American Society of Engineering Education, and described in a useful publication [59]. However, many collections exist and if case-studies are sent to them and accepted, a small fee is usually paid to the author.

A direct way therefore of helping colleges to prepare students for future employment in industry is for industrial enterprises to provide material for case-studies. Even if an industry cannot prepare the study, the material it provides should enable staff and/or students to prepare it for their own use. Colleges should approach industry for such material as industry is sometimes quite unaware of the educational value of their internal technical reports and associated information.

Secondment of engineers to colleges

It sometimes happens that an industrial organization will second one of its engineers for a whole academic year to a college [36]. The obvious benefit of this kind of resident professional engineer is that the student is exposed to lectures based on up-to-date practical experience. In addition, as one writer [37] points out, such a visiting professor will usually have few duties on committees and will thus be able to spend
more time than permanent staff attending to projects and mixing with students. He may also be in a position to make an unhurried but critical appraisal of the curricula and teaching methods.

In engineering colleges, full-time visiting professors from industry are rare. Yet the cost to the college need not be great, perhaps no more than the cost of any staff member, for the employer of the engineer might pay the difference, if any, between the engineer's salary in industry and in college. If an exchange can be arranged, as suggested in Chapter 4, then the extra cost to a college could be small.

Working in a college would bring benefits, in outlook and knowledge, to the engineer and so to his industrial employer. Where this arrangement has been practised there seems to be no doubt that all have benefited from it.

College staff on leave in industry

Many colleges practise what is sometimes known as sabbatical leave, which is leave granted for several months or a year for a staff member to work away from college. It is usually, but not always, granted with full pay and is a reward for services rendered. In some countries this leave will be taken in another college or a government research institution and few, if any, academics will choose it to go into industry (see Part Three, Latin America, for example). In other countries in North America, Europe and the Soviet Union, many academics do choose industry [60, 61 and Part Three, USSR].

A year in industry as a working engineer should be of immense benefit to the academic engineer, opening his eyes to the problems faced by industry. His professional status will be enhanced by his experience and his mind stimulated by his new environment.

Experience of this kind is best offered to an academic of some maturity, at the post-doctoral level or equivalent, who can make a substantial contribution during his stay in an enterprise. It is not really suitable for the young teacher trying to complete a higher degree.

Industry, which gains an engineer, will usually pay certain expenses and perhaps offer an emolument to add to the college salary, thus compensating travel expenses or the expense of living away from home if this is the case. It is rather short-sighted of the college authorities to reduce the pay of one of its academics who takes leave in industry, where he receives some remuneration. In due course the college will reap the benefits when the academic returns, as of course he should. Indeed many colleges grant long leaves of absence with pay only if the recipient will return for one or more years at least.
3. Assistance that colleges can offer industry

The resources of colleges

Some of the human and physical resources of engineering colleges can often be used to give direct assistance to industry. Human resources include academic staff, laboratory and other technicians, postgraduate and undergraduate students. Physical resources include not only laboratories and equipment but also collections of books and journals. There may also be special departments or units that have been established to provide services to industry as commercial ventures. Assistance to industry may or may not be charged for. It is not usual, for example, to charge for the use of libraries, but routine tests of materials such as samples of concrete are usually carried out only for a fee. Other types of assistance will incur fees that depend on the work done and the resources used.

The fact that an engineering college exists, however well known in a region, does not mean that industry will ask it for assistance. Indeed small enterprises, which could use technical help, are often reluctant to approach a university-level institution, while larger firms may tend to go to commercial organizations such as specialist consultancies. It should be college policy to help industry in any way it can; to do this a college must ensure that its resources and capabilities are known to industry. There are many ways to do this (see the joint ventures discussed in Chapter 4, for example).

In some countries (see Part Three, Denmark and Italy, for example) students and even some academic staff adopt the attitude that colleges should not help private industry but restrict assistance to publicly financed organizations. One reason offered for this attitude is that in those countries the engineering colleges are supported by public funds, so that all resources should be freely given to the public at large. Of course, the 'public' includes both public and private industry, and engineering colleges exist to serve all industry and not particular sectors
Nevertheless some students do refuse to work on projects originating in commercial industry, and even put pressure on college authorities to prevent staff and resources being used to solve industrial problems of commercial value. In general, however, both staff and students are happy to get involved with industry in one or more of the ways described below.

**Use of college equipment**

Engineering departments often possess test rigs and measuring instruments that can be used to make routine tests on materials and components. These tests can usually be carried out by a competent laboratory assistant. The tests often establish certain mechanical properties of materials and may involve issuing a certificate stating the results of the test. Some fee is charged and a useful income may result from this work. Some civil engineering departments regularly test and certify the breaking loads on standard samples of concrete from construction sites, and many carry out tests on all types of materials.

Some engineering colleges are equipped with instruments of such high quality that they can calibrate other commercial instruments. This is not always a simple routine comparison and may involve supervision by academic staff. In some of the poorer countries the university engineering departments, perhaps equipped through foreign aid, are the nearest thing to a standards laboratory in the country and full use should be made of their resources.

Apart from fees that are earned, this type of work brings a college into close contact with some sections of industry, perhaps leading to further mutual benefits.

**College staff as consultants**

Academic staff form a now traditional link between college and industry. In many countries it is quite common for academic staff to be approached by an industrial enterprise asking for advice [62-64]. In some countries, such as Italy, a professor may even be a partner in a consulting firm or set up his own commercial consulting organization. This normally requires permission from the governing body of the educational institution. In other colleges these consulting activities are forbidden to full-time employees. Most colleges, however, allow some consulting provided it does not interfere with college duties and that college resources are either not used or paid for at an agreed rate.
When colleges allow complete freedom to their academic staff to practise as consultants, this freedom is occasionally abused. College activities are minimized but the salary accepted in full. In fact it is difficult for one person to reconcile or harmonize his duties as an educationalist with the objectives of a commercial profit-making organization. It can be done, but usually it is the college activity that is neglected. Hence many colleges restrict the amount of consulting by insisting that each request for consultation be first approved by the head of the college or some other authority. A college may also lay down a maximum which can be earned in one year from consulting activities or ask for a percentage of the fees to be paid to the college. If colleges insisted on their academic staff being in the college and carrying out college duties for thirty-five or forty hours per week on a specified number of weeks per year as industrial organizations do, then consulting would have to be a spare-time activity. Most colleges do not operate in this fashion and there is no doubt that college and consultant duties tend to intermix. However, if the amount of consultancy is held to reasonable limits, the extra expertise acquired by the consultant will normally benefit the college in the end.

Interfacing units between colleges and industry

The difficulties and suspicions arising from consultancy work, and the need to have a satisfactory link between organizations that have different objectives, have led many colleges and universities to set up special units or departments to link them with industry. Such units may be restricted to engineering activities or they may relate industry to any part of a multidisciplinary university. There are so many of these units in the United Kingdom, for example, that there is even a professional association of university directors of industrial liaison for those concerned with helping industry and society to make more use of the resources of educational institutions. Similar units exist in many other countries such as Canada, France, Ghana and the United States.

These links seem to fall roughly into the four types [62] described in the following four sections.

Industrial liaison offices

Industrial liaison offices, or at least officers, have been long established in technical colleges but their appearance at universities is relatively new. Their main function is to inform local or regional industry about the human and physical resources of the college or university. This begins by the industrial liaison officer (ILO) visiting industrial
enterprises and organizations of all kinds, including hospitals and city governments, which make use of more than elementary technologies. Firms are invited to send representatives to the college perhaps on open days. The ILO prepares handouts for firms, newspapers, trade journals and so on on what departments do in research and development and in what areas staff have expertise. The science correspondents of radio and television networks may also be invited to visit the laboratories. These offices are sometimes used to place students in vacation employment, or as centres for employers to recruit prospective graduates. They are useful for disseminating information about public lectures or short courses of relevance to industry. They are not usually involved with 'sandwich' courses as it is better for departments to negotiate directly with industry on such matters.

The role of the ILO has been termed catalytic [62] because his or her object is to bring parts of the college into collaboration with parts of industry and society. Some of this collaboration should be in the form of consultant work, sponsored research, undergraduate and graduate project assignments, an exchange of engineering and scientific information, and so on.

**Contract offices**

Contract offices have grown up usually as part of the central administrative unit in order to introduce standard accounting procedures to contract negotiations, in place of the rather haphazard negotiations previously undertaken by academic staff. Thus while sponsored research or consultancies may be accepted by an individual or department, the actual contract is negotiated and administered by the contract office—which may be part of an industrial liaison office. In this way a proper estimate is made of the costs of such things as using college facilities, overheads and extra insurance. Any fees to be paid to college employees would also be negotiated at this stage.

Some colleges or faculties of engineering have their own contract officer. It is also becoming common for undergraduate project work to be based on sponsored work from industry and this must also be covered by contract.

Of course, when all contract work has to be negotiated through a central office, then the type of work accepted, and resources to be allocated, can be controlled. This can provide protection for the customer as well as the college. However, not all academics like centralized contracting. It does lengthen the time between accepting the work and the day it begins, but the advantages mentioned above probably outweigh this disadvantage and override apparent loss of freedom of action [63, 64].
Contracting through limited companies

In several universities in the United Kingdom contracts are arranged through limited companies. One example is Loughborough Consultants Ltd, at Loughborough University, and there are others at universities in Leeds, Bath and Aston. These companies do not have a large staff but run as businesses and profits go to the universities that own them. Certain advantages arise from being subject to the laws that govern limited liability companies in the United Kingdom. There may be examples in other countries of this arrangement.

Special research and design units

During the past twenty years many engineering colleges or universities have set up special units to provide consulting, design, research and development services to industry. Most of these units operate in a commercial fashion in that the work they do for industry is paid for by industry. The working capital usually comes from such sources as the college or university, a government ministry or other body, private venture capital and philanthropic foundations. Private venture capital can be obtained only if the industrial unit is a limited liability company aiming to make some profit for its owners. But whatever the financing arrangements such units aim to be self-supporting.

One reason for establishing such a unit is if the demand for services exceeds the available resources of the college staff. The demand can then be satisfied only by reducing attention to teaching and research. But colleges wish to receive fees, to help industry and keep staff and students in touch with industrial problems, and so these units provide a solution. For example the University of the Philippines has three such units—the Industrial Research Centre, the National Hydraulic Research Centre and the Building Research Centre. There are many in the United Kingdom such as the Industrial Research Centre at Salford University, the Engineering Design Unit at Newcastle upon Tyne University and perhaps thirty others. A somewhat similar unit, the Technology Consultancy Centre, exists at the University of Science and Technology, Kumasi, Ghana (see Part Three), and there are many others in the United States and other countries.

These units have some staff and physical resources, the staff usually being employed on contract. They also make use of the staff and facilities of college departments. However, the staff of the unit normally includes technicians who can produce a prototype of a device or make industrial tests on apparatus.

Industry sees these units as centres of research and development and assesses them in terms of value for money. It also, especially at first,
considers them suitable only for basic or long-term research rather than as producers of answers to current problems. In this, industry may be wrong, for several units in the United Kingdom and elsewhere make improvements to existing designs or produce innovations for development and manufacture.

College-based industrial units should undertake sponsored work only when certain conditions are satisfied. There must be at least one person in the industrial enterprise who is concerned with the contracted work, and the college must keep him fully informed of progress. Outside sponsored work can take up much time of busy industrial engineers if the college unit does not communicate, and this breeds dissatisfaction. It should not be left to the industrial client to maintain liaison, as some academics seem to think. The college is not doing industry a favour but selling services for money.

**Difficulties arising from special units**

Of course the industrial units on a campus have difficulties. Some college staff are reluctant to get involved in contract work or, if they do, take unrealistic views of contract agreements. Many problems demand an interdisciplinary approach and, in spite of all the lip-service paid to interdisciplinary activity, these groups can be difficult to assemble. There may be a lack of capital, but there should be no complaints about the fees paid. This is a matter to be settled when the contract is drawn up, and fees should be at a level appropriate to the work and its possible outcome.

The worst difficulty is lack of leadership and enthusiasm in the unit. The choice of a manager or director is probably the most important problem the governing council of the unit will face. One of the college staff might be a suitable person, perhaps to be seconded for a few years in the first instance. In any case it is not wise to make a permanent appointment to this type of unit, if it is possible to appoint for a fixed term. The management of research and development is a difficult task and success is not necessarily maintained over a long period of time.

**Professional training courses**

Some colleges have set up special units to give on-campus practical training in manufacturing technology and similar subjects to young engineers, undergraduates and graduates [65, 66]. Sometimes these units are called 'training workshops'. They are not meant to produce craftsmen but to introduce and use machines, tools and techniques for the construction of some apparatus which has been designed by a group
of students. The design studies will have been accompanied by lectures on relevant subjects.

To give authentic training requires a well-equipped department, and any college contemplating setting up such a unit should approach local industry for help. For example [65] at the Loughborough University of Technology, United Kingdom, the Centre for Industrial Studies has the following divisions: electrics and electronics (measuring equipment); basic modular training (standard machine tools); inspection; projects laboratory (electro-pneumatic equipment, etc., to facilitate construction); heat treatment and metal spraying; welding and fabrication; pattern shop; projects drawing office; laminated plastics (test, moulding and winding machines); foundry, fettling and die-casting; compressors; tools and material stores; advanced machine tools laboratory; projects manufacturing area (certain types of machine tool); thermoplastics laboratory; assignments assembly (fitting and assembly equipment, paint spraying); design drawing office (drafting and printing units), and various offices.

Technicians and craftsmen as well as academic teachers are associated with this centre. Courses can be given continuously over periods extending up to twenty-four weeks or in modular form spread out over longer periods. Short courses are given to engineering and science undergraduates from other universities. This type of co-operation is recommended for several colleges where the number of engineering students in each is not very large. Students can attend such a training session during vacations.

Obviously a well-equipped training unit can have other functions besides training. It can be a centre of construction or production for other college departments and many even take in work from outside, when there is spare capacity at known times, such as vacation periods.
This chapter will deal with the types of co-operation jointly undertaken by industry and engineering colleges, singling out for special attention college co-operation with government, state or other publicly financed research and development laboratories. This co-operation is sometimes positively encouraged by the authorities.

Joint appointments

The joint appointment of an engineer as a staff member in a college and as an employee in industry is not common. It implies that the engineer has responsibilities to two separate organizations and receives an appropriate salary from each. There are some obvious difficulties. The first arises from the different objectives and organizations of colleges and of industrial units. This demands that the engineer must really want to work, if only for a time, in this unusual way, and his personal and technical attributes must be acceptable to both parties. A test of this is whether each party would willingly employ the engineer on a full-time basis if such an opportunity arose. A second difficulty arises from the need to arrange the duties of the joint employee so that he can work in the institution for one or more specified days each week, and in industry for the other days. It is often the industrial partner who finds this most troublesome. Industrial enterprises usually find it unprofitable to employ an engineer (except perhaps as a consultant) for one or two days per week, and will agree to relinquish his services for only some hours or one day in each week. Even in one day the engineer can provide useful services as a teacher and as a supervisor of student projects.

In practice, there is a large difference between a joint appointment and an arrangement whereby an industrial engineer promises to lecture in college for a few hours or so each week, but remains a full-time employee of industry. Even if the engineer receives an extra fee for his
college duties, industry will inevitably claim first-call on his services and sooner or later the engineer will be unable to attend the college on the chosen day or days. This usually means he cannot carry out normal academic commitments. With a genuine joint appointment both partners know that they can employ the engineer only at agreed times. The college can then rely on teaching and other associated tasks being carried out.

The engineers interested in joint appointments seem to be either young and in their first careers or much older with senior status in their profession. A young engineer should be reasonably up to date on educational practice and can also bring from industry knowledge based on current technology in some field. A joint appointment will often suit an able young engineer who has not yet decided whether to remain in industry or return to academic life.

One reward for a young engineer holding a joint appointment is that he retains strong links with both industry and education. But he also suffers some disadvantages in that he is full-time in neither. He ought therefore to receive a further award and a financial one is often the most appreciated. These young people are almost always recruited from industry and the partners, and particularly the college, would be wise to ensure that they receive an increased salary. The engineer will be doing a harder job than before. It is unusual and probably inadvisable for a young engineer to have the appointment extended over more than one year. Some engineering colleges have found it quite rewarding educationally to employ several young engineers in succession under a joint arrangement, thus obtaining a variety of experience at relatively low cost. Of course the usual facilities should be made available for use by these part-time academics.

A senior engineer, usually in industry, who is interested in a joint appointment can be a most valuable link between the two partners. His authority is based on wide experience, perhaps in industry and colleges, and his technical expertise usually ensures that his views and comments are received seriously both in college and in his industrial enterprise, and by wider audiences in professional engineering organizations. Again there is everything to be said in favour of the college, and the industrial enterprise, defining when he is to be available. Joint appointments where a senior man turns up at a college when his industrial commitments allow are usually not completely successful. They are not completely unsuccessful either, because even unscheduled visits, or visits at short notice, do enable discussions to take place between academic staff and the industrial engineer. These discussions can be quite valuable (especially in areas such as research, education and training) but nevertheless the full potential of co-operation is not realised.

Joint appointees of senior status usually expect some kind of academic title such as professor, and often would waive any monetary
award from a college. It is, however, wise to expect and pay for specific duties, if possible on agreed days in a college. What has sometimes been found disastrous is the double appointment where an engineer receives a salary as a full-time professor and also as an industrial engineer. Loyalties are divided and duties intermingled and almost invariably the college suffers for the larger salary originates from industry. Double appointments lead to the 'flying professor' often restricting his visits to a department to a few consecutive days each month, even though he might be titular head of the department. This kind of appointment is to be avoided, whereas the industrially based extraordinary professor or senior academic working under a satisfactory contract can play a major role in co-operation between industry and educational institutions.

Joint appointments seldom materialize if the person concerned has to live away from home or commute long distances. Therefore, for success college and enterprise should not be too far apart.

Interchange and secondment of staff

It is sometimes possible, as has been found in the United Kingdom and elsewhere, to arrange for engineering educators to work in industry and for their places to be filled temporarily by engineers from industry. A direct interchange of staff between a college department and a large industrial enterprise is possible in favourable circumstances. For this to work, the senior authorities in an enterprise must foresee that it is to their ultimate benefit to have one or more of their experienced engineers seconded for a term or semester to a college. In return they will accept engineering teachers to work in industry during a long vacation or for longer periods. No special financial inducement is usually needed and salaries are paid by the original employers during secondment. If the people involved have to be away from home during secondment, the employers usually pay the required subsistence and travel allowances. It should be agreed that these extra costs are in part payment for the enhanced usefulness of the engineers on return to their parent organization.

It must be admitted, however, that while many firms and industrial units will accept engineering educators as workers—often on research or design projects—industry in general seems to find it difficult to release its own engineers to work as teachers in engineering colleges. This is especially true of small firms.

Naturally, an engineering college should take every opportunity to place some of its staff, especially junior staff, in industry for short periods, and at the expense of the college. In some countries, especially the United States, it seems relatively easy for engineering teachers to obtain suitable industrial employment for one term each year when
industry pays their salary. In many other countries all academic staff receive a salary for a whole calendar year and while parts of industry will accept seconded academic staff they are loath to pay a further salary. They argue that they already pay, through taxes, for the educational system. Of course, if an academic does some good work while seconded to industry it is not unknown for him to receive some special award.

**Joint conferences, seminars and colloquia**

Almost every country has engineering organizations that have been created for the advancement of some engineering technology—or at least one such organization within which there are specialist divisions. These professional societies are open to all qualified engineers and their meetings are forums at which engineering teachers and industrial engineers may meet and exchange views and experiences. Sometimes in co-operation with international organizations such as Unesco, UNIDO,¹ WFEO² and FEANI³ these societies arrange conferences on engineering topics, including engineering education. These conferences often lead to a fruitful exchange of views on the role of engineering colleges as centres of industrially important research and in the education and training of engineers for industry.

**Seminars**

Engineering colleges often conduct seminars in which advanced students consider some specific subject under the guidance of one or more teachers. These seminars are sometimes restricted to students and staff of the college. This is a pity, for engineers in industry might have been able to contribute to the discussions had they been invited. Colleges have everything to gain and nothing to lose by inviting industry to send engineers to these seminars. The industry-based engineers need not necessarily be studying for a higher degree as long as they are deeply interested in the subject concerned. Before inviting industry it is worth-while canvassing the views of possible participants on the best possible time to hold the meetings. College-based staff and students are usually able to accommodate a wider range of times, and even venues, than can industry-based engineers.

2. World Federation of Engineering Organizations.
3. Fédération Européenne d'Associations Nationales d'Ingénieurs.
Colloquia

A colloquium is similar to a seminar in that a specific topic is under discussion but dissimilar in that no one sets out to teach or guide the other participants. A good colloquium has some, though not all, of the characteristics of a 'brain-storming' session where ideas are put forward to advance a subject. Formal presentations are usually held to a minimum, although there is usually an initial presentation and the participants should know of the topic long before the meeting takes place. Not all engineering colleges hold colloquia of this type. However, they are often worthwhile and are frequently more entertaining and rewarding than attendance at a lecture followed by a few questions.

Colloquia should be joint affairs between colleges and industry whenever possible, but most seminars probably originate from college staff. In any case the participants from colleges and industry should take part fully in any discussions and studies. Very good relationships can be set up between industrial enterprises and college departments because of the involvement of their staffs in these discussions on advanced or important topics.

Joint research and development projects

It is fairly common for university researchers in science to engage in joint research projects [67]. A research worker or group of researchers in one college collaborates with research workers in another college, or even in more than one college. Each group utilizes what resources it has and works on its own agreed approach to a common problem. Results are exchanged as they accrue and, in general, the advances made by one researcher are greater than had he worked alone. Such collaboration succeeds and continues because the self-interest of each worker is well served. The chemical sciences have produced many successful examples of this kind of collaboration.

In engineering, such collaboration is not unknown but is less common than in the sciences. However, there are numerous examples of cooperative research between engineering colleges and industry. Indeed many research projects in colleges have their origins in industrial problems, and may indeed receive support from industry. However, the type of research problems that are passed over to the colleges depends somewhat on whether the industrial unit involved is part of a commercial enterprise or part of a publicly financed organization. Commercial enterprises are often in competition with one another and so tend to select topics for college research which are of importance for the future. Development projects with short-term commercial importance are not likely to be selected for joint research and development. On the
other hand, publicly supported research and development laboratories, or research laboratories supported by a whole industry, often do share their short-term research activities with university departments.

**Joint curriculum development**

Academics do not usually design curricula as a result of detailed discussions with engineering managers from industry. Yet there is no reason why industry-based engineers should not participate at every stage in the design of a new course or syllabus. Engineers in industry sometimes produce model curricula and usually have their work strongly criticized by academics. This kind of confrontation, and similar ones at engineering conferences, should be avoided by colleges inviting engineers from industry to discuss the content of syllabuses and schemes of study. Many college engineering departments practise these arrangements with considerable success in several countries—see, for example, a description of a particular case in the United Kingdom in Part Three.

**The Teaching Company Scheme**

This rather curious name refers to a programme set up in 1975 by the Department of Industry and the Science Research Council in the United Kingdom, with the aim of developing partnerships between polytechnics and universities and manufacturing companies. The ultimate desirable benefits were [68, 69]: to train able graduates for manufacturing industry; to give academic staff broad and direct associations with industry in research and as a background for teaching purposes; to retrain, and develop the capabilities of, existing company and academic staff; to improve manufacturing methods by the effective implementation of advanced technologies; and to raise manufacturing performance by effective use of academic knowledge and capacities.

The programme operates by a university or polytechnic recruiting good graduates, in consultation with a company, for two years, initially as teaching company associates. These associates, with academic staff, participate in a company programme to achieve a substantial or comprehensive change in manufacturing products and procedures. The associates spend most of their time in industry but are a permanent link with the college and, of course, can use its facilities.

The Science Research Council and the Department of Industry make a grant to each programme that covers the basic salaries of the associates and any academic support costs. Further support is also possible as time goes on and results are shown. Associates may have higher degrees, but if not it is possible for them to register as post-
graduate students, although the aim should be to enter industry in posts with substantial responsibility and rewards.

By 1980 about thirty schemes had been approved with the recruitment of sixty new associates per year being necessary. The initial funds allocated to the schemes are fully subscribed and there is no doubt many more programmes could be supported when, or if, more funds become available.

As might be expected a major factor in the success of a programme lies with the choice of the associates [70], for it is through them that there is day-to-day co-operation between an industry and a college. Furthermore, enthusiasm and interest of both parties will only be sustained if there are mutual benefits. It is still too soon to assess more than a few programmes but it would appear that they do considerably strengthen links between a college and a manufacturing company with benefits to the company in manufacturing capability and thus ultimately in profitability. The college, and the education it offers, benefits by the academic staff being involved in manufacturing problems [71].

Much of what has been said in Part One about ways of co-operation between engineering colleges and industry applies also to technical colleges. However, it seems useful to list in the following chapter activities that are of particular importance to technical college–industry relationships. The accounts of the different procedures used in various countries contained in Part Three are also relevant to Chapter 5.
Part Two

Technical college–industry co-operation
5. Activities of special importance for technicians

The duties of a higher technician

The terms 'higher technician' and 'technician' will be used here as the names for engineering technologists whose education and training have included both the theory and practice of some branch of engineering. A technician's education should equip him or her for useful and immediate employment in industry. This definition excludes the craftsmen and craftsmen/technicians whose training and education have been mostly concerned with acquiring practical skills. However, those people who in different countries have a variety of names such as higher technician (in most countries), higher technician and technician/engineer (as in the United Kingdom), technician and engineering technologist (as in Canada and the United States), and Techniker and Ingenieur graduiert (in the Federal Republic of Germany) are included.

The education and training of a higher technician is usually considered to complement that given to engineers, and thus has slightly different objectives. In its most appropriate form it is not just a truncated form of the education given to an engineer. The education provides enough theory to understand current technological practices in some particular, and perhaps narrow, field and also some skills in the use of measuring instruments and in other equipment. In general the education and training of a higher technician aims to produce a student who will be more or less immediately useful when employed in industry.

Technicians are employed as assistants to engineers and also as technologists in their own right. They work in the field, in laboratories, in design offices, on construction and production, in workshops, on maintenance and operation, as part of the sales force, and so on. Many of the day-to-day activities of engineering industries are supervised and controlled by higher technicians or technician-engineers. In well-run industry, where promotion depends on capability, the avenues of promotion are as open to technicians as they are to any other trained personnel.
Higher technicians often have duties in industry that merge with those of the engineer. Many have a design function and complete or finalize new designs initiated by others, or indeed work as engineering designers on new products. They produce the detailed specifications needed for the construction or production of goods and systems. Many technicians have a managerial function in that they control and direct the work of others. Indeed, some employers will not distinguish sharply between engineers and higher technicians, using them in the roles for which they seem best suited. However, to make a very broad generalization, the higher technician takes over from the engineer once a problem is found to have an acceptable solution [17-20].

Higher technicians and technician-engineers often have talents as entrepreneurs, setting up their own firms to produce a device that satisfies some need which they have uncovered. Sometimes, of course, they supply something to the firm they worked for, or even make something or provide a service which competes with their former employer.

The education of a higher technician

The education of a technician now falls into the tertiary sector of education in all countries, having been preceded by some form of secondary education. Thus in most countries higher technicians and engineers are educated in two parallel streams. These streams may exist in the same college, making use of the same pool of resources. Sometimes the streams exist in the same educational institution but are separated into different colleges with separate groups of teachers and separate physical resources. For example, many polytechnics and colleges of further education in the United Kingdom educate both engineers and technicians, sharing some of the same facilities. In the United States there are universities that educate engineers, engineering technologists and technicians using completely different resources for each group. In the Federal Republic of Germany there is at least one Gesamthochschule which is attempting to educate the (diploma) engineer and the technician-engineer (Ingenieur graduiert) in the same college.

On the whole, however, the comprehensive type of college producing both engineers and technicians is not favoured and most countries educate their engineers and technicians in separate colleges. There are certainly advantages in separation if the objectives of the two types of education and training are seen to be different. The task of each institution is then more clearly defined. Technical education can be full-time or part-time in a college, or a student may not even attend a college except perhaps for examinations.
Full-time education

The so-called 'full-time' higher technical education usually consists in fact of continuous periods in college extending over two or three terms (quarters) each year, and periods in employment. The employment may or may not be a compulsory part of the studies. In many countries it is not compulsory to work in industry between academic sessions because useful short-period employment is difficult to find. In other countries students are admitted to the full-time course only if they have previous practical experience in industry. A full-time course usually lasts between two and four years, the time depending largely on the level of the preceding secondary education and perhaps training. For example, the British technician-engineer and most German Ingenieur graduier graduate after a three-year course, while engineering technologists in the United States graduate after four years in a college that is often part of a state university. Technicians in all these countries can usually obtain a qualification after two years in a full-time course, provided it has been preceded by approved employment and education.

Part-time education

Part-time education exists so that people can earn a living and obtain practical experience while obtaining an educational qualification. In the so-called 'block release' type, employers allow workers to attend a technical college for a period of weeks, perhaps more than once per year. At other times the students attend evening classes. Another form is 'day release' whereby students attend a technical college for one day per week while working in industry for the rest of the week. Part-time students may also obtain their qualification by attending evening classes only, and in some countries special technical colleges teach technicians through correspondence courses, radio and television. Nearly all part-time students work in industry and are already craftsmen or craft and technical apprentices. Thus when they graduate as technicians they possess industrial manual skills that are of immense value not because they will make great use of them as higher technicians but because they will know what to expect from craftsmen or craft/technicians. It is unfortunate that in many of the less industrialized countries there are too few higher technicians of this kind.

True co-operative or sandwich courses for higher technicians—where a student spends, say, six months in college and six months in industry each year—do not seem to be favoured by industry, though they do exist (in the United Kingdom for example).

Work in industry which would seem appropriate for higher technicians, technician-engineers or engineering technologists is often carried
out by graduate engineers. There are several reasons for this, such as:
the shortage of available higher technicians; more employment
opportunities for higher technicians than engineers in some industries
and enterprises; and graduate engineers finding the role of a higher
technician more satisfying or matching their capabilities and desires.

The shortage of higher technicians, and sometimes a corresponding
surplus of graduate engineers, may be due to a failure by the educational
sector to appreciate the needs of industry. It is often due, however, to
political and social factors. In some countries practically all students
with higher secondary education expect to enter a university-type
institution such as an engineering college. A sharp division exists
between the craftsman (a manual worker) and the engineer (a desk
worker) and so entering a technical college from high school is the
choice of only a minority. The needs of industry can then be met only by
employing engineers as engineering technologists or higher technicians
for day-to-day rather than future-oriented tasks. Having inflated expec-
tations about their roles in industry, many will then be dissatisfied in
spite of the fact that the jobs might well be appropriate for their
capabilities.

Professional societies for higher technicians or technician-engineers

Higher technicians whose education has been that meant for an engineer
are found not only in newly industrializing countries but also in highly
industrialized countries. It is interesting that from 1982 the major
professional engineering societies in the United Kingdom will not accept
graduate engineers with low grades as having adequate qualifications
for membership. Only people with first and second-class honours
degrees will be accepted. Others, although having engineering degrees,
will need further qualifications; they could join a technician-engineering
society, however, following practical industrial experience.

Professional societies set up by technicians for the purpose of
advancing and disseminating engineering technologies are relatively
new. In the United Kingdom the major professional engineering
societies set up subdivisions for technician-engineers which are now
practically fully-fledged societies with their own regulations, entrance
qualifications, and so on [19]. They now concern themselves with many
technological practices which at one time would have been major
subjects for discussion at meetings of engineers. Certain higher techni-
cians, such as quantity surveyors, have been able to join a professional
society for many years, but the spread of these organizations is a
recognition of the importance of technicians and engineering
technologists in industry.
Continuing education for technicians

There is no finality in the education and training of technicians. New practices and knowledge are bound to affect the work of a technician and will have to be mastered. Technicians will need retraining and additional education from time to time. The technician societies mentioned above take part in this process of continuing education, and indeed it is one of the reasons for their formation. However, both industry and technical colleges must also take part. Sometimes industries can do all the retraining and re-education needed by their technicians but often it is better done in co-operation with technical colleges, which should ensure a broader training than an enterprise is likely to give its employees. Indeed it is the duty of a technical college to help introduce new knowledge and practices to practising technicians by means of short courses in college and in industry and by any other means that resources allow. Holding courses inside an enterprise is an excellent way of getting to know not only personnel but the practices of that particular industry. Continuing education is the subject of Study No. 3 in this Unesco series on engineering education [2] and should be consulted for further information.

College management

The precise form of college management depends largely on the educational system practised but some general observations can be made. The administrative head, or 'principal', should be an engineer or technologist with considerable experience of industry and of technical education. Only then will he, or she, be able to form satisfactory relations with industrialists and industrial engineers and technicians.

The headship of a technical college is an important post and should be rewarded accordingly, making it both important and attractive. It should certainly not be a stepping-stone in the careers of middle-grade civil servants in a Ministry of Education, as has happened in some developing countries.

The governing body of a college is usually some kind of council with appointed and co-opted members. In many countries such as Belgium, Switzerland and the United Kingdom, the council has a proportion of industrial representatives, usually engineers or technologists. This is the first step in college-industry co-operation and is a practice that should be followed wherever possible. Sometimes a college has a separate non-executive advisory committee with whom the principal can discuss matters relating to industry, but this does not seem as satisfactory as having representatives of a variety of large and small enterprises on the main governing council.
When industrialists are connected with the governing bodies, they usually emphasize the desirability of the teaching staff having worked in industry before taking up teaching. College administrators often prefer to appoint engineering graduates to teach technicians, which is acceptable if the engineers have the requisite experience, but there is sometimes a reluctance to appoint experienced higher technicians as teachers although these people may give the most valuable services. Industrialists on an appointing committee will help to counteract this tendency to overvalue initial academic qualifications relative to practical experience.

Departmental advisory boards

A successful college produces graduates whose qualifications are recognized as of value by industry. The students then know that the diploma or other qualification is worth striving for and will probably lead to a satisfying position in industry. Recognition certainly depends on the courses being closely related to industrial needs. The recognition of qualifications and the relevance of courses are both facilitated if engineers or higher technicians in industry participate with teaching staff in discussions about curricula (see 'Curriculum design' at the beginning of Chapter 2). It is common in some countries, but unknown in others, for a few practising engineers and technologists to be invited two or three times each year by a department for such discussions. This feedback from industry is most valuable not only for curriculum design but for other co-operation.

In some countries, Belgium and Switzerland for example (see Part Three), the board of examiners or examining juries comprises both college staff and industrial representatives. This practice seems to be successful and perhaps should be more widespread than it is. After all, technical colleges exist only to produce educated people with technical knowledge and skills for industry. The secretive way in which diplomas are awarded in some systems can hardly increase the confidence of industry in the quality of the education.

Industrial liaison officer

At least one member of the college staff should be an industrial liaison officer and provided with secretarial staff. Such an office should: assist all enterprises and other users of technicians in the region served by the technical college by informing industrialists of the current and future activities and functions of the college; channel information from industry into college departments and arrange opportunities for college teaching staff to visit industry; negotiate vacation and other kinds of employment for students who are not sponsored by an enterprise; and
bring to the attention of graduating students any known vacancies for technicians.

Such an officer, with experience of teaching and of industry, can play a most important role in setting up good working relationships between college departments and relevant industries. He should take information about his college and its courses into industry without waiting to be asked. He should see himself as a catalyst in the college-industry relationship and not, of course, as the only channel between college and industry. Many successful colleges have such offices and officers, and those that do not should consider carefully their merits and demerits.

Industrial officers should be located as near as possible to the college departments. Such an officer will probably report to the college principal, but nevertheless should not be placed in some administration building remote from the technical teaching staff and the students, with whom he should mix. A good industrial relations officer is not just a public relations man. He is that and more—he is a link between industry and the college departments who understands the functions and limitations of both parties.

Modular schemes of study

It was mentioned earlier that courses should be arranged to meet the needs of technicians and industry. There are many types of course but there is a tendency today to arrange courses in modular form. A final qualification is awarded when a certain number of approved modules have been completed, a module being one or more courses that together have an objective. Modular courses are relatively short, lasting perhaps from five to ten weeks when full time and longer if part time. To a large extent a student can then plan his own programme of studies to suit his needs, abilities, the time available and perhaps his finances.

Each module should be carefully designed, preferably after discussion with industry, and have a well-defined set of objectives. A module is completed usually when the student passes some kind of examination, but whether a student attempts one or more modules in a year depends on the student, and perhaps on his employer. Sometimes a certificate of progress is awarded when a certain number of modules have been completed, and this counts as a qualification of a kind. The final diploma might then be awarded when two or three certificates have been obtained. This procedure enables a student to demonstrate to employers that he is progressing in his studies. Technician studies in the United Kingdom, for example, are moving away from national certificates and national diplomas to new technician engineering courses which are usually given in modules.
Projects for students and aid to industry

Experimental and constructional projects should be part of any technician course, and because communication is part of education students should write reports for specified people (such as an engineer, another technician or a non-engineer). They should also present results in seminars to their fellow students. Small enterprises can often set up closer relationships with technical colleges than with engineering colleges and are also often happy to pass problems on to the college. These problems can be used as the basis for projects. Technicians can often bring in projects from their own employers, and in some cases part of the work may be carried out in industry. The point here is that project work is just as important in technical education as it is in engineering education.

Project work should provide credit towards the final qualification. If teams of students work on a project—and this is to be encouraged—then there is usually no difficulty in discovering the contribution of each student. Indeed, the students are invariably quite clear about any individual’s contribution.

Visits to industrial enterprises and organizations

Technician students are almost always curious about what goes on in industry, and especially when they themselves have been or are employed in industry. This curiosity should be encouraged and satisfied whenever possible. However, the college staff involved in taking students to an industrial enterprise should always visit the place beforehand, to meet people and to learn something of the industry. They should then preface the visit by giving a short lecture to the students about the functions of the enterprise they will visit. The full educational value of the visit will then be realized. Taking this kind of trouble is also a good way of setting up sound college-industry relations.

Seminars, lectures and conferences

There are fewer meetings of these kinds for technicians, especially for higher technicians, than there are for engineers. One reason is that few employers encourage technicians to attend meetings that take them away from their employment for more than a few hours. Another reason is that in some regions there are fewer technicians than engineers. Also there may be no professional societies for technicians. Nevertheless it should be considered a duty of a technical college to introduce new technological advances to working technicians and to reinterpret exist-
ing knowledge in a form suitable for higher technicians. This usually means avoiding the use of higher mathematics but in fact most engineering practices and advances can be adequately explained without them.

Commercial technical journals suitable for technicians are available in some countries but not in others. In any case technical colleges can help industry by holding seminars on a particular topic, organizing lectures at times when technicians can attend, and perhaps occasionally convening a major conference. College managements should note this important duty and staff their colleges appropriately. A good staff will be composed of teachers with engineering qualifications and of higher technicians, both groups having industrial experience. It is not a happy practice to make some kind of hierarchical distinction between lecturers with higher technician qualifications and those with engineering qualifications, for both are needed. Further promotion should depend on ability and usefulness, not on initial qualifications. There is almost always an excellent feedback from industry to college when this role of disseminating information is carried out skilfully.
Part Three

Country and regional examples
Introduction

The following accounts are mostly based on material supplied to the Unesco International Working Group on Education-Industry Co-operation in the education and training of engineers and technicians, either by its members or through the Fédération Européenne d'Associations Nationales d'Ingénieurs (FEANI), Paris, France. They show some particular examples of the things that can be done in the area of education-industry relations and co-operation. The countries and regions represented are as follows: Afghanistan, Belgium, Canada, Denmark and Scandinavia, France, the Federal Republic of Germany, Ghana, Italy, Kenya, Latin America, Peru, Sri Lanka, Switzerland, the Union of Soviet Socialist Republics, the United Kingdom, and the United States of America.

Further examples of different activities in other countries may be obtained from the references.
Technical schools have existed in Afghanistan for more than half a century but the two institutes of higher education, namely the Faculty of Engineering at Kabul University and the Polytechnic Institute, were created only in the past twenty years. The need to provide food, shelter and jobs in Afghanistan requires the establishment of larger industries and increased production of agricultural products. To provide the required industrial manpower about three more universities with engineering colleges will be needed. The formation of one new engineering college was announced in 1978 by the Ministry of Higher Education.

The existing engineering institutions are aware of industrial needs and have devised innovative methods of teaching and training engineers. Both small and large industries, with the exception of the textile industry, have a very short history. The industries and educational institutions have grown simultaneously and in a way co-operation has therefore been inevitable. For example, about 60 per cent of a new detergent factory was built using the facilities and staff of the Faculty of Engineering at Kabul University.

In the past the intention of the Faculty of Engineering was to produce graduates in a wide range of disciplines relevant to growing industries, such as food-processing, management, and chemical and agricultural engineering. At present, however, the faculty teaches only mechanical, electrical, civil, architectural and agricultural engineering, the latter jointly with the Faculty of Agriculture. It also does vocational technical teacher training.

The Polytechnic Institute is following a similar programme but with more emphasis on practical work and specialization. The capacity and

1. Based on material supplied by Professor B. Sayar of the University of Kabul and a member of the Third Meeting of the Unesco Working Group on Education-Industry Co-operation.
staff of the Polytechnic is almost ten times that of the Faculty of Engineering but student enrolment levels are similar.

**Education-industry co-operation**

A programme of six months of practical training is compulsory for all students and it is placed in the ninth semester of the curriculum. The students are introduced to different industries according to their fields of study and are required to submit a report on their work and observations. In this programme the students learn what industry requires of an engineer, and perhaps find employment after graduation. Due to lack of good co-ordination this programme is not as productive as expected. A college committee organizes the programme but there is a need for a similar office in each ministry that controls an industry and its training officers. Mutual understanding and planned arrangements between the two responsible bodies would assist in a smoother operation and a more fruitful outcome. At various times, of course, students are also taken on short visits to appropriate industries in Kabul.

In the fifth year of the curriculum a seminar is offered. Outstanding industrial officers and experienced professional engineers are invited to give lectures on actual engineering problems and successful and effective solutions. Administrative, managerial and technical problems are given as examples. Sometimes students are required to do field research and present their findings orally and in writing.

For many years the graduates of the Faculty of Engineering were assigned to key administrative positions and it was found useful to introduce a series of non-technical courses such as management, accounting and marketing. Early in the 1970s a consulting centre was formed within the faculty and from among the staff of the faculty. This is called the Centre for Engineering Consulting Services and Applied Research (CECSAR). During the past ten years many practical engineering projects have been investigated in the centre and many staff members, students and technicians have been involved. The results have been shared with the ministries, the industries and the staff of the faculty. In addition to providing experience, this programme has helped the staff of the faculty financially and has saved thousands of dollars in foreign consultancy fees.

**Conclusion**

These programmes have helped in establishing closer ties between industries and the Faculty of Engineering and the students have been exposed to practice before graduation. On many occasions students have
been hired in the industries where they have spent their practical training programme or where they have established contacts through consulting work. It has also been a common practice to invite part-time lecturers, including the presidents of engineering firms, to deliver lectures for one or two semesters. The faculty has also hired senior officials and experienced engineers for teaching, thus introducing industrial requirements into the curriculum and hopefully producing engineers more acceptable to the industries. Generally, however, the colleges have shown more interest than industry in co-operation, which is why it was suggested that training officers be established in industry.
Belgium: the education of industrial engineers

Engineers in Belgium are educated in two types of institution. The first comprises the Faculties of Applied Sciences, Agronomy, and certain other disciplines which are part of the universities. The education lasts five years—after completion of secondary education—and leads to the diploma of ingénieur civil or ingénieur agronome [4, 66].

The second type of institution has evolved over a long period with the aim of producing industrially oriented technicians, and now engineers. Many of these institutions were created by the initiative of industry. Some of them now have university status and educate engineers for a course which lasts four years—after five years of secondary education. In what follows this second type of engineering education will be used to illustrate the co-operation that exists between engineering education and industry.

This second type of course leads to the diploma of Industrial Engineer, and probably involves less time studying pure sciences than do similar courses in the university faculties. The educational programme leading to the diploma of Industrial Engineering is called in law a higher technical education of the second degree. Higher technical education of the first degree is a shorter course (not at university level) and it leads to a higher technician qualification. In many ways the involvement of industry with both courses is similar.

Higher technical education began in 1825 when the École des Arts et Métiers was founded by the town of Gand in co-operation with the local textile industry, which helped to support it. Between 1899 and 1929 twenty more higher technical institutes were created, thirteen by private initiative, five by various towns and two by provinces. In each case the initiative came from industry and from industrial workers. Similar

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1. Based on material supplied by Industrial Engineer R. Lully-Coman and Civil Engineer A. Gravy, respectively vice-president and secretary of the Belgian National Committee of FEANI.
institutes were later created for agricultural education. The new institutes were near the new centres of industry and covered all aspects of industrial activity. In due course a further twenty-eight were created, sixteen by the state, five by provinces, three by towns, and four by private initiative. More agricultural institutes were also created.

Belgian industry has always supported higher technical education and has helped its institutions develop through gifts of equipment, materials and money. At one time only those institutions founded by the state received state support. Most did not and industry concentrated its aid into these for several reasons, one being that bureaucracy put many obstacles in the way of industry providing aid to a state institute. Industry and the higher technical institutes have therefore collaborated for a long time and this collaboration included, of course, the choice of subjects taught, practical training and administration.

Technical education is now closely controlled by the Ministry of National Education and Culture. The ministry is in complete control of its own institutes, but public bodies such as provincial governments and town councils which have set up institutes have control over most day-to-day administrative matters, as do the private bodies which created institutes. All these administrators are advised by various councils and committees, usually statutory committees set up by law, in many of which industry participates, including those concerned with part-time and continuing technical education.

College-industry collaboration

ADMINISTRATION AND CURRICULUM DESIGN

The by-law of 1953 provided that more than half the members of administrative committees must be persons competent to represent economic and social activities. Each speciality taught in an institute has its own advisory council made up of industrialists. It discusses curricula, practical training, new technological developments and even participates in the jury of examiners assessing diploma work. This co-operation of institute and industry is in fact controlled by law (1924) and this law came into being because of industrial pressures. It rationalized and standardized many aspects of engineering education including standards of admission, scientific levels of study, length of studies and national control of final examinations.

At the national level industry participates in the Council of Higher Technical Education, set up initially in 1970 as a successor to similar bodies. It is concerned with programmes of study, the resources needed to teach a certain subject, and of course the organization of technical education. The parliamentary and other discussions that preceded the setting up of higher technical education of the second degree and its
corresponding institutes relied on information supplied by industrial representatives.

EDUCATION AND TRAINING

Practising engineers have always participated in technical education and industrialists have encouraged this tradition. Usually these part-time professors give specialist courses related to their own work, and are seldom asked to take charge of general courses. Sometimes, in subjects such as electronics, automation and welding, they may be in charge of laboratory instruction, perhaps for one half-day per week. Part-time teachers drawn from industry must now hold either the university diploma of Civil Engineer, or sometimes diplomas of Industrial Engineer or Technician-Engineer.

STUDENTS IN INDUSTRY

It is a necessary part of the course leading to the diploma of Industrial Engineer that students work in industry. Unfortunately the student vacations coincide with industrial holidays and students are therefore often inconvenienced by having to fit in industrial work at other times. The Higher Committee of Technical Education is now considering adjusting the academic year so that students can work in industry at a time convenient to both parties. Sometimes industrial work can be combined with final project work, and a student works in industry between completing his final theoretical examination (June/July) and the end of the second session (October/November). The final defence of his project work is in November, after which the diploma can be awarded. This can be arranged, as yet, in only a few establishments.

EVALUATION OF EDUCATION AND TRAINING

Representatives of industry and university professors always participate in the jury of examiners on theoretical and practical subjects, and at the defence of the final project thesis. This participation is valuable to the institutes and to industry. Industry is made fully aware of the levels of instruction and the standards of examination on which it can comment to the professors. Furthermore it can advise on changes of direction in a technology, leading perhaps to a change of the curriculum.

By a law of 1977, holders of the diploma of Technician-Engineer obtained between about 1900 and 1979 can under certain conditions have their diplomas assimilated within the grade of diploma of Industrial Engineer. This requires an examination of scientific qualifications and practical experience. The committee that assesses applicants for transfer has representatives of the Federation of Belgian Industry. Indeed the French section of the committee is presided over by the managing director of a large industrial enterprise.
Canada: a college for advanced engineering practice

Developing the professional competence of engineers

The example from Canada concerns a college that has been established with the support of major Canadian companies, the Engineering Institute of Canada, the Government of the Province of Quebec and the Government of Canada, primarily for developing the professional competence of young practising engineers. It is different from existing colleges in that it emphasizes engineering practice in all its aspects.

It was planned particularly, although not exclusively, for those developing countries that wish to appoint their own nationals to senior positions and thus lessen their dependence on imported engineers and technology. The development of the professional engineer continues after a university course and is composed of experience on the job supplemented by further studies. It should comprise:

- Understanding of many related subjects, such as finance, safety, resource and environmental considerations, legal standards, human relations, etc.
- Maintenance of up-to-date knowledge of a rapidly advancing technology, which is a compound of engineering science and engineering practice.
- Development of the engineering judgement needed to assess and combine all relevant factors and thus determine the optimum design in any given situation.
- Development of the management skills required to co-ordinate men, materials, machinery and money effectively to achieve the desired optimum result.

1. Based on material supplied by Professor D. L. Mordell, formerly Dean of Engineering at McGill University, Montreal, and now at the Canadian College of Advanced Engineering Practice, Montreal.
Some of the needs can be met by courses given at a university. However, university professors are usually more highly qualified in research than in practice. For those who can teach the latest engineering practice and management to the younger engineer, we must rely upon experienced engineers and managers who are engaged daily in the problems of practical engineering.

The optimization of procedure and designs, the acquisition of good judgement, real experience of management and human relations, and the difficulties of applying theories to practical situations can be learnt only by practice, either in a consultant's or a designer's office, or with a director or in a factory. However, an engineer is normally learning only during a small portion of his working time. A junior engineer spends most of his time carrying out routine tasks.

In a highly industrialized country such as Canada most engineers learn from experience. That it takes five times as long as it needs to reach a level of competence does not matter too much, as a rule, for the young engineer is doing a useful job supervised by his seniors. Even so, there are situations when it would be advantageous for younger engineers to gain competence much more quickly and take on responsibilities at an earlier age.

**Canadian College of Advanced Engineering Practice**

This college was established to speed the development of professional competence in young engineers. It enjoys the co-operation of universities, which will admit college trainees to those courses best given in a university, but it also offers its own carefully designed courses, lectures and case-studies. Courses are designed by practising engineers and case-studies are drawn from recent practical experience of Canadian engineers of major projects in Canada and abroad. Thus they include not research results but the latest successful engineering practices drawn from all over the world.

Its pattern of operation is that of a 'staff college' and its student engineers, particularly those from countries where wide experience is slow or difficult to obtain, take a two-year programme of integrated course work and assignments to monitored job experiences. This programme is believed to equal not less than ten years of random exposure in industry, with its usual long periods of repetitive work between valuable learning experiences. The college has an advisory board of practising engineers and others with university experience [72].
The programmes

The college offers programmes in three major areas: engineering works (design and construction); engineering operations (power systems, transportation and communication); and engineering in industry (manufacturing and maintenance).

Because of the need of some countries to develop engineers as potential professors of engineering, and because these professors need practical up-to-date experience, arrangements can be made for trainees to acquire experience at a university in teaching or demonstrating, if required.

The detailed programme is worked out to suit each individual's needs, and progress is carefully monitored. A typical programme, for instance, would include study of such things as general project management, estimating, budgeting, finance, computing, human relations and communication, legal problems and work overseas, safety, and a series of case-studies presented in seminars.

There must, however, be flexibility as all trainees have had at least five years of experience before coming on the course. As a guide it is expected that, during the first year, the trainee will spend three periods of four months on specific areas such as planning, estimating, purchasing and control systems. During the first year he will do most of the course work.

In the second year the trainee will spend six months on general project management or on planning a major project. He will be attached as an assistant to a senior engineer or manager. In the second six months the trainee will be similarly attached to a project manager or a construction superintendent on some major overseas project, to gain experience in another developing country than his own.

These periods of attachment are designed as training periods. Progress is carefully planned and monitored by the college to ensure the optimum results. The actual experiences are discussed in seminars attended by all trainees, so that there is maximum benefit to all.

The trainees

The trainees are engineers with at least five years of experience who have shown evidence of great ability. They must be supported by their employer or government who should 'second' them to the college for the two-year course. Developing countries can sometimes arrange for financial aid for their trainees, from such agencies as the Canadian International Development Agency, the Department of Inter-governmental Affairs of the Province of Quebec, the Commonwealth Foundation and Unesco. The college itself sometimes provides
assistance to trainees to help defer some of the costs of living in Montreal.

Co-operative (sandwich) type education in Canada

In recent years co-operative-type university education in Canada has increased in popularity. The engineering departments at Waterloo University, Ontario, are committed to this type of education and training and probably attract more potential engineers as applicants than other colleges of engineering in this country. A good account of this educational practice and its links with industry can be found in the Proceedings of the Third Unesco/UPADI Seminar on Education–Industry Co-operation, published by the Union of Engineering Societies, Mexico City, Mexico.
Denmark and Scandinavia: co-operation for several purposes

Until 1957 engineering education in Denmark took place at the Danish Technical University and led to the degree of Civil Engineer in the usual variety of engineering disciplines. The course lasted about four and half years for civil and chemical engineers and five and a half for electrical and mechanical engineers. Within the five-year period practical training was included. The degree is considered equivalent to the Master's degree given in many other countries [73].

In 1957 the Danmarks Ingeniørakademi (DIA) was founded as an optional and shorter form of engineering education. The course lasts three and a half to four years and leads to the degree of Ingeniørakademi. It is considered equivalent to the Bachelor's degree in other countries. The DIA aims to give its graduates theoretical and practical knowledge, enabling them to practise as professional engineers [74].

Technicians are educated in a variety of institutions providing full-time and part-time education and training. For example, the teknikums educate and train higher technicians or technician-engineers. Their courses last three years and lead to the diploma of Ingeniør—the common title is teknikum-ingeniør. Entrants to a teknikum must usually produce evidence of previous practical training as well as an approved secondary education.

Education-industry relationships will be described below using chemical engineering at the DIA as an example.

Practical training at the DIA

A thorough theoretical foundation is provided at the DIA, without losing sight of the practical application. Thus the student is taught the relevant

1. Based on material supplied to the Unesco Working Group on Education-Industry Co-operation by one of its members, Professor L. Alfred Hansen of Danmarks Ingeniørakademi (DIA).
branches of fundamental mathematics, physics and chemistry as well as the theoretical and empirical basis of specific engineering subjects.

Chemical engineering students spend their fifth semester on various practical courses. One of these, of particular importance, comprises four weeks of work in chemical factories—one week in each of two factories and two weeks in a third factory. The work is organized as follows.

The students work in a factory in groups of six under the guidance of either a teacher from the DIA department or a local chemical engineer. The work might be characterized as typical engineering assistant work. The students perform measurements and calculations on working equipment; they set up energy and material balances, calculate efficiency, suggest improvements, and so on. They also collect facts and conduct interviews on such topics as organization, safety hazards and protection of the environment. From their previous two years' studies and laboratory work the students have already acquired sufficient background to perform these tasks. At the end of the four weeks they spend one or two weeks writing their reports, partly as group work, but also alone. The demands on the quality of these reports are kept very high. The reports are regarded as an important exercise in professional communication, and all aspects of their quality are discussed with the authors.

This form of practical work has proved of great value. The students derive great educational benefit from it, and their motivation for the final year of theoretical studies and project work is considerably enhanced. What is most important is that the students understand and accept the educational scope of this practical work, and in most cases they enjoy themselves, even if the work at the factories may be rather demanding.

However, these arrangements obviously create demands on the teachers and the factories. The work of a student must be well planned in advance: his time must be filled by relevant activities; and the expected results must be worth while. Also the co-operation of the factory staff must be ensured for the inquisitiveness of the students sometimes requires considerable patience from a plant manager or an operator. The company must also be willing to let the students question, look into, discuss and report on anything.

Thus, because of the requirement to provide supervision and liaison, this practical work is expensive. Also, because of the problem of confidentiality combined with the demands such visits put on the plant personnel, some companies hesitate or refuse to accept such arrangements. Fortunately, however, a great many Danish firms are helpful and patient, mostly because they agree with the teachers and students that these four weeks in industry are educationally very rewarding.
Project scout: a link between ideas and industry

Denmark is almost completely devoid of natural resources such as coal or oil. Hydraulic power is non-existent, but the country's soil and climate are well suited to agriculture. However, the notion that Denmark is mainly an agricultural community must now be discarded. Less than half of Danish exports come from agriculture, and only about 10 per cent of the population work in primary agricultural production. Industrial production is now the most important activity of the Danish economy.

Danish industry cannot make a living by producing what any other industrialized country can produce. Typically, the Danish shipbuilders have great difficulty in competing with countries where the wages are lower and where the steel is a home product. Danish industry must be based on ideas, know-how and design. But the road leading from an idea to a finished product may be long and difficult. The man with an idea may not appreciate its possibilities, nor know how to get it developed into an industrial product. The industrialist may be unaware of the existence of important ideas and inventions, or he may be unable to develop his own ideas for lack of research manpower and facilities. In Denmark many opportunities for inventors and producers are wasted in this way, but now something is being done.

The Danish Council for Scientific and Industrial Research is establishing a position for a 'project developer' or 'project scout', whose job will be to organize the co-operation of the creators of ideas, researchers and industry. He is not only to be a mediator; he and his staff will work actively in the formulation and planning of research and development projects based on ideas that might otherwise be ignored.

It is obvious that the engineering schools, and their research and development institutes, will often be partners in these arrangements. The creation of this new concept therefore represents a new and valuable link between industry and the engineering schools.

Contract research in Scandinavian countries

All Scandinavian countries (Denmark, Norway and Sweden) have long traditions of close co-operation between engineering schools and industry which has been relatively unhampered by rules and restrictions [63, 75, 76]. During the past decade, however, conditions have changed considerably in Denmark, and similar changes are expected (or have already taken place) in the other two countries. The changes in Denmark can be summarized as follows:

The decision to accept or reject a proposed research contract no longer rests with the professors or other qualified teachers; such decisions
are taken by the laboratory board which consists of four teachers (the professor may not be included), one student and one member of the office or workshop staff;
The possibilities of promising the contract partner confidentiality, let alone secrecy, have diminished rather drastically;
The participation of students in contract work as part of their studies is restricted, or even forbidden.
These changes are closely connected with others concerning the management of higher education. Democratization is advancing rapidly. In Denmark the prerogatives of the professors have disappeared almost completely. Professors and younger teachers are now equally eligible for membership of all governing bodies, and students and non-academic staff are members of these bodies, together holding up to 50 per cent of the seats.

Some students (and some teachers) now doubt that co-operation between private enterprise and engineering schools on research projects is of much value to the schools in particular and to society in general. A few lines from a report (1976) of a Norwegian committee on contract research may serve as an illustration. These lines are taken from a statement by a minority consisting of the student members of the committee:

We advocate a stronger social engagement in research. We want a development towards research for the benefit of people as a whole. . . . This development is not ensured if the research of universities, etc. is subject to the rules of the free market in which Norwegian research will serve the interests of those who are able to pay.

Such views are endorsed by many politicians and are, therefore, reflected to some extent in recent preparations for new legislation. This development is widely deplored in engineering schools and in industry.

At the Technical University of Denmark contract work is not, of course, a primary objective of the laboratories and departments. Such work can be undertaken only if it does not interfere with the educational and general research duties of the department in question. Nor may the departments accept contract work in competition with private firms that could also do it. The Technical University’s contract is therefore always based on special knowledge and/or advanced equipment.

Fees for contract work are paid to the central administration of the university, which allocates it between the university, the Ministry of Education and the department according to a prescribed formula.

So far there are no written rules concerning confidentiality. According to accepted practice, however, the department has the right to publish the results of its project work unless, in a particular case, an agreement of confidentiality is set up. Such agreements are valid only for a limited span of years.
The participation of undergraduate students in contract work is subject to considerable restriction. A student's normal course work or his research project cannot be part of a contract research project. An undergraduate may be employed in and paid for contract research work, but this does not yield him any credits in his studies. If the result of the work is published, any participating student has the right to be mentioned as a co-author.

Contract research may, of course, be carried out for private or public enterprises, or for international bodies.

Training of technicians in Denmark

Technicians are trained in the following fields: electronics, mechanical industry, supervision of machinery, building, woodworking industry, forestry, agriculture, food production, dairy industry and chemical laboratory work. Most courses are divided into two or three parts, which can be taken successively, often with compulsory practical employment in between and each of which leads to a higher level of competence. Some technicians remain on the lowest level, which may be reached after a one-year course or in some cases six months.

It is an important feature of the Danish system that technicians cannot become engineers by taking a shorter supplementary engineering course, much to the regret of progressive politicians who think it desirable and feasible that anyone should be able to end up anywhere in the educational system from any starting-point (to put it in a simplified form). Of course, a technician can become an engineer, but only after a full engineering course with possible reductions in practical work. The engineering schools have maintained the idea that an engineering education should start with high-level courses in mathematics and physics (which will be new to a technician).

Another important feature is that the applicants must have learnt a trade, or be skilled workers, before they can enter a technician school; for example, only carpenters and cabinet-makers can enter a woodworking technician school and the technician courses aiming at mechanical industry take in only skilled mechanics. However, some of the fields listed above, such as forestry and chemical laboratory work, have no corresponding trade. Technician students are admitted to these courses directly from school (mostly at the age of 17 and with lower secondary certificates). The training in these cases is of a sandwich nature, with long spells of employment in industry between the more theoretical parts.

As far as co-operation between industry and technician schools is concerned, the practical training of the technician students must take
place before they enter the technician school or, as mentioned above, is arranged as regular employment in industry between school courses. Without this practical experience in learning a trade or being employed for some period or periods in practice the students would make poor technicians. The success of the technician schools is also largely due to the fact that most of the teachers have had considerable practical experience in industry.
There are about 154 colleges in France that educate and train engineers. Some, in fact, are faculties of universities but many are not and the latter include the well-established grandes écoles. The length of courses after normal secondary school education is usually five but sometimes four years. Many of the five-year courses are split into two parts: the first two years are mostly devoted to the study of mathematics and science as a preparation for a competitive examination leading to entry into an engineering college; and the final three years are spent studying engineering. After a five-year course French industry expects its young engineers to assimilate rapidly the priorities of any enterprise that employs them and to contribute to its progress. Co-operation between industry and engineering institutions has no standard pattern and examples of co-operation between two colleges and industry are described below.

The training of higher technicians in France takes place in certain lycées techniques. In these technical institutes students follow a two-year course leading to a qualification of Brevet de technicien supérieur (Higher Technician Certificate). Entrants often already possess the Brevet de technicien (Technician Certificate) if they have been educated at a secondary technical school and have had industrial experience. But it is possible to enter with the ordinary baccalauréat from secondary school, in which case higher technician training will normally take three years.

1 Based on material supplied to the Unesco Working Group on Education-Industry Co-operation by Professor J. Guy of ECAM, Lyon, through FEANI, on an account of engineering education at ESIEE given by Professor P. Bildstein at a conference at Hull University, Hull, United Kingdom, in April 1980, and on other sources.
École Supérieure d'Ingénieurs en Électrotechnique et Électronique (ESIEE)

This is a new engineering college in Paris, created in 1966, and running a five-year course as one unit. The college is a public institution and is one of the schools of the Paris Chamber of Commerce and Industry. Entry is by a competitive examination and an interview that sets out to test motivation, creativity, communication skills and ability to work in a group.

A knowledge of the English language is considered important and lectures may be given in English. It is also possible to learn German. Indeed students must spend at least six weeks in a foreign country before graduation and this period can be extended up to two years. Arrangements exist between ESIEE and some universities in the Federal Republic of Germany, the United Kingdom and the United States so that students may complete their studies in the fifth year abroad and obtain a United Kingdom or United States Master's degree, or German diploma, as well as the diploma of the ESIEE.

In Paris all students spend most of their fifth year engaged in work on an industrial project, usually in groups of three. The projects originate in industrial firms that support the work by the payment of a substantial fee. They are supervised by a member of the college staff and each week a visit is made by an engineer from the co-operating enterprise.

The acceptance of industrial projects by the college and a student group begins in the fourth year, so that two months before the fifth year begins in September, projects have been chosen, and groups formed and much information has been acquired. Student participation in these early discussions helps to motivate students. The payment of a large fee by an enterprise ensures that the firm remains interested in the work and co-operates as closely as it can. It also means that the project may have to be conducted within certain constraints, such as confidentiality, use of standard components, manufacturing constraints, financial or cost limits, and so on. The outcome is meant to be a design or device of real industrial value.

About 250 projects were completed in the first ten years of this programme. To help organize the projects ESIEE set up a service organization called SEFI (Service d'Études et de Fabrications Industrielles). This co-ordinated the facilities of thirty-five laboratories, workshops, storerooms, computers and libraries for use during project work. SEFI has a permanent administrator who is also in charge of financial arrangements.

ESIEE derives many benefits from this kind of semi-commercial co-operation with industry, among which are the following: (a) maturity, independence and a sense of responsibility has shown a significant
improvement throughout the fifth year; (b) the project work is a positive experience which removes any fear of industrial employment, and in later years is considered the most important activity in the educational programme at college; (c) students have to write reports each term and prepare a final report, an abstract and a technical note, and also make a public defence of their work to a board of examiners. All this enhances communication skills; (d) the students learn how to tackle a complex problem, to define goals, to find information and work as a group; (e) the students have to make choices and face evaluation later, as well as work within financial constraints; and (f) they obtain an intimate knowledge of at least one enterprise and of industrial organization.

The academic staff who act as supervisors have to meet engineers from several enterprises during the projects (each academic is usually concerned with several projects). They thus come into contact with new technologies, and indeed SEFI has to be able to use new devices and techniques as soon as industry. For example, devices such as the microprocessor were being used in projects in 1972. This means that the teaching curriculum is under constant scrutiny, and is revised as technologies change. In addition the government has recently chosen ESIEE as a centre for the continuing education of engineers in small industries.

École Catholique des Arts et Métiers (ECAM)

For twenty years and more ECAM, in Lyon, has organized industrial project work as the major activity in the final year of its three-year course. This course is preceded by two years of preparatory studies so that to obtain the engineering diploma requires five years of post-baccalaureate studies.

Project discussions begin in the penultimate year of the course, at a time when final-year students are getting seriously involved with their own projects. There can then be a valuable interchange of information about project work between students. Project suggestions arise in industry and the work is usually carried out in industry, except when the enterprise is too far from the college or if the firm is a small one without suitable facilities. In these cases the work is carried out at ECAM. Projects are usually undertaken by two students because working in groups has beneficial effects. A group is more confident in its industrial surroundings than a single person might be, which in turn leads to a wider range of contacts with the personnel of the firm and much faster progress in the project work.

The object of this final year, mostly in industry, is to obtain a knowledge of industry and its organization so that later transition into industrial employment will be smooth and successful. The students work
on projects of real value and so perform as engineers rather than as observers or trainees. They see the first suggestions for project work expressed quite briefly, and come to realize that the ultimate objective will only become clear as work proceeds. Indeed the first part of the work is to define what tasks need to be done, within what boundaries and limitations, and with what means.

Valuable information can be obtained from the industrial liaison officer at ECAM who will discuss good examples of project work and the need to use all available resources and information in finding solutions. It is hoped that a prototype of some kind will be the outcome of the work, although this is not always possible.

Each student spends about 600 hours in industry on his industrial project but so that he may have opportunities to collect information, develop ideas and express in writing any plans for future action, the industrial period is split up into discontinuous and continuous periods. At first one and a half days per week, from October to February, are reserved for work in industry rather than in college. Then for three or four weeks the students work in industry for five days per week. This is followed by another period of about two months when students go to their enterprise for one and a half days per week. Finally, three or four weeks are spent continuously in industry to conclude the work and write a report. This enables students to discuss their problems with industrial and academic engineers.

To get a project going in the new and strange environment of an industrial enterprise needs time but it is considered that this 'incubation' period is well worth while. Projects have to be suitable to both parties in a co-operative venture and there must be sufficient industry within, say, 50 km of ECAM to operate as described. Fortunately ECAM is near a great number of small, medium and large industrial enterprises with mechanical and electro-mechanical interests. This is the type of industry for which ECAM prepares its engineers.

CHOICE OF SUBJECT

ECAM and industry are now more or less equal partners in this project work. The work proposed by an industry must be of some importance and obvious usefulness if it is to motivate students who may be tired of class studies. Subjects for projects are collected, in May and June of the year before the final year, by the industrial liaison officer who asks industries for suggestions in the previous April. Some enterprises wish to extend their research and development work by adding some of the final-year students to their human resources, and so suggest topics. Many come back time and time again. Some subjects, however, are suggested by students who have developed particular interests. The liaison officer then approaches a suitable enterprise to find out if such a project is of
interest to them. If it is not found acceptable by an industry, then it is rejected.

When sufficient proposals are available they are brought to the notice of the students. Any groups interested in a proposal are informed of the enterprise concerned and of any previous projects that might have been carried out there. Finally the chosen groups meet some industrial representatives for further discussions and at least 80 per cent are offered summer vacation work for one or two months before returning for the final year. This is encouraged by ECAM as, in effect, it lengthens the industrial stage of the educational process.

At the beginning of the final year all groups will have chosen, or been allocated, industrial projects—helped where necessary by the academic staff. Further information is given about industrial organization, the work of the engineer not only as a technologist but as a leader and teacher of others, and about the work-force of industry.

**EVALUATION OF THE INTEGRATED STAGE**

About 50 per cent of final-year credits are awarded by a jury of examiners who read the student’s reports, and then question the student about his work which he has to defend orally. The jury comprises a professor and his assistants and four to six industrial representatives from several enterprises. One jury usually examines four groups (eight students).

The report itself is evaluated in terms of its organization, style, exposition and analysis; the oral defence is evaluated in terms of quality of exposition, mastery of the subject, assessment of results, replies to questions, knowledge and even bearing and manners.

The other 50 per cent of the credits are obtained from an evaluation of the work done in industry by a group. The industrial supervisor and someone from the college take part in this exercise. Ten criteria are used: work and methods, determination and perseverance, human relations, diligence, analytical ability, inventiveness and skirting of difficulties, design ability, efficiency, progress reports and the final results of the work. The results of this evaluation are inscribed on a standard form with qualifications ranging from ‘exceptional’ to ‘insufficient’ in six grades. This evaluation is not easy to make but, in principle, produces a profile of the future engineers, expressing strong and weak points in their methods and behaviour.

Of course, other work is carried out in college during the final year and project work provides only some of the possible credits towards the diploma. It is, in fact, surprisingly low at about 15 per cent of the total. The reasons given for this are that there is a lack of homogeneity in the projects, and in the facilities available in different enterprises, so that it is not easy to compare the value of different projects. Furthermore, it is
stated that students are so highly motivated that examination credit is not really necessary. The worth of this work in the future is well recognized.

CONFIDENTIALITY

It is found that the smaller the firm the more likely it is to be concerned with the secrecy of work done. Many small firms use the integrated final year to obtain student engineers as researchers. Furthermore, small firms are loath to protect new prototypes by patents until they are absolutely sure of the practical value of an invention, so that they try to keep project results secret for some time. These concepts are new to students but in this way they learn the necessity for innovation, and the moral obligations and discretion required of engineers if an invention is to be exploited successfully. Thus discussions about certain projects are sometimes restricted to the examination and project defence, and the industrial composition of the jury has to be carefully selected, possibly by the industrial enterprise itself concerned with the project.

Students are almost always paid a salary which covers food and travel while working in industry. There are considerable differences between the amounts paid by different firms, which does lead to discontent among students. However, it has not been found possible to insist on a uniform rate of payment.

ECAM, as a result of these industrial projects, plays quite an important role in the scientific and technological development of small firms. This, in turn, means that small firms are prominent among enterprises queuing up for student engineers to work in their laboratories and factories, or to carry out project work for them in ECAM itself.

The type of education-industry co-operation devised at ECAM, primarily as a means of aiding the transition of the young engineer from college to industry, is a success. It has turned out to be a mechanism for keeping academic staff in touch with industrial problems and also for helping industry.
Federal Republic of Germany: co-operation with large- and small-scale industry¹

The federal structure of the Federal Republic of Germany is reflected in the wide diversity of its types of education, and in the contrasts between industry and engineering colleges. The mode of collaboration depends on the size of an industrial enterprise and a distinction will be made here between large enterprises—taking as an example Siemens A.G.—and small- and medium-sized companies as represented by the association of German mechanical engineering companies (Verein Deutscher Maschinenbau Anstalten or VDMA). This note limits itself to the education and training of engineers at universities and specialized university institutes (Fachhochschulen).

Collaboration between industry and education is organized mainly by the different engineering disciplines and their associations representing industry, and the engineering colleges, to which might be added a direct role played by the largest industrial concerns.

**Collaboration with large firms**

Collaboration is organized through various industrial organizations such as:

- **BDA**, the Association of German Employers and its committee on professional and continuing education and training.
- **BDI**, the Association of German Manufacturers and its committee on professional education and training.
- **DPG**, the German Physical Society.
- **DKI**, the German Commission on the Training and Education of Engineers.
- **KWB**, the Council of German Industries for Professional Education and Training, and its several committees on this subject.

¹ Based on material supplied by Dr Ing W. H. Epperlein of Siemens A.G., at the request of the Secretary-General of FEANI.
LBI, the Association of Bavarian Manufacturers, and its committee on the provision of future technicians.
SEFI, the European Society for the Education and Training of Engineers.
VAB, the Amalgamated Trade Unions in Bavaria, and its committee on training of technician-engineers.
VDE, the Association of German Electrical Engineers, and its committee on education and training.
VDI, the Association of German Engineers.
VDMA, the Association of the Mechanical Engineering Industries in Germany, and its committee on management training.
ZVEI, the Association of Electrical and Electronic Industries, and its committee on professional training and education.
Large firms are normally members of their associations, and of the administrative councils of specialized university institutes. They may also be represented on curriculum-design committees at universities.

In addition to this rather extensive involvement of industry with the education of engineers and technicians, many firms use the educational institutes for contract research. Siemens, for example, currently has research contracts with about 100 teachers.

More than 200 current university professors have worked for Siemens in the past, and the firm encourages such transfer even though in the short term its own research activities are adversely affected. Some sixty of its own engineers are part-time teachers in various colleges, either in charge of courses or as appointed professors. The large firms also organize many seminars and conferences, not only for their own engineers but also for academics from the universities and institutions. These meetings often take place on university premises. Some professors are invited to spend a sabbatical semester or year working in a firm’s laboratories on research and development. All these types of collaboration lead to joint research activities on new problems and in new areas. Large firms also provide teachers for continuing education of the type organized, for example, by colleges in Wuppertal and Esslingen.

It is traditional in engineering education in the Federal Republic of Germany that students visit industrial enterprises accompanied by their professors. A large firm will accept up to eighty groups, each comprising twenty to fifty students, in one year. Professors are also invited to deepen their own knowledge of new technological activities.

Training periods are an integral part of engineering studies and large firms make a considerable effort to organize special courses of practical studies for engineers and technicians, many of which last one semester.

1. Of associations for the support of universities and of the specialized university institutes.
At Siemens, some 650 university students, 500 higher technical students and many other technicians have attended these training periods. A further 1,000 students have spent their vacations working at Siemens plants and laboratories.

Some firms will allow advanced students or academic staff to work in their factories and laboratories in order to further their studies, write a paper or book, or research for a doctor's degree. Firms may also help research in the colleges by gifts of money and of apparatus. These gifts, from Siemens alone, amounted to about DM 4 million per year in 1976-77. Several firms also publish technical reviews, films and slides that are available free to colleges.

Collaboration with small firms

The activities of small- and medium-sized engineering enterprises in the field of industry-education co-operation are almost always channelled through the associations, of which VDMA is a good example. Some 90 per cent of VDMA members have 300 employees or less, yet it has a fund for research and education. During the period 1950-60, some DM 20 million were used to support new teaching posts including university chairs, to contract teaching, to research on the problems of engineering education and training, to make various studies, to organize student visits to industry, and to support university libraries.

In addition, VDMA support is used to equip offices and laboratories in universities and university institutes, and to encourage studies related to mechanics and mechanical engineering and their application in industry, including small industry. Since the late 1960s, when the government began to spend more on technical education, VDMA has concentrated more on the promotion of research and education in the area of mechanical construction, providing up to DM 1.5 million each year for this purpose. Engineering teachers now often carry out co-operative research and development with small industries. VDMA also provides the colleges with a great deal of information about real, practical problems in industry. Firms send their specialists to colleges to collaborate directly with teachers and students rather frequently.

VDMA arranges a permanent exchange of information between its members and teachers on matters concerning the professional engineer, study courses and the education of trainees. These activities fall also within the purview of such bodies as BDI and VDI. Other associations, similar to VDMA but for special branches of industry, carry out similar activities. They exist, for example, in the areas of machine tools, prime movers, pumps and compressors, materials handling, drive mechanisms, office machines, data-processing and textile machines. Each of these organizations promotes co-operation between industrial enterprises and professors in the universities and institutes.
Engineers in Ghana are educated at the University of Science and Technology, Kumasi, where the Technology Consultancy Centre is located. Technicians are educated in colleges in Accra, Kumasi and several other centres.

**Technology Consultancy Centre**

The gap between the curricula in engineering colleges and the practices of local industry in Ghana, and other African countries with similar economic development, has long been recognized. Measures taken to redress this situation include: exchanging staff between institutions and industry; attaching students to industry for vacation training; and appointing liaison officers to advise institutions on the design of adequate curricula with regard to industrial requirements.

Of these three practices, the first is the most effective. This is because the experience of staff determines the type of curricula and course content that are utilized in an institution. In spite of this, in many African institutions the practice is superficial and not widespread.

A recent survey of African engineering institutions indicated that exchange of staff between institution and local industry is not carried out on a permanent basis and is so informal that it does not allow the staff of an institution to identify with the problems of industry. This is because the number of staff who actually work with industry, either during their study or sabbatical leave, is very small indeed. Additionally, most institutions do not officially regard the payment of consultancy fees as incentive for the services of their staff. However, at Kumasi

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1. Based on material supplied to the Unesco International Working Group on Education-Industry Co operation by Dr B. A. Ntim, a former member of the group and officer of the consultancy centre.
University of Science and Technology, a formal establishment exists to offer technical service and advice to industry. In what follows, an attempt is made to describe the objectives of this establishment and the benefit derived from the increased effectiveness of the institution's staff and students in meeting the social and economic needs of the country.

The Technology Consultancy Centre was set up in January 1972 as a department of the University of Science and Technology to strengthen the links between the institution and industry. The centre enables government departments, established industries and individual entrepreneurs to draw upon the services of the professionally qualified staff of the Faculties of Art, Agriculture, Architecture, Engineering, Pharmacy, Science and Social Sciences and now of the School of Medical Sciences.

The centre has become established as an agency for the stimulation of grass-roots development by means of appropriate technology. It seeks to upgrade existing craft industries such as textiles, pottery and woodworking by the introduction of new products and improved manufacturing techniques and it endeavours to generate new small-scale industries based on products developed in the university faculties and utilizing, as far as possible, local raw materials. The aim is to assist the craftsman to take a forward step in technology but a step of which he himself has appreciated the need and has anticipated the reward. Additionally, the centre aims to assist the would-be entrepreneur. One mechanism which has been found useful has been the establishment of production units on the campus. In these units, production methods can be refined, markets for the products identified, raw material sources located and the would-be entrepreneur can be exposed to most of the managerial problems that are likely to arise.

The focus in the centre has been on adopting and adapting existing technologies to solve multidisciplinary problems. Thus the centre collaborates with other research institutes in the country in the search for appropriate technologies. Problems are often referred to other intermediate technology groups outside the country such as the Intermediate Technology Development Group in London. Other collaborating agencies include Georgia Institute of Technology, VITA and IRRI of the Philippines.

Initially, the centre was envisaged as a clearing-house for passing inquiries from industries onto the faculties. Thus its establishment consisted of the director and his deputy, with one or two research assistants and supporting office staff. This proved quite inadequate for the extension work that is needed to bring a project into fruition, a role which can hardly be undertaken by faculty staff. As a result, a number of research assistants, popularly known as trainee project managers, have now been engaged in the field of rural development, textiles and metal products. The centre therefore has six technical staff supported by
five clerical and accounting staff. In addition, four pilot production units, which are under the direct control of the centre, employ about sixty staff, many of whom are paid from the sale of the products.

Consultants from the faculties for specific projects are paid 70 per cent of the accrued fees to maintain and encourage their interest in the centre's activities and objectives. The remaining 30 per cent is shared equally by the centre and the academic consultant's department.

The centre has its own accounting and transport system and in this sense operates independently of the cumbersome university system. So far the financial contribution of the university has been the salaries of established staff and an annual subvention to cover administrative, maintenance and travelling expenses. Finance for the centre's projects has come mainly from external sources and, in particular, from non-governmental agencies. The other source of income is consulting fees.

**Services to large-scale industries and government agencies**

The largest operation in terms of financial outlay that has been undertaken by the centre for a government agency has been the repair of large air-conditioning plants in the largest hospital in Ghana, namely Korle Bu. Two senior staff of the Faculty of Engineering aided by two technicians and two students were involved. The three air-conditioners had lain idle for more than six years waiting for spares and refrigerant and this long wait had led to further deterioration in terms of blocked pipes. Some 'cannibalizing' and the importation of a few essential items led to the full repair of two of the plants at a cost of about $80,000. This work would have cost the government $1.7 million had it been done by an external agency.

In the middle of 1974, some university staff were called upon to inspect the cutting machines of the Brick and Tile Factory which had broken down and had caused work to stop in the whole factory. One machine was taken to the mechanical engineering workshop on the campus, examined and the fault corrected. The important result of this work did not lie in the actual repair but in the realization that there was no engineer or technician in the factory who could carry out routine maintenance. This was serious for an organization where investment in capital plant was no less than $2 million, and the matter has been put right since the university intervened. Unfortunately, this lack of maintenance personnel was not an isolated case. The same problem had occurred at Korle Bu Hospital and still occurs in many government establishments. In the case of the hospital, Professor Kessey, the centre's chief consultant on this project, continues to advise the Ministry of Health on such matters as the recruitment of operating and maintenance personnel and the selection and purchase of essential items. In
general, the centre emphasizes the importance of routine maintenance in any government establishment with which it has any connection.

The centre has also been involved in the design and survey of the government's feeder road projects, in evaluating the assets of two gold-mining companies, and has been asked to evaluate much abandoned heavy electrical and agricultural machinery, a job that in the past would have been allocated to foreign consultants.

Well-established industries in the private sector, such as breweries and timber companies, are now approaching the centre and getting effective solutions to their problems. This is rapidly helping to create confidence in the ability of the local professionals and scientists who in the past had been shunned by well-established industries.

Between thirty and fifty senior staff of the university have now been actively involved in providing services to government establishments and large-scale private industries through the centre. Table 1 shows those activities in 1975-77 for which consulting fees were charged. This is only a small proportion of all the services rendered by faculty members, of which most are carried out by the faculties themselves.

### Table 1. Consultancy services carried out by faculty staff

<table>
<thead>
<tr>
<th>Project</th>
<th>Staff involvement</th>
<th>Student involvement</th>
<th>Amount earned ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975/76 Valuation of engineering assets</td>
<td>2</td>
<td>—</td>
<td>1 500</td>
</tr>
<tr>
<td>Repair of air-conditioning plant</td>
<td>4</td>
<td>2</td>
<td>15 170</td>
</tr>
<tr>
<td>Feeder Road Survey and Design</td>
<td>4</td>
<td>2</td>
<td>13 400</td>
</tr>
<tr>
<td>Calibration of oil storage tanks</td>
<td>2</td>
<td>—</td>
<td>4 040</td>
</tr>
<tr>
<td>1976/77 Valuation of engineering assets</td>
<td>2</td>
<td>—</td>
<td>9 680</td>
</tr>
<tr>
<td>Valuation of estates</td>
<td>2</td>
<td>—</td>
<td>2 460</td>
</tr>
<tr>
<td>Design of Cottage Sugar Plant</td>
<td>3</td>
<td>1</td>
<td>5 000</td>
</tr>
<tr>
<td>Cold Chain Project for WHO</td>
<td>1</td>
<td>2</td>
<td>8 070</td>
</tr>
<tr>
<td>Development of 1-ton capacity trolley</td>
<td>2</td>
<td>—</td>
<td>1 500</td>
</tr>
</tbody>
</table>

On average, about eight of the seventy senior staff members of the Faculty of Engineering are actively involved at any one time in providing consultancy services for large-scale industry and government agencies through the centre.

**Help for craftsmen and entrepreneurs**

The centre is attracting many inquiries for technical business assistance from small enterprises and individual craftsmen dealing with products
such as soap, glue, bleaching fluids and alcohol. In all these cases faculty staff have been intimately involved in product development.

Much help has recently been given to an entrepreneur to establish a plant to dry spent grain from the breweries to be used as animal feed. This project, which uses a screw press designed and constructed at the centre's workshop, received the same attention as was given to the establishment of spider glue manufacture. One of the trainee project managers was detailed to look, together with the entrepreneur, into all the aspects of the establishment, such as the location of the project, transport for raw material collection, labour requirements, sales promotion and markets, forecasts of unit and overhead costs and profitability. Now the project can no longer meet demand and an additional press is being added to the original two. A half-ton capacity grain dryer has also been manufactured to aid drying during the rainy season. This dryer was first designed by a student in the engineering faculty before being developed by faculty staff for commercial purposes.

Collaboration between the entrepreneur and the trainee project manager is close. It is clearly necessary to have an ambitious entrepreneur but the effective transfer of technology relies heavily on the interaction between the client and the agent of change.

Requests for the chemical analysis of products are often brought to the centre. Some examples of products analysed are cassava starch, various soaps, chlorinated bleaches, sea shells and latex fluid. These analyses, normally carried out by members of the Faculties of Science and Pharmacy, precede any advice given to the entrepreneurs. They form an important and necessary part of the centre's ability to offer effective advice to would-be entrepreneurs.

The centre has given advice to many would-be entrepreneurs wanting to start new manufacturing businesses. These include the manufacture of gunpowder, rubber mouldings, wood and coconut charcoal, cosmetic powder, leather bags, paper envelopes, sugar, alcohol, gum arabic, typewriter ribbons, chlorine from brine, buttons from bones and locally available plastics, glue from local leather and frootum rubber for the timber industry. The initial feasibility studies have been carried out by members of staff and technicians within the faculties who enjoy their association with such practical problems.

The advice offered is generally implemented to the general satisfaction of the centre. However, since its inception, the centre has helped establish seven new manufacturing enterprises outside the campus, five in the small-scale soap industry and the other two in the glue and animal feed industries. Indirectly, about five new establishments in the field of soap and glue have sprung up.

Many more new establishments are contemplated. These industries continue to serve as clinics for both staff and students.
Pilot production units

Research and development work in university sometimes leads to the discovery of products that could be produced and marketed in the country. These products, originating from an academic institution, are not readily adopted by existing businesses. For this reason, production units have been set up on the campus with the following aims: to train craftsmen and managers in the skills of the new industry; to complete product development under production conditions; to test the market for the product in a realistic way; and to demonstrate to entrepreneurs the viable operation of the activity.

Four production units are already operated within the Faculty of Engineering, producing such items as hand-operated well pumps and traffic-light units. Services provided include motor rewinding and metal plating, the latter having been recently established. Additionally, four production units producing steel bolts and nuts, weaving items, soap and process plants, and agricultural implements are operated within the centre, making a total of eight units that can be used by engineering students as clinics.

These units have provided practical experience in student training. For example, all first-year students spend some time observing the operation of these units. Other mature students choose some aspects of the units' development problems as topics for their projects which they work on intensively in their final year. A typical example is the development of an appropriate high tensile steel die for the hot forging of coach bolt heads. A handful of students each year are able to work within the production units for a period of between eight and ten weeks continuously during the long vacation. During this period the students gain experience of production and are exposed to development problems to which they are encouraged to provide solutions under staff supervision.

The centre also interacts with the Faculty of Engineering by developing the prototypes of various devices and implements which have been the subject of study by final-year students. Examples of this have been the bellows irrigation pump and the grain batch dryer, which were initially designed and produced by final-year students within the Engineering Faculty.

Recently an in-depth study into the productivity of the Steel Production Unit has been undertaken by staff of the Department of Economics and Industrial Management. The study revealed a number of weaknesses, including loss of output due to incorrectly made products, waste and theft; under-utilization of hours due to lateness, extended breaks, machine faults and material shortage; and a bonus scheme that was based on group operations and revenue.
Various recommendations were made, including the introduction of a new incentive scheme based on individual output. As a result, productivity has doubled. Thus these production units can offer the staff and students a practical outlet for testing their academic theories.

Conclusion

The establishment of the centre has helped develop linkages between staff consultancy work and faculty curricula. Staff are increasingly encouraged to involve students in outside consultancy work and newly qualified engineers are now working for industrial establishments which had provided consultancy work for them as undergraduates. This is a useful means of establishing permanent and close links between an engineering institution and industry to illustrate their classroom lectures and thus increasing the awareness of their students of the needs of local industry.

It is still uncertain how this mechanism of education-industry cooperation is affecting curriculum design but it is clear that at the next opportunity to revise the curriculum, which in engineering happens every four or five years, many of the staff will know more of the needs of local industry.

One of the opportunities offered by the establishment of the pilot production units is the development of entrepreneurship. Students have a chance to study all aspects of the operation of a business. In addition a related management training course is offered by the Department of Economics and Industrial Management. The experience at the centre indicates that really good entrepreneurs are scarce in Ghana. Yet a team of consultants from the World Bank has called for the establishment of 240 new small-scale industries each year for the next five years. Clearly this target can be attained only if enough entrepreneurs can be identified and trained. The entrepreneurial training programme offered by the centre’s activities is hopefully a useful contribution to the development of small-scale industry which will increase employment in both urban and rural areas.
University professors in industry

Until recently, it was common in Italy for university professors, and their assistants, to engage in industrial activities. They acted in a personal capacity, as partners in an engineering consulting firm or as consultants to a particular enterprise. In some universities they were even appointed directors of industrial corporations.

Whatever the situation, university staff were thus involved in up-to-date industrial problems, acquired industrial experience and became aware of what industry expects from a young graduate engineer. Furthermore, their experience was transferred into lectures and other teaching activities and their academic work was influenced by their professional practice.

This was a most efficient way of relating engineering curricula to the changing needs of industry. Recently, however, this tradition has been under attack. Public opinion has been alarmed by episodes in which it appeared that certain professors devoted most of their time to private practice to the detriment of their academic duties. The high rewards some professors are supposed to earn outside the universities have been envied by more junior or less fortunate academic staff. The trade unions of academic staff are, on the whole, against extramural activities of this kind, and pressures may cause new legislation that will prevent such work.

There is thus a real danger that engineering professors will lose direct access to professional experience of industry of a continuing nature. In turn engineering curricula will be less relevant to modern technologies.

1. Based on material presented by Professor D. Zanobetti of the University of Bologna at the Third Meeting of the Unesco International Working Group on Education-Industry Co-operation.
Teaching at universities by industrial engineers

Another common practice has been the use of professional engineers in industry as part-time teachers in universities, usually teaching specialized subjects, or even as laboratory demonstrators. Certain well-known colleges relied heavily on these part-time teachers in engineering, with the academic staff mostly teaching basic or engineering sciences. In some provincial universities this practice has been almost a necessity because of their inability to attract permanent resident academic staff of high quality.

The use of part-timers, especially too many of them, has certain disadvantages; in some cases able engineers have made poor teachers. However, they do bring the problems of industry into the classroom, and students benefit from knowing practising engineers. Conversely, of course, the part-time teachers have also benefited. Teaching is well known as one of the best ways of learning, and professional careers have often been helped by this educational process.

Nevertheless, this activity is now also under pressure, with many junior academic staff agitating against the use of part-time teachers. The trade unionization of junior staff has polarized attitudes so that the tendency now is to fill all posts with permanent staff, even though better qualified engineers in industry are available. Again a useful education-industry relationship is being weakened.

Contract work at universities

Contracts between an enterprise and a college for research and development in the college often prove useful for training junior staff, and postgraduate and undergraduate students. Work should be accepted because of its technical content and not be allowed to degenerate into purely commercial activities—such as routine testing—which have no particular educational or scientific value.

Contracts vary in importance and duration, ranging from a straightforward test or measurement to work extending over several years and involving the recruitment of special personnel and the acquisition of new equipment. Today there is a tendency to look upon this type of activity more favourably than work carried out in industry by professors or by professors in their private capacity as consultants.

However, professional engineering work in a college may have ethical and legal consequences that are best avoided. The issue of secrecy may arise. It is impractical to try to preserve secrecy in a college. Some kinds of work, especially design, which might lead to legal action if something goes wrong, are also best avoided. Colleges usually accept contract work from industry today only because of its technical and
scientific content and they steer away from contracts insisting on secrecy or making the college liable for safety or applicability.

**In-plant training for students**

Colleges in Italy and other countries with similar educational systems tend to treat in-plant training in the form of vacation employment as of marginal importance. Vacation employment for students is often the concern of student associations or student unions. Students seem to derive personal benefit from periods of this kind in industry, but the benefits to industry are not clear.

The co-operative or sandwich type of course in which students spend compulsory periods in industry before graduation is not used in Italy. There is only one way of becoming an engineer and that is by taking a five-year course at a university. The academic degree is called the Laurea and the holder can use the title of Dottore in ingegneria (Dott. Ing.), so that the first degree is the doctorate. This degree does not entitle its holder to practise as an engineer. To do that a state examination must be passed, after which the successful candidate is registered as an Ingegnere. No industrial experience is required before registration.

**Industrial representation on college committees**

Such representation is not universal and when practised has been found to be critically dependent on the personalities of the representatives. Sometimes it is useful to have a representative from an organization that gives financial report to the university or college.

Of course, industrial engineers attend advanced lectures and seminars, by invitation, and this activity is of some value in setting up education-industry co-operation. It is not as useful, however, as the practice whereby university professors participated in industrial work by paid part-time employment as consultants.

**Technical education**

Technicians are usually educated in a istituto tecnico, or technical college. Admission is granted to applicants who have completed the first three years (scuola media) in a secondary school. The technical school course lasts five years so that the graduates are 19-20 years old. A technical qualification in Italy is not considered an entrance qualification to a faculty of engineering in a university.
Kenya: Faculty of Engineering, Nairobi

Engineers are educated in the Faculty of Engineering, University of Nairobi, while higher technicians are educated in polytechnics in Nairobi, Mombasa and Kisumu. The engineering course occupies ten terms (quarters) in the university, is spread over three years, and leads to a Bachelor's degree in civil, electrical or mechanical engineering.

Higher technician qualifications are almost always obtained only by candidates who have lower technician qualifications and some industrial experience. Higher technicians receive a theoretical education which overlaps that of an engineer to some extent and they may be classed as technician engineers.

The contribution of engineers is considered to be a major parameter among those determining the rate of economic growth and national development of Kenya. There is a shortage of engineers and especially of those who can be immediately productive when first employed. Employers currently seem to prefer graduate engineers who have been through a practically oriented degree course, perhaps more practical in content than the existing course. However, the latter provides an intensive and adequate theoretical education; there is little room within it to introduce practical training. There is one long, three-month vacation between the second and third years when students are expected to obtain employment with engineering firms and hence some practical experience. Recent inquiries show that many students do not obtain this type of employment and the experience that goes with it. There are several reasons for this and one may be that the existing course lacks a practical dimension that is necessary for directing students towards the real nature of the engineering tasks ahead of them.

1. Based on a paper presented to the Third Meeting of the Unesco International Working Group on Education-Industry Co-operation by Mr F. J. Gichaga of the University of Nairobi and a member of the working group, and on other sources of information.
In Kenya an engineer is considered to be properly qualified only when he is registered as an engineer. Registration follows a favourable assessment of his education and subsequent training by an official panel of professional engineers. A graduate is usually required to have three years of practical training and suitable experience before he can be registered. An employer is supposed to give the young engineer the opportunities and facilities, under guidance and supervision, he needs to pass his professional examination.

Unfortunately, many employers are over-anxious to get immediate production work from the young graduate engineer and neglect their training function. There is thus a lack of efficient arrangements for the supervision and continuous assessment of the postgraduate training of many engineers.

The problems of practical training for technicians and higher technicians are less serious. Employers recognize that technicians must have a reasonable range of practical skills and must arrange for appropriate instruction.

Although the government has set up a mechanism for registering engineers, it has not set up regulations ensuring that graduates do, in fact, get an adequate practical training. The Institution of Engineers of Kenya (IEK) and the Engineering Registration Board are, of course, aware of the problem. One scheme under consideration would require a prospective employer of a newly graduated engineer to submit a training plan to IEK or the board for approval, and thereafter enter into an agreement with the graduate engineer. IEK might monitor the subsequent training.

Something must be done, however, within the degree course and it is considered necessary that the Faculty of Engineering ensure that its students obtain vacation employment. More use could be made of case-studies drawn from industry as elements of instruction, and perhaps a fully equipped training workshop should be set up. It might also be necessary to lengthen the present course to introduce more practical topics.
A questionnaire covered the following subjects: any existing programmes established to enable engineering teachers to work for a period in industry; any obligations on teachers who did obtain leave to work in industry; and opinions on the value of this procedure to engineering education. The questionnaire also requested information as to how teachers were paid when working in industry. Space was given for suggestions and comments.

The questionnaire was sent to 158 institutions and professors obtained from a list provided by the Engineers Association of the Pan-American Union, but updated only to 1974. Forty-nine replies were received from institutions in Argentina (9), Brazil (11), Chile (5), Colombia (4), Dominica (1), Ecuador (1), Honduras (1), Mexico (9), Peru (6), Uruguay (1) and Venezuela (1). Replies were not received from El Salvador, Guatemala or Haiti.

Sabbatical leave seemed to be possible in sixteen institutions in Argentina (6), Colombia (2), Ecuador (1), Mexico (1) and Peru (6), but was not granted until a teacher had worked continuously in a college for at least six years in most countries but rising to eight years in Colombia and ten years in Ecuador. In some cases, two colleges in Argentina and one in Colombia, no minimum period of teaching was stipulated before sabbatical leave could be granted. Even when sabbatical leave was possible some institutions had not granted such leave to any engineering teachers. Academic performance as well as length of service was taken into account by all institutions which had granted leave and all these

1. Dr Doris Maravi-Guttara of the National University of Engineering in Peru undertook to find out whether much use was made of sabbatical leave in industry by engineering teachers. A survey was made by questionnaires and the results reported to the Third Meeting of the Unesco International Working Group on Education-Industry Co-operation. This is a summary of the results.

2. Figures shown in parentheses indicate number of replies received.
institutions expected a report and a further period of teaching in the college.

Except for the Universidad del Valle División de Ingeniería at Cali, Colombia, there are no programmes for sending teachers into industry. In the Colombian college a teacher retains his full pay, and can receive more from the industry in which he works. He has to report back every three months and on his return must prepare a final report on his industrial work. He then has to teach for at least another two years before he can leave. This programme seems to have worked well.

Apart from this, what sabbatical leave has been taken has not been in industry. Usually teachers have undertaken further studies, including research, at another institution where they have received no further stipend.

Institutions that already grant sabbatical leave would like it to continue, and prefer that such leave should be governed by regulation and not by the personal decisions of vice-chancellors or deans. Those without sabbatical leave would certainly like to have it introduced. Industrial sabbatical leave should be counted as being equally meritorious as leave taken in another university. Indeed, sabbatical leave for engineering teachers might be restricted to industry, with study leave being a separate matter.

Other information indicates that most of the institutions—both engineering and technical colleges—do not have sabbatical leave provided by regulations, or even by custom. Study leave for further studies, and preferably given to young teachers striving to get a higher degree, is fairly widespread, if not universal [77].
Peru: co-operation at the National Engineering University

Staff residencies in industry

The National University of Engineering (UNI) in Peru has a programme that provides one of the most important relationships between the colleges and industry. Academic staff are invited to work in various enterprises as engineers where of course they enhance their knowledge of industrial procedures; this is subsequently reflected in their teaching. They may also lecture to personnel in the enterprise or organize seminars on special topics.

The university can and does send some of its academic staff to serve as members of various committees such as those organized by the Bureau of Standards (ITINTEC), the Institute of Mining Research (INCITEMI), and the National Service for Industrial Training (SENATI). These links enable some faculty staff to keep in touch with certain industrial activities. Unfortunately no members of industry are invited to serve on committees set up by the university, as yet.

UNI has a requirement to undertake industrial-type research whenever its resources of manpower and equipment enable it to do so. The university is not in a position to finance much research itself and it has a limited budget for books and journals. Many staff also have heavy teaching duties. Nevertheless, it does accept projects that are accompanied by financial support. Such projects often originate in industry but are supported by funds administered by ITINTEC. These funds arise from a levy made by the government on every industrial enterprise amounting to 2 per cent of net income.

Some of the funds associated with a research project can be used, to a limited extent, to give extra fees to the personnel involved with the

1. Based on material supplied to the Unesco Working Group on Education-Industry Co-operation by one of its members, Dr Doris Mariavi-Gutiaia of the National University of Engineering, Lima, Peru.
Research students often participate in these research projects. Some staff, and departments, carry out tests and measurements for industries and provide computing or consultancy services, for which fees are charged.

Senior undergraduates who participate in study programmes that involve work in industry obtain extra credit, for approved industrial work, towards their diplomas. Students in industry usually get a stipend. Placing students in industry is not easy in disciplines where student numbers are large, but easy where numbers are small such as in mining, metallurgy and geology. Hence not all senior students can obtain industrial training. A few enterprises also give scholarships to students whom they wish to attract into their employment.

There is no doubt that the education and training of engineers demand a greater effort from the university and from the industrial sectors of the country. To make the university-industry relationship more fruitful the following steps should be taken: encourage university-industry working groups of all kinds; evaluate actual curricula by joint committees in each field of specialization and revise accordingly; encourage more staff members to take up industry residency programmes; formulate policy which will encourage university staff to direct their attention to solving local industrial problems, a joint job for government, university and industry; and reinforce the link between professional societies and the university.
Sri Lanka: education—industry co-operation at university

One of the two institutions in which Sri Lankan engineers and higher technicians are educated is the University of Moratuwa, situated at Katubedde about 15 km from Colombo. This institution was created as the Ceylon College of Technology with UNDP-Unesco assistance in 1963, and was later made a campus of the University of Ceylon. Unesco then operated and staffed at this institution a UNDP project called 'Industry-oriented Training of Technicians and Engineers'. Recently, the institution was elevated to the status of a technical university and became known as the University of Moratuwa. Students receive engineering degrees and technician diplomas on successful completion of their studies. The National Diploma in Technology (NDT) is awarded in civil, mechanical, automobile, chemical, electronics and marine engineering, and in rubber technology and textile technology. The B.Sc. degree is awarded in civil, mechanical, electrical and electronics engineering. The university also offers degree courses in some applied sciences, namely mining and mineral processing, material science and chemical engineering.

The duration of the NDT course is three years, and comprises two full years of academic studies followed by one year of supervised in-plant training. The B.Sc. courses last nearly five years, consisting of three years of academic studies, nine months of in-plant training and finally one more year of academic studies. The particular time for in-plant training in the B.Sc. course was chosen on the assumption that the students by then would have learned enough theory and would be mature enough to gain real benefit from a period in industry. At this

1. Based on a report from Dr P. C. Varghese for presentation at the Unesco Regional Seminar on Education-Industry Co-operation, on the material supplied by Professor I. A. Botcharov to the Third Meeting of the International Working Group on Education-Industry Co-operation, and on the paper presented by Dr Upali Kuruppu at the International Symposium on Postgraduate Engineering Education for Developing Countries, held in Paris, 11-14 December 1979.
stage they can also make a reasonable contribution to the work of the enterprise in which they work.

**Importance of industrial training**

The Sri Lankan economy is mostly agricultural and manual. Children come into contact with mechanical, electrical and electronic appliances only spasmodically. The environment under which they are brought up is such that use of tools, working on machines, and preparing and planning for getting a job done are subjects in which training must be imparted and the relevant discipline taught at the institutions themselves in which they are educated. These environmental characteristics introduce certain factors into education and training which are reflected in the teaching methods and curriculum. In a country such as Sri Lanka where industry is not well developed, it is necessary to introduce compulsory and properly supervised industrial training into the curriculum for technical education.

**Placing students in industry**

In many countries the main obstacles in implementing student training have been the difficulty of finding places in industry, and ensuring proper supervision once there. This has been partly solved in Sri Lanka by establishing, in the Ministry of Industry, an organization called the National Apprenticeship Board (NAB), which looks after the placement of all students for industrial training. It has also been found that block periods of training, stipulated as one year for NDT students and nine months for degree students, greatly assist student placement in industry.

**Supervision of training**

An important problem encountered in the training of students in industry is the provision of adequate supervision. It has been learned from experience that leaving the students to take care of themselves does not produce good results. In fact, unsupervised training is a waste of the time of both the students and the industry. In the absence of adequate and proper supervision, an industrial training programme may as well not be launched.

This requirement has been met by appointing a full-time staff member to be responsible for industrial supervision. A senior engineer with considerable industrial experience has been appointed to plan, coordinate and implement the training programme on behalf of the
teaching institution. Similar officers have been appointed in the NAB. In addition, one officer in each of the several large industrial organizations has been assigned the additional duty of supervision of the trainees assigned to that organization. This combined supervision, by the educational institution, the placement authority and industry, has yielded good results. As a result the students take the training seriously, and this benefits the industry they work with.

At the end of the training period, the NDT students' training is evaluated. The degree students must also submit a written report of their work. A student is recommended for the award of diploma or degree only after the evaluation (and report) have been satisfactorily completed.

Stipends during training

One of the most difficult problems that had to be solved was the resistance of the students and their parents to paying the expenses incurred during the period of training. As the students have to live outside their normal places of residence, these expenses are a real problem to their parents. The period that the students need to complete the course requirement is also made longer. The only answer was to devise a method of paying the students during the period of in-plant training.

As the students are sent for training at a stage when they can be useful to industry, it was finally agreed that they could be paid a stipend during training. This is paid by NAD, and the amount is sufficient to meet the expenses of the students. With this arrangement, the students are happy to undertake the training programme.

Training standards

So that the industrial training should be useful, standards were drawn up for each branch of engineering. These were developed for each branch of study by a committee consisting of the head of the department at the campus and representatives from NAB, the Institution of Engineers (Sri Lanka) and industry. Training standards have been finalized for all the NDT and degree courses now being offered by the university. They ensure that the training imparted by each institution is of the standard specified by the university.

Role of the Institution of Engineers (Sri Lanka)

The Institution of Engineers (Sri Lanka), the body representing all professional engineers in the country, has been actively encouraging this
scheme of in-plant training. This institution alone has the authority to
give the charter (for practice of the profession) to a person after
successfully completing the prescribed examinations and period of
supervised training.

The willingness of the institution to recognize the supervised training
in their charter has contributed a great deal towards its acceptance by
everyone concerned. The insistence on supervision if the training was to
be recognized by the Institution of Engineers greatly helped the university
getting supervision accepted by the industries.

Acceptance by industry

There has been a welcome change in the attitudes of industry to the
industrial training of engineers and technicians. A number of minor
difficulties remain but the co-operation of industry, the university and
government is expected to overcome them. The acceptance of the
usefulness of industrial training has been a great step forward.

Part-time courses for practising engineers

Postgraduate courses have been introduced in the university, with the
help of Unesco/UNDP aid in civil, mechanical, electronics and telecommu-
nications engineering, for practising engineers employed in govern-
ment departments and public and private organizations in and around
Colombo. This was carried out in spite of the fact that the staff of the
university was inadequate, and its resources limited. The main
departures from the usual programmes were by making the courses part
time and oriented towards industrial subjects of relevance to various
industrial organizations and government departments.

Thus in civil engineering, instead of beginning postgraduate courses
in disciplines such as structures and hydraulics, it was decided to offer
courses such as building science and technology, hydrology and water
resources engineering, and irrigation engineering, which were relevant
to the needs of the various departments. By this means it was easy for the
university to persuade the departments not only to send their staff
members on a course but also to provide some of their senior, well-
qualified staff as part-time lecturers. As these part-time students were
full-time employees of the various organizations, no extra fees had to be
paid to them. Thus both the university problems of inadequacy of
teaching staff and limitation of financial resources were easily solved.

These postgraduate courses are of two years' duration and are
conducted for two full days (usually one week-day and Saturdays) a
week and six to eight hours a day. All the courses have two separate and
distinct components, a course work to be completed according to a set
calendar and a dissertation which the student can submit at his own pace
after the completion of the course work. The course work is completed in
four terms of two to twelve weeks each, and the number of student
'contact hours' is twelve to fourteen per week, making a total of 500
hours in the four terms. Generally, three subjects are taught in each
term, making a total of ten to twelve subjects in all.
To sustain the student's interest and to see that none of his efforts is
wasted, it was decided that successful completion of the course work
would make the student eligible for the postgraduate diploma of the
university and that, in addition, successful completion of the dissertation
would make him eligible for the postgraduate degree of Master of
Science. The student was given the option of choosing between these
after the completion of his course work.

Continuing education of engineers

A number of short courses run for one or two weeks for engineers and
technicians were another feature of the Unesco programme at the
university. They were of two categories. The first dealt with recent
advances in technologies and design procedures, and the participants
were design and development engineers in industry. It was the regular
practice of the university to give one or more of these advanced courses
(run by the Unesco expert assigned to postgraduate programmes) before
the postgraduate courses began. These short courses were very popular
and the departments released a large number of their staff to attend
them and gain up-to-date knowledge in a specific field. The number of
participants usually varied from 30 to 50 but sometimes reached 100.
The fees charged were kept so low that even private students could pay
them from their own resources. One by-product was that many of the
participants subsequently registered for the part-time postgraduate
courses.

The second type of short course was directed more at technicians
engaged in the day-to-day working of industry. They were also of one to
two weeks' duration. Industrial concerns were very co-operative in
sending many of their staff to these courses. Here again, the Unesco
experts played a leading role in organizing the courses. Fees were kept
low to attract as many participants as possible.

One by-product of these courses was the benefit the students subse-
quently received during their in-plant training with industry. In fact,
this type of involvement by the university with industry should be a
regular feature of any institution that has a programme of in plant
training for its students. The short courses seem to make industry feel
indebted to help the university in return for the training it has received.
This two-way process will work better than any government legislation or resolutions by professional bodies or academic organizations requesting industry to take responsibility for the in-plant training of students.

**Preparation of publications**

One of the disadvantages of a small country like Sri Lanka is the lack of textbooks written by local authors. The country depends on imported textbooks which are not only expensive but in some cases irrelevant to the practices followed by local industry.

The Unesco experts working on this project have been helpful to industry in compiling lecture notes and manuals for the various courses and making them available to industry. Some of these notes have been popular and are regularly used by the country’s designers and industrial personnel.

**University services to industry**

Another way the university co-operates with industry is through consultancy services by the university on solving industrial problems. The university has provided staff facilities for laboratory testing and industrial consultancy.

In the first case, the university laboratories are used for testing materials such as soils, concrete, cotton and rubber, and finished industrial products such as concrete sleepers, imported television sets and indigenously made electronic devices.

Industrial consultancy is a broad term comprising such activities as problem-solving, engineering design, product development, feasibility studies, repairs and maintenance and information services. However, most of the work done by the university has been restricted to problem-solving and engineering design.

In the university’s experience, unless efforts are made to foster industrial consultancy by establishing a separate department or a consultancy centre, and institutional help is given through this unit, industrial consultancy tends to depend more on the individuals concerned than on the institution itself.

**Direct co-operation with industry**

The Sri Lanka Government has been forward-looking in using the services of senior academicians of the university on the board of government corporations. Such appointments are allowed to run parallel
to the academic appointment or on a secondment basis for a definite period or term. The Professor of Electronics, for instance, served as Chairman of the Ceylon Electricity Board for three years and the present Chairman of the Steel Corporation is a staff member of the university. Many staff members are also part-time members of the boards of corporations such as the Cement Corporation, the Tyre Corporation, and the Fertilizer Corporation of Sri Lanka.

The university also utilizes many people from various government departments and private organizations for teaching regular courses in the university on a part-time basis. This is possible because the university is near the city of Colombo, and there is a liberal attitude by industry and the government to permitting their staff to undertake such work. As much as 20 to 25 per cent of all the courses are given by these external lecturers. This practice has helped expose the students to the problems of industry, right from the beginning of their studies. It has also helped senior personnel in industry to keep abreast of the developments in their fields. The programme has thus worked to the advantage of both the university and industry.
Switzerland: co-operation benefits everybody¹

Industry and educational institutions

The relations between engineering colleges and institutes and industry in Switzerland are particularly close and numerous. They stem from the extreme economic importance of industry to the country and its high density of industrialization. These relations depend largely on continuing, or even daily, collaboration between engineering educators and industrial engineers which is now long-established and forms a tight network of personal relationships.

The Swiss people discovered long ago that in a country without raw materials except in the form of hydroelectric power it was necessary to export machines and apparatus to buy natural products, and even food, which they lacked. Industrialization came by necessity and not by choice, and in a direction that led to the production of high-quality goods—that is, with a large added value—which in turn meant a large investment in research and development. In a population of some 6 million inhabitants, about 700,000 work in industry, half of them in engineering or metal work. Many technologists are employed, including about 6,000 university-educated engineers and 15,000 technician engineers (or higher technicians).

Industry is highly diversified. The engineers and higher technicians needed are educated and trained in two university colleges: the École Polytechnique Fédérale de Zurich and the École Polytechnique Fédérale de Lausanne, and in twenty-three higher technical institutes. Eight of the latter give courses in the evening so that students can both study and work in industry. In the technical university colleges there are about 6,000 students, of whom about 1,000 graduate each year, and there are about 15,000 students in the higher technical institutes, of whom about

¹ Based on material supplied by Professor H. Mocafico of the École Polytechnique de Lausanne, who is also Chairman of the FEANI Committee on Education and Training.
1,500 graduate each year. The two federal colleges are completely supported by central government, while the technical institutes are supported partly by the government and partly by local (cantonal) authorities. Nevertheless, all are controlled by the Federal Department of Industry, Commerce, Arts, Crafts and Labour. Financial support from private industry seems to be given only to certain of the evening technical institutes.

**Industry and curricula**

Authorities in industry have no official power to intervene in the technological institutions, but it is quite normal for industry to be consulted on many aspects of engineering and technical education. The actual long-term policy, within which an institution creates courses of instruction, are worked out by a governing council of the college or institute which co-operates closely with business and industry. Many institutions have various kinds of consultative committees which comprise members of the institution and representatives of business, industry and culture. The precise way in which an agreed course is taught is left to the teaching staff. The staff, however, always consult industry about the content of a course and its presentation.

There is, however, one aspect of the educational process in which industry must participate by official ordinance, and that is at the end of a course. The examination jury which finally recommends the award of diplomas comprises representatives of industry and teachers.

**The teachers**

The composition of the teaching body and the method of recruitment always ensure close relationships with industry. In general, teachers will have worked in industry before entering the educational field. Furthermore, it is common for industry to engage full-time professors as consultant engineers to enterprises. Some of the professors are also part-time and give courses that are related to the work they do in industry or in firms of engineering consultants and designers. These part-time teachers are often distinguished engineers.

Senior engineers in industry who are also part-time teachers not only bring practical experience, but also help to strengthen the close network of personal relationships between engineers in education and industry. These professional links are in the interest of both parties.

Industry is, of course, very interested in the continuing education and training of its engineers and makes its own contribution in this area. The so-called courses of the third cycle or of further education are
organized by the colleges and institutes, while other shorter courses are often the responsibility of professional associations. In both cases, however, some of the instructors will be provided by industrial organizations.

The relationships so far described between educational institutions and industry arise within well-organized systems, but there are other ways in which these relations are encouraged. For example, the Institute of Hydraulic Machines at the Lausanne Polytechnic has allocated some hours in its plan of studies for invited lectures by prominent industrial engineers. These lectures are followed by discussions and the subjects chosen are expected to be both topical and of practical engineering importance.

**Contract work, consulting and standardization**

Engineering and technical colleges are frequently asked by industry to undertake research or development. The problems posed to the technical colleges are usually of a practical nature while those offered to the two technological universities tend to be of a more theoretical or speculative kind. In this way industry can obtain solutions or information on problems it may not have the expertise, apparatus or time to solve itself. The colleges, of course, also benefit in many ways.

Advanced and postgraduate students are, whenever possible, associated with contract work for industry. It familiarizes them with the type of problem they are likely to meet in industry, and is of direct benefit to their education. For a college, contract work is an opportunity to increase its competence, and its influence and reputation. This influence can become, in its turn, a factor in local industrial development. The Polytechnic at Zurich has played a part in attracting new industries around Zurich, so that the region contains the most important industries in the country.

Of course, work for industry by colleges must be undertaken with suitable precautions. They must not become subservient to private industry because of the finance they can attract for the work done, but must take care to remain independent. They must remain centres that benefit the whole community and not particular parts of it. Furthermore, independence ensures that industry will look upon the teachers as neutral experts who can be consulted in some types of disagreement, or who will test materials or apparatus without bias. The expertise of college teachers is also used by governments and other bodies when standards are being drawn up. These official standards may concern materials, constructional methods, safety, and so on.
Training students

It is common practice in Switzerland for industry to participate in the education and training of engineering and technical students in three ways: by allowing and encouraging visits by students to factories, workshops and installations; by offering periods of training in industry to students during their studies; and by allowing students and staff to use equipment and measuring apparatus not to be found in the colleges.

Visits of students to industry are organized well in advance and are arranged to suit the stage reached in the studies of a student. Periods of training and work in industry usually last many weeks or even months. In some subjects these industrial periods are obligatory and an integral part of the course. There is close co-operation between industry and institutions in these matters.

In some courses, part of the students' practical education is in industry, using apparatus put temporarily at their disposal. It is also common for industrial enterprises to give equipment to colleges of all kinds, or alternatively to make it available on very favourable financial terms. In effect, a subsidy without strings is made to a college.

Conclusions

The continuing relations between industry and the engineering and technical colleges in Switzerland are firmly believed to be in the common interest. This is natural in a small country which is highly industrialized and where industry is of vital economic importance, and where there is a close network of personal relations between engineers in industry and in the teaching profession. The colleges not only teach but are centres of study, research and culture, and they play an important part in the life of the country.
In the fifteen national republics of the USSR all engineering and technical education is state-controlled. There are many educational and research establishments operated by the USSR and state governments and also by various ministries that control certain industrial activities. Since modern industry relies so heavily on highly educated engineers, technologists and scientists as well as on all kinds of technicians, there is close co-operation between industry and educational institutions at all levels. As will be seen, most academic staff are appointed for periods of five years only, after which time they must apply for re-appointment, perhaps in competition with applicants from elsewhere. Re-appointment in engineering depends not only on achievement records but also on attendance at refresher courses at advanced institutions, or in industry, or both. These refresher courses are concerned with the educational process as well as with research, as examples below will show. Students, of course, also make direct contacts with industry, as part of the mechanism ensuring a smooth transition from educational institution to industrial employment.

**Refresher courses for academic staff**

It is well known that the quality of engineering students' training depends upon the professional qualification and industrial experience of academic staff. The importance of continuing education for academic staff has increased due to the rapid development of science, industry and education. Education-industry co-operation in academic staff training has therefore become very important.

1. Based on material supplied to the Unesco Working Group on Education-Industry Co-operation by Professor V. A. Botcharov, a member of the working group.
Academic staff gain new knowledge by: self-education; laboratory and field experimentation; part-time contract research for industry; applied engineering problem-solving; part-time consultancy; field trips and industrial visits; and professional seminars and conferences and similar, usually part-time, activity.

Refresher courses in industry

For those academic staff who have already completed refresher courses in academic institutions or who wish to be acquainted with industrial problems, then in-plant refresher courses are offered. They last three months every five years in the most advanced industrial factories and institutions.

Occasional visits to industrial factories and institutions by staff members are not sufficient in themselves because the dynamic development of industrial technology requires that staff members be acquainted with industrial personnel and be integrated from time to time in the routine of industrial projects, technology development, research and the implementation of results into practice. On the other hand, more detailed study of industrial problems by faculty staff members is beneficial to industry, since it obtains scientifically based advice from staff members.

A course lasts thirteen weeks, with a nominal eight hours a day, five working days a week (see Table 2).

As an example, a study of computerized designs of metal-forming equipment was based on research and design work in a plant. It included the following topics: technological requirements; noise and safety requirements; strength, stiffness, endurance requirements; cost analysis; dynamic lubrication and wear requirements; and system analysis and parameter optimization. The model and full-scale tests of equipment conducted in the company’s development laboratories needed study of a programme of tests, stress analysis, energy consumption analysis, reliability tests, etc. Current and prospective problems were investigated by case-studies; and direct participation of the staff member in design and research projects was required. To extend the engineering outlook of the staff member a number of field trips were planned to the following companies located in the industrial region: Institute of Engineering Research, a hydraulic press design department, an excavator plant and a radio-television plant.

While on a refresher course the staff member is usually asked by the industrial plant to lecture and arrange seminars related to the field of his specialization.

The curriculum in Table 3 is an individual rather than a general case, giving only an idea of refresher course procedures followed by staff members during the past decade.
A final written report on the refresher course has to be submitted to the academic senate of the faculty and an oral report has to be delivered in the department. The staff member is required to set up a list of projects recommended for intensive research by the staff of the departments, postgraduate and undergraduate students. On approval by the academic senate, the projects will be implemented on contract or on a joint research basis with industry. The success of co-operation between educational institutions and industrial plants depends upon the will of university staff to solve applied industrial engineering problems. The refresher courses taken by staff members in industry help to establish valuable links between university and industry.

<table>
<thead>
<tr>
<th>No.</th>
<th>Course</th>
<th>Number of study hours</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>1</td>
<td>Theory, design and dynamics of machine tools</td>
<td>32</td>
</tr>
<tr>
<td>2</td>
<td>Automation in production engineering</td>
<td>32</td>
</tr>
<tr>
<td>3</td>
<td>Automatic machine tools</td>
<td>64</td>
</tr>
<tr>
<td>4</td>
<td>Theory of reliability of machine tools</td>
<td>32</td>
</tr>
<tr>
<td>5</td>
<td>Systems of programmed control</td>
<td>32</td>
</tr>
<tr>
<td>6</td>
<td>Subsidiary mechanisms</td>
<td>32</td>
</tr>
<tr>
<td>7</td>
<td>Hydraulic and pneumatic drive and control of machine tools</td>
<td>32</td>
</tr>
<tr>
<td>8</td>
<td>Advanced machine tool design</td>
<td>64</td>
</tr>
<tr>
<td>9</td>
<td>Kinematics of machine tools</td>
<td>32</td>
</tr>
<tr>
<td>10</td>
<td>Principles of automatic machine tool design</td>
<td>32</td>
</tr>
<tr>
<td>11</td>
<td>Methods of presentation of experimental data</td>
<td>32</td>
</tr>
<tr>
<td>12</td>
<td>Methodology of course and diploma design projects</td>
<td>32</td>
</tr>
<tr>
<td>13</td>
<td>In-plant training</td>
<td>80</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>528</td>
</tr>
</tbody>
</table>

However, faculty staff are occasionally given an opportunity to devote full-time attention to updating their own professional knowledge. To meet these requirements a planned system of refresher courses for engineering teachers has been introduced in the USSR. According to a government Act, the courses have to be taken by staff members for three to four months every five years, fully paid and free of faculty duties.

Refresher courses for engineering academic staff can be taken at regular intervals in industry, or advanced institutions of engineering, or both.
Country and regional examples

TABLE 3. The curriculum of an in-plant thirteen-week refresher course taken by an Associate Professor of Mechanical Engineering from the Moscow Bauman Higher Institute of Technology, Autumn 1976 (15 September to 15 December) at the Heavy Duty Presses State Company, Voronezh

<table>
<thead>
<tr>
<th>No.</th>
<th>Course</th>
<th>Number of hours</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>1</td>
<td>Design of metal-forming equipment with the help of computers</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>Model and full-scale tests of equipment</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>The current and prospective problems in machine design and production</td>
<td>120</td>
</tr>
<tr>
<td>4</td>
<td>Design and research projects</td>
<td>120</td>
</tr>
<tr>
<td>5</td>
<td>Industrial visits</td>
<td>40</td>
</tr>
<tr>
<td>6</td>
<td>Final report</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td><strong>TOTAL</strong></td>
<td><strong>520</strong></td>
</tr>
</tbody>
</table>

**Refresher courses at academic institutions**

Faculty staff members are supposed to undertake one term (three months) refresher courses offered by leading academic institutions, where there are faculties of advanced studies. The academic staff members, while attending refresher courses, can update and deepen their knowledge in some field of specialization, as well as in general science, educational psychology and educational technology.

The refresher courses have to be taken once every five years, which is the period after which there should be visible progress in industry and in educational technology. As already mentioned, all academic appointments in universities and colleges in the USSR are for periods of five years, and refresher-course attendance is a necessary requirement for re-election.

There are a number of advanced institutions where refresher courses are offered in general engineering and specialized fields. All of them are located in the industrial, scientific and cultural centres of the fifteen national republics of the USSR. The fields of refresher courses offered by institutions vary, depending upon the most important academic and scientific achievements of particular institutions. The Faculty of Advanced Studies of Leningrad Institute of Technology offers refresher courses in the following fields: general and experimental physics, machine design, theory of machines and mechanisms, production technology, machine tool design, hydraulics and hydraulic drive of machines, automatic control systems, engineering safety control and foreign languages. The term of study is four months. The enrolment of 450 participants takes place twice a year in September and February.
The curriculum is designed to meet the most up-to-date requirements of a specialization and emphasis is given to the advanced study of a specialized field subject, general science, computer applications in engineering and educational psychology. There are a number of elective courses as well as project work. Table 4 shows a typical example of a course at the Moscow Institute of Automotive Mechanics.

General courses are delivered to all participants in the different courses. The lecturers are outstanding professors from corresponding university departments. The aim is to provide the most up-to-date information on educational technology, psychology and sociology as well as the fundamentals of industrial legislation.

Related subjects cover innovation, patent policy and information, fundamentals of ergonomics, anthropometry, environmental, aesthetic and other modern requirements of machine design, optimization of design parameters, problems of the mechanics of continua as a base for many applied engineering disciplines such as hydraulics, elasticity and plasticity. There are four elective subjects in this phase, introducing new trends in engineering education which were not present in the engineering curriculum of ten to fifteen years ago.

Specialized subjects given in the third phase are different. An example of courses delivered in metal-forming technology and machine design is given in Table 4. Note that in addition to entirely technical subjects there is a short course introducing the procedures of departmental management which helps to avoid many mistakes in the participants' own future work, and in the organization of the work of the departmental staff.

The specialized subjects are taught to small groups of about five to seven and individual guidance by a professor of a specialized department is quite common. Considerable attention is paid to the laboratory training courses. No formal examinations are required but every participant has to present a report on an interdisciplinary project given individually and supervised by the professor of a specialized department.

A number of visits to research institutions of the National Academy for Science, advanced industrial research laboratories and production factories as well as short in-plant training is scheduled as a part of the curriculum.

Another example of the curriculum for the refresher course taken by academic staff members shows a more intensive approach to the specialized studies (Table 2). It is hoped that refresher courses train the staff members of engineering faculties in new means of research and new theories. Much attention is paid to the theory of specialized subjects, application of computers in engineering, statistics and theory of engineering experimentation.

Upon completing these refresher courses, the participants, who are lecturers and professors in different universities and engineering col-
TABLE 4. Curriculum of three-month refresher courses for academic staff in 'metal-forming technology and machine design' at the Moscow Institute of Automotive Mechanics

<table>
<thead>
<tr>
<th>No.</th>
<th>Course</th>
<th>Number of study hours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>I. General</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Selective problems of comparative philosophy</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>Social activity of the students</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>Educational psychology</td>
<td>40</td>
</tr>
<tr>
<td>4</td>
<td>Educational technology and audi-visual aids</td>
<td>20</td>
</tr>
<tr>
<td>5</td>
<td>Fundamentals of industrial legislation</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>114</td>
</tr>
<tr>
<td>II. Related subjects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Inventions and patent legislation</td>
<td>12</td>
</tr>
<tr>
<td>7</td>
<td>Fundamentals of modern machine design</td>
<td>16</td>
</tr>
<tr>
<td>8</td>
<td>Vector and tensor analysis</td>
<td>36</td>
</tr>
<tr>
<td>9</td>
<td>Mechanics of the continuum</td>
<td>36</td>
</tr>
<tr>
<td>10</td>
<td>Electives</td>
<td></td>
</tr>
<tr>
<td>10.1</td>
<td>Theory of engineering experiment design and analysis</td>
<td>24</td>
</tr>
<tr>
<td>10.2</td>
<td>Computer application in engineering</td>
<td>24</td>
</tr>
<tr>
<td>10.3</td>
<td>Industrial economics and management</td>
<td>24</td>
</tr>
<tr>
<td>10.4</td>
<td>Theory of reliability of machines</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>124</td>
</tr>
<tr>
<td>III. Specialized subjects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Basic concepts of research, academic and social</td>
<td>10</td>
</tr>
<tr>
<td>12</td>
<td>Mechanics of plastic deformation of metals</td>
<td>72</td>
</tr>
<tr>
<td>13</td>
<td>Modern theory of metal-forming and forging plant design</td>
<td>30</td>
</tr>
<tr>
<td>14</td>
<td>Modern processes of hot and cold metal-forming</td>
<td>46</td>
</tr>
<tr>
<td>15</td>
<td>Methods of experimental analysis of machines and</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>technological processes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>204</td>
</tr>
<tr>
<td>IV. Independent work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Project (research, design)</td>
<td>50</td>
</tr>
<tr>
<td>17</td>
<td>Reference</td>
<td>20</td>
</tr>
<tr>
<td>18</td>
<td>In-plant training and seminars</td>
<td>44</td>
</tr>
<tr>
<td>19</td>
<td>Modern and classic art</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>134</td>
</tr>
<tr>
<td></td>
<td>Grand total</td>
<td>576</td>
</tr>
</tbody>
</table>

Leges all over the country, remain in continuing correspondence with the advanced departments, discussing current problems. They usually attend annual seminars and conferences and in many cases apply to do
advanced degree research in those leading institutions. In the seminars and discussions outstanding scientists and industrial engineers provide the most up-to-date information, fresh ideas and engineering problems.

**Influence of academic staff with industrial experience**

The influence of industrially experienced staff on academic teaching and on research is positive in the following ways:

- The theoretical problems given in lectures are usually illustrated by examples reflecting their personal industrial experience, which students seem to appreciate.
- The lecture courses are often supplemented by guided field visits demonstrating the close association of theory and practice.
- The method of engineering case-studies is used in some engineering courses to develop the student's ability for innovation and creative thinking.
- The topics of course projects given to the students are often associated with real industrial needs and problems. This imparts a stimulating sense of reality and importance to the students' course work and study.
- The most interesting topics of course projects are usually utilized by students in more detailed studies for their diploma projects. The results of the projects are communicated to industrial companies.
- Students usually take keen interest in the individual or group research projects supervised by industrially experienced staff members, and the results of the projects are often reported at annual conferences of students' engineering research societies.
- Contract research projects are preferentially offered by industry to industrially experienced staff members. This provides opportunities for student participation in research.

As a result of knowing people in industry, staff members often invite senior industrial experts for lecturing and project supervision. For example, the chief designer of the Voronezh Heavy Duty Press Plant has given a number of lectures to undergraduate and postgraduate students. Later it was suggested that he submit his design and research achievements for a C.Sc. (Ph.D.) and he has now successfully obtained this degree. A permanent joint seminar on current and prospective problems of machine design and analysis was established and a five-year agreement on scientific-technological co-operation between the department and the industrial plant was concluded.

As a result of the seminar activity some engineers from industry joined in part-time postgraduate study and research in mechanical engineering. One of them has already submitted his Ph.D. thesis, and the others are working successfully under the supervision of faculty staff members.
The Mechanical Engineering Department assists the industrial plant in curriculum planning for in-plant refresher courses in industrial engineering and helps by delivering lectures on advanced topics of machine design and analysis.

Conclusion

The examples described above have become rather typical of education-industry co-operation in the USSR during the past decade. Today's rapid advances in science and technology require close industry-university co-operation to obtain mutual benefits, including the improvement of the quality and efficiency of an engineering student's training.
USSR: co-operation in engineering education and training

In the USSR an important and highly developed system of co-operation exists between engineering colleges and industry which is multifold and mutually beneficial. The system is as follows:

Forecasts of industrial development are used by educational institutions to create a 'model of an engineer' for the next five, ten and twenty-five years. The considerations and requirements of industry have priority in the design of curricula. All aspects of education and training are discussed with the leading enterprises and engineering societies at periodical joint conferences. No curriculum can be accepted by the educational institutions without approval by industry.

Leading engineers and industrial researchers are appointed by educational institutions for full membership of scientific and academic councils. Making up at least 25 per cent of the council’s body, the industrial specialists exert a direct influence on education and research activities in colleges and departments. They also play a part in awarding scientific degrees and academic titles to the teaching staff.

Prominent industrial engineers and researchers are appointed to lecture in courses that require case-studies and up-to-date information on production. If highly qualified they are awarded the academic title of associate or full professor. Implemented industrial projects are recognized by scientific councils as publications if given invention certificates. Professors coming from industry bring realism to theoretical studies and help the educational institutions respond more fully to the requirements of industry.

Each engineering diploma thesis must undergo critical appraisal by a supervisor. This engineer furnishes a written appraisal of the work two or three days before it is considered by the state examination

1. A communication from Professor Y. A. Botcharov.
committee. The chairman of the committee and at least one quarter of its thirteen to fifteen members must be representatives of industry, and the rest faculty professors. Thus industry examines the quality of engineers trained at the educational institutions and controls the applied aspects of their qualifications.

Industrial enterprises are appointed by the academic councils as examiners of C. Sc. and D. Sc. degrees in addition to examiners who are professors. A clear idea of the applied value of a thesis is thus obtained. The procedure for earning scientific degrees is the same for applicants from industry as for those from academic institutions.

The teaching staff of engineering colleges have to undertake a three-month refresher course in industry free of faculty duties every five years, as described in the previous contribution on the USSR.

An important aspect of education-industry co-operation is research on industrial problems by teaching staff through contracts with industrial enterprises. There are more than 400,000 teaching staff in USSR universities and colleges, with 140,000 associate professors holding C. Sc. (Ph. D.) degrees and more than 15,000 professors with D. Sc. degrees. Their participation in the progress of technology is essential. Teachers and students who are actively involved in research under these contracts are paid extra and may thus increase their salaries by up to one half. The laboratories are supplied with the modern equipment needed for research and are subsequently used for student training.

In accordance with a government act the educational institutions use the facilities and experience of industrial enterprises for the practical industrial training of engineering students for about 13 to 15 per cent of their study time. This aspect of education-industry co-operation is extremely important and will be discussed later. Students' scientific/technological societies play an active part in solving the problems of local industry during periods of practical training. The research clubs are able to sign direct contracts with local workshops and enterprises, and to participate in the research contracts of departments.

Since 1972 every engineering diploma graduate is appointed on probation for one year at the industrial enterprise that recruits him. While carrying out their engineering duties during this time the young engineers also study specific features of production, economics and management which are relevant to their work.

The progress of the graduates is carefully studied by experienced engineers and after the probation period the graduate may be offered a permanent position. The teaching faculty monitors the probation period by visits and participates in an assessment committee. This feedback helps academics spot any shortcomings in education and training, and so improves the academic process.
Educational institutions provide young industrial employees with educational opportunities in the form of evening and correspondence courses. Every enterprise must arrange its work timetable so that evening classes can be attended and so that the working student can take ten to fifteen days of paid leave twice a year for examinations. For undergraduates there is one day a week free of work in addition to the usual week-end; and for graduates there are three months for diploma project and thesis writing.

Recently signed agreements of scientific-technological co-operation between the leading industrial enterprises and academic institutions embrace all previous experience in co-operation, and stress the immediate practical implementation of the scientific results of joint programmes of research and development. Such agreements involve teaching staff, senior students, and engineers of industry in creating innovative scientific-technological activity for the benefit of both parties and the national economy.

**Practical training in workshops**

Engineering students spend 13 to 15 per cent of their time in practical training, a total of twenty-five to thirty weeks, divided into three or four periods of increasing complexity (see Table 5).

<table>
<thead>
<tr>
<th>No.</th>
<th>Titles of practical training</th>
<th>Polytechnological</th>
<th>Other technological colleges</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Semester</td>
<td>Time</td>
</tr>
<tr>
<td>1</td>
<td>Workshop training</td>
<td>1, 2</td>
<td>136 hours</td>
</tr>
<tr>
<td>2</td>
<td>First technological</td>
<td>6</td>
<td>4 weeks</td>
</tr>
<tr>
<td>3</td>
<td>Second technological</td>
<td>8</td>
<td>8 weeks</td>
</tr>
<tr>
<td>4</td>
<td>Operational</td>
<td>10</td>
<td>4-8 weeks</td>
</tr>
<tr>
<td>5</td>
<td>Pre-diploma</td>
<td>11</td>
<td>10 weeks</td>
</tr>
<tr>
<td></td>
<td>Total practical training time</td>
<td>Weeks</td>
<td>26-30</td>
</tr>
<tr>
<td></td>
<td>Percentage of study term</td>
<td>%</td>
<td>12.8-11.7</td>
</tr>
</tbody>
</table>

The first period is designed to acquaint the students with industrial conditions of production, to enable them to operate machine tools in production shops and to help them understand the complexities of a machine construction plant. For example, practical courses have been arranged at the Moscow Auto ZIL production complex that manufac-
tures trucks. It has a foundry, forges, sheet-metal works, machining operations, heat treatment, assembly and test departments, and industrial research laboratories. It is widely used by colleges for all stages of practical training of engineering students.

The second period is to acquaint the students with the technology of producing machines and instruments in the field of the students’ specialization. The students are trained in industrial design offices as technicians or assistant engineers.

The third period involves the students in industrial activity as assistants to those in charge of assembling and testing the machines and instruments. Operational training is based on the theoretical courses in machine design, analysis and tests.

The fourth period concluding practical training is organized on an individual basis and takes place at the industrial plant or research institute where the graduate will take up an engineering position on probation after graduation. During the pre-diploma training the graduate is directly involved in the routine of engineering responsibilities and is properly prepared for future career development.

Conclusion

The main elements of education-industry co-operation in the USSR were developed gradually over the past thirty to forty years. The social ownership and centralized control of industry in the USSR enables both education and industry to create practically unlimited means of co-operation, the result of which is the growing quality of engineering training. The progress of national industry depends largely on the qualifications of the graduates and their ability to solve industrial problems.

Close education-industry co-operation is the only possible way to train highly qualified engineers with these abilities, which are of immediate benefit to the national economy and social progress.
Engineering education and training in the United Kingdom in the future will undoubtedly be influenced by the Report of the Committee of Inquiry into the Engineering Profession, chaired by Sir Monty Finniston [78-80], and education-industry co-operation will almost certainly increase rather than diminish if the main themes of the report are adopted.

The education of engineers and higher technicians is still considered to be the joint responsibility of colleges and industries. For example, academic qualifications by themselves do not enable an engineer to become a full member of the major professional engineering societies nor a member of the new professional societies for technician engineers. Approved practical experience must be obtained before membership is granted. Some of this experience may be gained during the course through short periods of employment in industry; the rest is obtained after graduation.

Degrees in engineering are available in universities, where courses are of three or five years' duration, or in polytechnics and colleges of further education where they last four years. Universities are entitled to give their own degrees but the polytechnics and colleges of further education have their courses approved by the Council of National Academic Awards (CNAA), which is also the ultimate degree-giving body. Almost all CNAA engineering degree courses are of the 'thin sandwich' type with six months in each calendar year allocated to academic studies and the other six months to employment in industry. Some of the new five-year courses in universities combine academic studies and one year in industry and lead to the Master's degree.

Technician qualifications can be obtained by both part-time and full-time studies in technical colleges, colleges of further education and polytechnics. Until recently the qualifications were National

1. Based on material obtained by the author from experience, observation and references.
Certificates and National Diplomas at the Ordinary and Higher levels, and Certificates of the City and Guilds Institute. Technical education has now been reorganized and the National Certificates and Diplomas will be replaced by qualifications governed by the Technician Education Council (TEC). TEC courses may be offered as part-time or full-time courses. A CNAA degree at an ordinary or pass degree level is also considered as a technician-engineer qualification and may be obtained in three years in some colleges.

The Open University also has a degree in engineering that can be obtained through home studies, tutorial meetings, summer schools and television instruction after four years of study. Not all the major engineering societies in the Council of Engineering Institutions accept this qualification as an exemption from all parts of their entrance examinations as yet.

There is a large variety of degree and technician courses devised to suit local, regional or national needs. Technician courses and CNAA courses are controlled by committees of experts set up by the Ministry of Education. The universities are autonomous bodies that devise and control their courses, and are constrained only externally by the size of grants given to each university by the government through the independent University Grants Committee. Two examples of university-industry co-operation are given below. The first is an example of close co-operation over some years in the design of an M. Eng. degree scheme. The second is of an engineering degree obtained by part-time study and suitable for technicians.

A co-operative degree course at the University of Bath

This new degree is an attempt to break away from a pattern of engineering education which separates the academic and professional development of the student. It has been made possible through close co-operation of the School of Electrical Engineering and industry represented by one large company, GEC-Marconi Electronics Company (GME). The engineers at GME have had a continuing interest in engineering and technical education and, for example, issued a report in 1977 entitled *The Content and Structure of First Degrees in Engineering* [80]. A similar report on technician courses was also issued by GME. The School of Electrical Engineering at Bath and GME engaged in a joint two-year study of the education and training of electrical and electronic engineers. The outcome of this study was a course nominally of four and a half years and leading to a Master's degree in Engineering (M. Eng.) [80-83].

This new degree scheme takes into account the needs of industry, the university and the student. Although derived by joint co-operation
between one university and one company it does not aim to produce graduates for such a specific sector of industry that career opportunities would be limited. On the contrary the need for a broad education is not overlooked, nor is the need to provide adequate motivation.

A society and its industries require engineers who can achieve objectives set within the technological, commercial, organizational and social environments of an enterprise; who can maintain a programme of professional development and make good use of sources of information; who are creative and yet able to take a questioning, critical attitude to innovations whatever their source; and who can co-operate with, and win the co-operation of, others in the enterprise in order to carry out and develop the functions and activities of the enterprise.

British universities have a long and jealously guarded tradition of independence which gives them freedom to adapt or change to meet the evolving needs of society and industry. Universities need this freedom to achieve a balance between education and vocational training and so devise curricula which are in the long-term interests of students and of universities. The co-operation with industry at Bath has in no way impeded the capacity of the School of Electrical Engineering to respond to new advances in science or technology or to modify curricula, as might be the case if the course were sponsored or dependent on external accreditation.

The motivation of students depends on recognition of good work, the provision of interesting work, the relevance of studies, the giving of responsibilities, their personal ambitions and the prospect of a satisfying and rewarding career. Students need these motivators and it is hoped that this new course provides them.

SUPPORT AND ROLE TECHNOLOGY

The course includes three areas of study: the central or main electrical engineering science and technology; the support technology; and the particular role technology. The main core of studies reaches a slightly higher level than do the other, shorter academic degree courses offered by the school. The significant feature of the new course is the introduction and development of the concept of support technology. This covers areas of knowledge, skills and expertise that relate to and support the main activity of an electrical and electronic engineer in industry. It includes such subjects as quality assurances and reliability, production engineering and engineering materials, but also other activities which will enable an engineer to operate successfully within a commercial and social enterprise.

The inclusion of support technology was preceded by a thorough analysis of the responses of GME engineering managers to a question-
naire about the desirable strengths and apparent deficiencies of young
graduate engineers. Subsequent discussion by GME and the school
identified target capabilities for support technology. The targets set
were that a graduate engineer should:
Be aware of the activities carried out by people in industry and of the
significance of the contribution made by each activity.
Understand and perceive the needs, requirements, capabilities and
limitations of people in industry.
Be able to make full and proper use of existing systems and procedures
for communication and organization in industry.
Understand the commercial structure of industry.
Appreciate the implications of commercial constraints on engineering
activities in industry.
Appreciate the purposes and motives in the running of a commercial or
public enterprise and be able to relate them to the general needs of
the national economy.
Understand the basic principles of quality and reliability in engineering
and appreciate their design, production and commercial implications.
Be skilled in the theory and practice of objectives and subjective
measurement and in the analysis, interpretation and evaluation of
information.
Seek to gain and improve knowledge and understanding of relevant
product technology.
Know enough about the properties, and limitations, of engineering
materials to understand the reasons and implications of material
selection procedures.
Understand the principles of design and be capable of executing design
studies taking into account electrical, mechanical, material, produc-
tion and commercial constraints.
Understand, and be able to use, the principles of system analysis in the
identification and solution of problems.
Have sufficient knowledge of production systems to be able to identify,
relate and make proper use of the component parts of a system.
Be able to appreciate the concept of a product system and the
significance of this concept for product design, control, production
and operation.
From these general objectives a series of themes were developed as a
preliminary to curriculum design. These themes are not necessarily
separate courses and are:
The human component. How environmental, social and personal factors
affect the skills and performance of people. The necessity for a good
communication system for the exchange of ideas and information
and to transmit instructions clearly, accurately and unambiguously.
That products for use by people should be designed with a proper
regard to the principles of ergonomics and human engineering.
Industry and commerce. The purposes of industry and the legal constraints on industrial and commercial procedures, and how the activities of an enterprise can be planned and monitored.

Production. Industry has to produce goods and services by the most economical and efficient means while meeting customer specifications, requirements and delivery dates. The most effective use of assets committed to production depends on careful control of many interdependent activities including those of engineers who, in turn, affect the production system by their activities.

Quality and reliability. Materials, processes, services and products must be suited to the uses to which they will be put, and maintain this suitability for specified time intervals in specified environments, and within constraints of cost. Quality control should ensure that all materials and products whether bought or produced meet the user's specification at the least cost. Thus quality achievement must be an integral part of design, and one of the responsibilities of the design engineer.

Measurement and information. Wherever possible the behaviour of materials, products and systems should be defined in quantitative terms and performance assessed by appropriate measuring techniques, taking into account any uncertainty in the measurements. The collection, storage, processing and transmission of information in order to exercise control, or monitor performance, predict changes and so on is an essential function of industry, and has important implications for commercial activities.

Engineering materials. The selection and use of materials must be made with due regard to availability, cost, durability, processability and so on when a design is being made. The electronic engineer particularly must understand the principles of the material sciences.

Engineering design. Design is a process embracing the activities of problem identification, problem-solving, decision making, product creation and material selection. As such it includes both product and system design and the design process can be used in solving complex professional problems. Design is a powerful aid to learning because the process itself is essentially a learning process and the development of design skills demands the use of information from a variety of sources and the recall, use and interrelating of information assists comprehension of the knowledge and of the design problem.

Wherever these themes or associated objectives have a well-defined knowledge requirement, then syllabuses can be developed to present the information in the most appropriate form. However, in support technology many objectives or targets refer to skills, abilities and attitudes that cannot be adequately fostered in the usual teaching situation such as a lecture. This, coupled with the need to provide adequate levels of motivation and self-motivation in the students, has caused the adoption
of small-group activities based on case-studies, simulations, design work and role-playing exercises. Small-group work also encourages the development of skill in communication, co-operation and the integration of all aspects of the curriculum. Case-studies based on industrial source material relates academic studies to the industrial work in a natural way, so avoiding the dichotomy that can arise when 'industrial studies' is presented as an academic course apparently divorced from the study of, say, electrical engineering.

THE COURSE CURRICULUM

The course extends for four and a half years and its design is constrained by the thirty-two-week academic year, existing thick and thin sandwich courses, and an academic type of three-year course in the School of Electrical Engineering. The main engineering component extends over four years; support and role technology over the first three years, and the final six months are spent in industry completing an advanced project (see Fig. 2).

Students on this course are normally sponsored by some industrial enterprise, and during their studies each student spends five periods in industry. The first period of four weeks introduces the students to the business of a company interpreted as a system, and also to some workshop technology. Tutorial assistance is provided.

The periods in industry at the end of the first, second and third academic years are each concerned with a specific area: engineering for production in the first year; commercial activities in the second year; and engineering design in the third year.

The aims of each of these periods will be: to help a student understand the structure of each area of activity, its elements, motivations, related technologies and interfaces with other external and internal organizations; to demonstrate the complexities of the environment which will have human, physical and organizational elements and to indicate the different roles that exist and the knowledge and skill requirements of each role; to help a student appreciate how support and role technologies are involved with the central activity of an area; and to provide opportunities for the student to develop personal skills appropriate to the stage of his course.

Each student is carefully briefed before entering industry and a study programme is prepared by academic and industrial tutors. The programme includes a topic for research by the student and he presents a paper at the end of the industrial period.

The final period in industry during the first half of the fifth year lasts about six months and is spent on an extension of fourth-year project work in the school. The student takes a product design through a production specification.
Part-time degree course in engineering technology

Some colleges prepare students for degrees awarded by the Council of National Academic Awards (CNAA) and obtained by part-time studies [19]. A typical degree scheme is often based on the release of students from employment for one day per week for about thirty-two weeks per year. The minimum duration of study is four years but studies can be spread over up to seven years. The final award is a B.Sc. degree in engineering (pass degree standard).

Nearly all the students admitted to these courses are employed as technicians or higher technicians in industry and have obtained Higher National Certificates or maybe Ordinary National Diplomas in some branch of engineering. These part-time courses are designed to meet the needs of local industry. The typical degree course to be described was designed to produce engineers concerned with the control, maintenance, supervision and operation of mechanical and electrical engineering.
equipment. In the near future these graduates are most likely to be described as technician-engineers rather than engineers because their academic qualifications will not suffice for immediate admission to a major professional engineering society without further study and examination.

One combined course in electrical and mechanical engineering consists of about sixteen units of which not more than four can be studied in any one year. A unit requires attendance at the college for eighty hours. Four units studied each week will necessitate a student attending ten hours for one day of each week for thirty-two weeks each year. Instruction in one unit lasts two and half hours and usually comprises a one hour lecture, followed by a tutorial or examples class and/or some laboratory work. Further study at home is also expected and is indeed necessary. This part-time study towards a degree is not easy, yet it has proved attractive to many ambitious technicians. Of course, the practice of day release, which many industrial enterprises recommend for their better technicians, adds to the attraction of these courses.

The study units might be as follows:

*First year:* mathematics and computing; electrical engineering science; mechanical engineering science; principles of experimentation and measurement.

*Second year:* engineering mathematics; mechanics of solids, electrical technology; industrial organizations.

*Third year:* thermodynamics and fluids; control engineering I; mechanical failure; management and industrial studies.

*Fourth year:* control engineering II or utilization of electrical plant; analogue and digital techniques; process plant engineering; projects.

The order in which some subjects are studied can be changed but since the course has a specific aim related to the needs of a range of processing industries few elective subjects are available. Two project assignments are given in different subject areas. There are also four annual residential week-ends (Saturday and Sunday) at the college which, among other things, enable the students to discuss the course with college staff and industrial representatives.

This course, and similar ones, is strongly supported by local industries that participate not only by allowing students one day off each week but also by specifying industrially oriented projects and by accepting college staff who wish to be seconded to industry from time to time. The course is thus the outcome of a joint activity between the college and local industry, which alone almost ensures success.
United States of America:
examples of co-operation

Engineering and technical education in the United States is not controlled by the federal government but is offered by a large number of private and public institutions. The public institutions may be operated by state, city and community governments of various kinds. Curricula and teaching methods are not standardized in any way but there is a system of accreditation or recognition by the Accreditation Board for Engineering and Technology, Inc. (ABET) whereby a specific curriculum leading to a qualification in some branch of engineering is recognized, or accredited, as being of adequate standard. Not all institutions put curricula forward for accreditation and not all curricula that are offered will necessarily be accredited. ABET is newly organized (1979), having replaced the original Engineers' Council for Professional Development (ECPD).

Just as there is a large variety of educational practices in the United States, there are many ways in which the institutions and industry interact. Students in most institutions work in industry during some or all of the longer vacations. In most institutions a student can, with permission, spend a year away from college, thus in effect choosing a co-operative scheme of studies. Many institutions encourage co-operative degree courses corresponding to the so-called 'thick sandwich' schemes where a year in school is followed by a year in industry. Degree courses are then lengthened to five and perhaps six years. Technician education can be full time, part time and sandwich, or take place in evening classes or through television programmes. Many academic staff undertake research for industry and much consulting work is done by distinguished academic engineers for both private and public organizations. Student project work is a common form of interaction with

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1. Based on material supplied to the Unesco Working Group on Education-Industry Co-operation by Professor T. T. Woodson of Harvey Mudd College, by Professor Keshavan of Worcester Polytechnic Institute, and others.
industry and some examples are described below. Such projects are now probably the most usual way in which engineering students first begin to apply their theoretical knowledge to practical problems.

Much use has been made in the United States of ‘case-studies’ in engineering, where a ‘case’ means a first-hand description of an engineering problem and the subsequent stages wherein an engineer or an organization succeeded, or failed, to find a solution or meet specifications. Universities use case-studies to introduce real engineering to the classroom and many hundreds of them are now available for distribution. An example is described later.

Finally, there is a brief account of higher technician education and training. Recently, the degree of Bachelor of Technology has grown in popularity. This four-year course has a practical bias and tends to be based on the known, immediate needs of industry. The graduates correspond somewhat to what are known as technician-engineers in some countries, such as France and the United Kingdom. Technicians are also educated in courses lasting two and three years. The B. Tech. course may be given in an institution, such as a state university, which also educates engineers in Bachelor of Science or Bachelor of Engineering courses.

Examples of co-operation in education

In the United States well over half the engineering colleges and schools have regular informal or contractual links with industry, both for funded research and for consultation work by academic staff. A smaller number have arrangements for industrially oriented student projects. Five examples of co-operation are described below.

One of the first schools in the United States to initiate co-operative engineering education was the University of Cincinnati in Ohio. Now called the 'professional practice programme', this type of education has been in operation since 1906, comprising alternating quarters of on-campus study and off-campus industrial work during the second, third and fourth years of a five-year Bachelor of Science (B.Sc.) curriculum. Table 6, column 1, shows that 1,800 Cincinnati (CINN) engineering students work one term per year in 300 industries. The students receive wages but no academic credit, and participation is compulsory. The programme is funded and administered internally by the school, simply with the co-operation of the companies which offer jobs to the students.

The 'Engineering Clinic', also a professional programme, at Harvey Mudd College (HMC), Claremont, California, was started in 1963 and comprises a sequence of courses lasting one and a half years taken during the third and fourth years of the four-year B.Sc. curriculum. These are open-ended project courses for some industrial client (or city
or hospital) in which the students, working in teams of three or four on the campus, spend about 800–1,000 man-hours per academic year on a project. They start with the 'proposal' and the liaison with industry and go on to the field and laboratory work, the reporting and the final delivery. Professional level hardware and formal reports are the expected results, answering a client's serious specific need, for which work the clients have been paying a fair fixed fee. The money goes to the college to cover this more expensive form of instruction. Engineering staff all usually serve as advisers. Fifth-year Master's degree candidates are required to take the leadership of these projects at double academic course credit. In any case, the senior student is the team leader. One hundred students and ten faculties are involved each year (see Table 6, column 2).

In the spring term of 1980, for example, some 100 students worked on twenty-four different projects under the guidance of about thirteen academic staff. All the projects were sponsored by industrial firms or public organizations. Projects included the re-design of an isolation mounting for a gyroscopic device, a micro-circuit flat panel display, strategies for energy-saving in small businesses and determination of the liquid phase reaction kinetics of an industrial chemical process.

Kansas State University (KSU), Manhattan, Kansas, instituted its project work in 1966 for the senior year of mechanical engineering. As a required two-unit course, the M.E. Design Lab guides up to eight fourth-year student teams through one semester working on real problems for industrial firms. The clients sign agreements with the university, and the students visit the firm at the beginning and end of the projects but substantially no funding and only limited liaison are involved during the term (see Table 6, column 3).

Worcester Polytechnic Institute (WPI), Worcester, Massachusetts, undertook in 1971 a major revision of its entire curriculum with undergraduate projects—rather than courses—as the heart of the educational system. Each student must undertake three projects each of seven weeks and pass a final-year examination in order to obtain a degree. The examination is called a 'competency examination' and is both written and oral, resembling somewhat a Master's degree examination. One project amounts to writing and then reading a paper at a seminar and depends on a study of selected subjects in the humanities. The Interactive Qualifying Project (IQP), which relates society and a technology, and the Major Qualifying Project (MQP) complete the three [84-86].

Almost all the MQPs originate in industry, public and private, as do some IQPs; but many IQPs originate from students or college staff. More than 250 firms and agencies had worked with WPI students on projects up to 1978. Each sponsor pays direct costs, including telephone, transport, components and other hardware, and usually they also pay an
<table>
<thead>
<tr>
<th>Line No.</th>
<th>Programme</th>
<th>Founded</th>
<th>Funded</th>
<th>Location in curriculum</th>
<th>Discipline(s)</th>
<th>Level</th>
<th>Approximate student participation per year</th>
<th>Programme format</th>
<th>Student participation</th>
<th>Project preference solicited</th>
<th>Assessment</th>
<th>Team</th>
<th>Compensation</th>
<th>Faculty participation</th>
<th>Client participation</th>
<th>Approximate numbers</th>
<th>Relationship to college</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>CINN</td>
<td>1906</td>
<td>Internal</td>
<td>Internal/project fees</td>
<td>Mechanical</td>
<td>Senior</td>
<td>45</td>
<td>1 term</td>
<td>Yes</td>
<td>Yes</td>
<td>Grades</td>
<td>No</td>
<td>No</td>
<td>All in department participate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>HMC</td>
<td>1963</td>
<td>Internal</td>
<td>Internal/project fees</td>
<td>Mechanical</td>
<td>Senior</td>
<td>1700</td>
<td>1 year + ongoing</td>
<td>Yes</td>
<td>Yes</td>
<td>Credit</td>
<td>No</td>
<td>No</td>
<td>Approximate numbers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>KSU</td>
<td>1966</td>
<td>External</td>
<td>External/internal</td>
<td>Mechanical</td>
<td>Senior</td>
<td>1 term</td>
<td>1 semester</td>
<td>Yes</td>
<td>Yes</td>
<td>Compensation</td>
<td>No</td>
<td>No</td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>WPI</td>
<td>1971</td>
<td>External</td>
<td>External/internal</td>
<td>Mechanical</td>
<td>Senior</td>
<td>16</td>
<td>7 weeks academic year</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>UMASS</td>
<td>1973</td>
<td>External</td>
<td>External/internal</td>
<td>Mechanical</td>
<td>Senior</td>
<td>1 semester</td>
<td>1 semester</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. HMC not organized into departments.
2. Includes fifth-year Master's students.
4. A = acceptable; AD = acceptable with distinction.
5. NA = not applicable.
additional fee of up to $1,000 per project. There is a waiting list of clients for project work. Work can be done on campus, in industry or in a mixture of both. In 1978, the distribution was as follows: 24 per cent at a company as an employee; 12 per cent part on campus, part at a company; and 64 per cent on campus.

At any one time, about 1,500 students are working on projects, some 500 of them with industrial clients, mostly on MQP projects. WPI has five project centres, outside the main campus, where there has been a series of projects. Two of these are at industrial enterprises and three are located on the premises of public bodies. The weekly student newspaper carries information about projects and project proposals. Projects are varied, ranging from the design of a new loom shuttle for the textile industry to work on the conversion of carbon dioxide to sugar for use in aerospace vehicles. IQPs have included efficiency studies of city agencies including a police department, the design of small car parks for a city, establishment of education classes for prison inmates, and so on. Study guidance is given by the academic staff; but courses are attended only as needed and are often available in the collection of video-tape recordings that can be borrowed from the library (see Table 6, column 4).

The University of Massachusetts (UMASS), Amherst, undertook in 1973 an optional programme in their Mechanical Engineering Department, made available to third and fourth-year students in their B.Sc. studies. Choosing this programme at the end of the second year, students leave the traditional course structure and begin an individual study-cum-project sequence. The students, working half time on projects, usually proceed individually rather than in teams. The projects average three months in length. Faculty staff assign projects as an 'engineering service for industry and community', and maintain thorough records, keeping in close touch with the student's progress. At this college the students' educational goals, status and progress are closely co-ordinated with their studies, the choice of client and the project.

This programme is highly selective, involving about fifteen students, four faculty members and fifteen outside clients (see Table 6, column 5).

Extension to foreign universities

Each of the colleges mentioned above has its own educational objectives, placing different emphasis on the various possible student skills: problem-solving, engineering sciences, computation, creativity, professional ethics, engineering judgement, planning, organizing, interpersonal awareness, leadership, communication and self-confidence.

A survey of these colleges in 1976 revealed that the participants considered programmes successful and planned to continue them. Each
Country and regional examples

is tailored to the needs of local faculty, students and communities. Following co-operation between Harvey Mudd College, the California State University at Los Angeles and the University of Paraiba, Campino Grande, Brazil, the Engineering Faculty of Paraiba has set up an engineering clinic on the same pattern as that at Harvey Mudd College. Although having to begin in a small way it has so far been successful in attracting project proposals.

The Georgia Institute of Technology, Atlanta, which has had twenty years' experience in industrial development through its Engineering Experimental Station, has also turned its attention to helping some Latin American countries set up new small industries. This has been done mostly by co-operation with local colleges and has involved both their staff and students. Indeed the network of institutions co-operating with Georgia Tech now extends outside Latin America to Ghana, Kenya, the Republic of Korea, Nigeria and the Philippines.

Use of case-studies

One substitute for practical experience is case-studies, which have been used extensively in the education of lawyers, medical students, students of business and management, and now engineers. More than 150 engineering institutions use studies of real engineering situations as part of their courses. Hundreds of case-studies have been written up and are available to colleges; many of them were prepared at Stanford University, California.

Case-studies can be used as: reading assignments; background information for a problem; material for problem formation; subjects for class discussion; illustration of theories; thesis topics for advanced degrees; material for further research; and examination problems.

They are also used for engineering orientation, in mechanical design and drawing, design in other specialities and for courses on legal and professional responsibilities. Consider as an illustration Case No. ECL-14, from the list at Stanford University, called 'Failure of a Ball-Bearing'.

Jack Wireman, a mechanical engineer in a real company, is faced with a ball-bearing failure in a new electric motorized pump. A contract for 200 such motors was recently received by the corporation and the terms required that demonstration motors would run 2,500 hours without failure. The first motor was shipped, installed on a customer's test stand, and a bearing burned out after 1,800 hours. Wireman substituted another bearing with a design life of 6,500 hours but it failed in only 700 hours. The customer was becoming nervous because a period of four months was required for testing time and an approved motor had
not yet been received. The motors cost about $2,000 each and the corporation was a small company trying to break even after some years of losses.

Wireman asked for consultation from one engineering professor at a well-known Institute of Technology and another from a bearing expert in another state. Both analysed the data and made recommendations which disagreed between themselves and with the bearing company. This case describes the situation that stretched over a number of months; but the episodes and decisions that are important occurred within matters of minutes, and these are the ones that are given to the students. In conclusion, Wireman thought through the evidence and came to his own solution, which in this particular case yielded a motor that ran the required 2,500 hours.

This particular case runs to seventy-two pages of which fifteen is text and fifty-seven are exhibits, ranging from specifications of the bearings, photographs of the failures, correspondence between the major parties, and diagrams of the actual physical arrangement. It is relevant to fluid mechanics as well as materials and manufacturing practices.

The programme at Stanford University in which case material was obtained and edited into suitable form was supported for a number of years by the United States National Science Foundation. Generally, graduate research assistants were used as case writers to do most of the errand work and the writing. They reported to the director of the programme who did the editing; but the final choice and editing were done by a professor, so that each case was tailored to a definite teaching objective. This, of course, avoided the major stumbling block of finding the time for the professors themselves to write the cases. The professors were generally satisfied with cases written this way. Some said that this produced better case-studies than they could write from their own experience, because they would be too biased to describe the problem objectively.

Anything from several weeks to several months are needed to prepare a case-study. Most originate from engineers in private industry, and a few from government departments. Some private corporations and foundations also supported the preparation of case-studies, paying out-of-pocket expenses and sometimes part of a salary.

The general conclusions have been that case-studies are an extremely useful supplement to classroom theory and laboratory instruction. Following the ten-year experience at Stanford University, many other colleges have now written up case studies and have joined Stanford in making this material available to any engineering college (through the United States Inter-collegiate Case Clearing House, Syracuse University Case Program, Syracuse, New York) and from the American Society for Engineering Education, ASEE, 1 Dupont Circle, Washington, D.C.).
Co-operative technician training

The responsibility for training technicians in the United States has now become vested in two-year and four-year institutes across the country. Industrial co-operation takes several forms. Those listed below apply now to the education and training of both engineers and technicians in the United States: alternating semesters of work-for-pay and academic studies; summer vacation jobs; projects and research assigned from industry; scholarships; funding grants to institutions; and governmental support plans.

Co-operation is with private and public industries, and with government laboratories and engineering departments.

The primary mode of industrial co-operation in the training of technicians is the first of these: alternating work and study, called 'co-operative education' in the United States and Canada. In fact, at present 119 four-year colleges and 223 two-year (community) colleges have co-operative education programmes in engineering technology (technician training). The programme may last from one to as many as seven terms, varying from institute to institute. Approximately 10 per cent of all the 177,000 co-operative students are enrolled in engineering technology. The remainder are scattered among different fields, ranging from agriculture to social science.

Co-operative education has been going on in the United States since 1906, when it was initiated at the University of Cincinnati. The first programme was in engineering; the next was in business at the same institution in 1919. It was followed by Antioch College in 1921, and then by other engineering colleges, but the adoption by other branches of education proceeded slowly until the 1960s when engineering technician training blossomed. Since then enrolments have increased by an order of magnitude, to the 20,000 engineering technicians of today. Numbers of co-operative education programmes given are as follows: 1906, 1; 1961, 65; 1970, 350; 1973, 567; 1974, 775; and 1978, 992.

Industry-college co-operation is thus both widespread and common. Reports of student reaction verify both the student acceptance and the faculty and industry approval of this form of integrated education.
Appendices
Appendix 1

Participants in the Unesco International Working Groups on Education—Industry Co-operation

Dr Abdel H. M. Abdella,
Department of Agricultural Engineering,
Faculty of Shambat, Sudan

Professor Y. A. Botcharov,
Department of Mechanical Technology A.M-6,
Bauman Institute of Technology,
Moscow B-5, USSR

Professor W. Fishwick,
c/o Department of Engineering Sciences,
Exeter University,
Exeter, United Kingdom

Mr F. J. Gichaga,
Department of Civil Engineering,
University of Nairobi,
P.O. Box 30197, Nairobi, Kenya

Professor L. A. Hansen,
Danmarks Ingeniørakademi,
Building 101 A, 2800 Lyngby, Denmark

Professor S. Kazem,
Faculty of Engineering,
Kabul University,
Kabul, Afghanistan

Ing Doris Maravi-Guttara,
Department of Industrial Processes,
National University of Engineering,
Apt. 1301, Lima, Peru

Dr M. S. Moayeri,
School of Engineering,
Pahlavi University, Shiraz, Iran

Dr B. A. Ntim,
Technology Consultancy Centre,
University of Science and Technology,
Kumasi, Ghana

Professor B. A. Sayar,
Faculty of Engineering,
Kabul University,
Kabul, Afghanistan

Mr S. Tchovete,
Unesco National Commission of the United Republic of Cameroon,
BP1600, Yaounde,
United Republic of Cameroon

Professor T. T. Woodson,
Harvey Mudd College,
Claremont, Calif. 91711, United States

Professor D. Zanobetti,
Faculty of Engineering,
University of Bologna,
Bologna, Italy

1. The late Dr V. Broida of FEANI, General R Bureau of FEANI, and Dr H. Deimann of UNIDO attended the Second Meeting of the Working Group in Paris, in 1976, as observers.
Appendix 2

Committee on Engineering Education in Middle Africa (CEEMA): A Survey on University—Industry Co-operation in Engineering

The survey revealed that there is some measure of co-operation between faculty and industry at all the universities surveyed. The most common form of co-operation is in the field of industrial training. About half of the faculties insist on compulsory industrial training during the vacations, while for the rest it is optional.

To improve the quality of engineering education and the use of engineering manpower and facilities in the universities in Middle Africa, the following points should be noted:

1. Compulsory industrial training during vacations, backed by adequate workshop practice on the campus, should be practised by those faculties which do not already do so.
2. The services of a full-time industrial training officer are needed for routine administration and record keeping in the industrial training programme.
3. In addition, as many faculty members as possible should be involved in visiting and supervising students during their industrial attachment.
4. Professional bodies and governments should help the faculties in bringing pressure to bear on those industries that are not playing their full part in industrial training.
5. Industry should be represented on faculty committees, particularly those on curricula revision.
6. Government, industry and university should encourage staff to direct their research efforts into areas of local needs. This can best be done by sponsored research, which is not yet developing quickly enough.
7. Professional engineering practice should be seen as a necessary aspect of academic life in engineering. Universities that do not have definite policies on this issue should formulate some. Essentially, staff should be encouraged to take up industrial fellowships during their study leave. It might be necessary to make agreements with industry to ensure that staff on industrial fellowships are not enticed into industry permanently. In addition

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1. Based on a survey made by Professor P. M. Githinji of Nairobi University, Kenya, and Dr B. A. Ntim of the University of Science and Technology, Kumasi, Ghana, and published by Dr S. E. Chukwujekwu of the University of Benin, Nigeria, as executive secretary of CEEMA in July 1976.
staff should be encouraged to act as consultants to both the university and to industry. There must be adequate safeguards to ensure that teaching and research do not suffer.

8. Institutions should recognize the value of part-time lecturers from industry. They should be used not as a stop-gap measure but as a deliberate policy of bringing institutions and industry together.

9. More efforts should be made in formulating the graduate training programmes. Faculties should take more interest in this and, where necessary, they should take the initiative in starting discussions with the professional institutions and with governments.

10. Faculties should be encouraged to carry out a critical assessment of vacation industrial training to see whether it produces an improvement in the practical aptitudes of students by their final year.

11. CEEMA, with the help of Unesco or some other body, should carry out a survey of the progress of graduates over a five- or ten-year period.

It seems that in most cases of successful university-industry co-operation, the initiative and the driving force must come from the university. Industry is in many cases a reluctant participant, though it may sometimes take the initiative.

The university authorities must recognize the peculiar nature of engineering education, and reduce the number of obstacles they sometimes put between engineering faculties and industry.

Governments and professional societies should act as catalysts in this process. Governments, in particular, should promulgate laws to facilitate industrial training and discourage the use of foreign consultants where local personnel can fulfil the functions.
Appendix 3


PREAMBLE

Many of the above identified obstacles could be attacked through the development of appropriate mechanisms or instruments. These instruments could include legislation and active encouragement by government departments, universities, industrial organizations and engineering professional societies, so as to facilitate the realization of features of the ideal model. It also should include the promotion of good communication between training establishments and industry through joint projects.

The members of the meeting unanimously agreed that the recommendations concerning the development of co-operation should be addressed to: institutions for engineering education; industrial organizations; government bodies responsible for the development of industrial and educational policies; engineering professional organizations; and international organizations.

In drawing up a series of general recommendations the working group agreed that:

The goals of engineering education must be primarily to train engineering personnel able to contribute, through their engineering careers, to national economic and social development.

Engineering education has special qualities that distinguish it from other areas of higher education, and that the need for it to be sensitive to industrial progress and requirements including manpower needs is one of the most important of these qualities. Another is the need for continuing professional growth after graduation.

Engineering students must be educated so that they develop attitudes, aptitudes and approaches of an innovative and profoundly practical nature, and be aware of man’s technological history and the impact of his works on the environment.

Teachers and students in educational institutions need to be in close contact with practising professional engineers and their working milieu.

Their education should quickly expose students to the multidisciplinary nature of engineering practice in the modern world.

Good communications and the sharing of experiences on a local, national,
regional or international scale can do much to stimulate the renovation and development of the education and training of engineers. Employability of engineering personnel is an important criterion of progress and efficacy of educational institutions, which should be flexible enough to respond to changing industrial demands.

A. RECOMMENDATIONS TO EDUCATIONAL INSTITUTIONS

1. That educational institutions encourage their staff, both senior and junior, to engage in appropriate industrial activities which in most cases may take a consultative form. Strict regulations should ensure that the time allocated to and the commitments involved with these activities should be in proper balance with their academic duties.

2. That educational institutions make use of part-time personnel both at the professorial and assistant levels with a view to ensuring that the educational activities in the institution be related to the actual situation of the engineering art as locally practised.

   The educational operation should take into consideration the teaching abilities of part-time personnel and allow for their appropriate training in methodology.

   The educational operation should also take into consideration problems of part-time remuneration, which in most cases should be limited to a level that is nominal but not discouraging. In many cases for higher executives or for limited academic activities, part-time teaching may take place on a voluntary basis.

   Calendar arrangements might be studied in cases where the physical distance between industry and the educational institution, coupled with poor communication, as in some developing countries, makes it difficult for the part-time personnel to teach for the whole duration of the academic year.

   That educational institutions of the developing countries, when making use of foreign contract personnel, should require sound industrial experience for personnel recruited for teaching or research activities.

   That educational institutions encourage their engineering departments and laboratories to engage in appropriate industrial activities taking such forms as consultative services, measurements or analysis, research, bibliographical studies, computer programs, and that they use in these activities, to the extent possible, junior staff and students with a view to improving their training.

   That educational institutions also encourage the use of sabbatical or similar leave, where applicable, for periods of service in industry for all their teaching personnel.

3. That educational institutions take into consideration all the above in their recruitment, manning tables and overall staff policies.

4. That educational institutions introduce limited periods of industrial practice in the first or second year of study, as one way in which the student may ascertain his aptitudes and become better oriented. It is felt, however, that such industrial training stages should preferably be limited in time and be guided and appraised by academic personnel from the institution.
5. That educational institutions introduce in all their subjects design approaches, the appraisal of alternatives, economic factors, and practical engineering considerations.

6. That when recruiting teaching staff educational institutions should always bear in mind the desirability of offering teaching careers to engineers currently working in industry and having strong academic as well as industrial backgrounds.

B. RECOMMENDATIONS TO INDUSTRY

1. That within the context of lifelong education, all industrial enterprises should give priority to training programmes for their own personnel, for students, and for teaching staff coming from educational institutions.

2. That such training activities be promoted and supervised by independent training boards composed of members from education, industry, government, and trade unions or professional bodies. The efficacy of such training should be systematically evaluated.

3. That industry should co-operate with education by releasing and encouraging its senior personnel to serve as part-time teachers or research consultants in educational institutions, so as to ensure that local industrial problems are appreciated by staff and students.

4. That industry should co-operate with educational institutions by offering vacation training facilities to students and in receiving students on technical visits or on project work.

5. That industry should show flexibility by providing temporary employment for academic staff on sabbatical or short-term leave, to enable them to become conversant with current engineering practice.

6. That industry co-operate with educational institutions by sharing professional literature, mounting joint seminars, expert meetings, and engaging in continuing education activities on a mutually beneficial basis.

7. That industry should provide data to governments and educational institutions on manpower needs and technical problems.

C. RECOMMENDATIONS TO REGIONAL, NATIONAL OR OTHER ASSOCIATIONS OF ENGINEERS

1. That such associations should clarify and publicize their role in their region or country, detailing their activities in promoting education-industry cooperation.

2. That professional engineering bodies should participate in advisory boards of three different types, so that education benefits from the influence of the practising engineer:
   (a) Advisory boards for engineering qualifications. The professional engineering bodies should take the primary responsibility for such boards in co-operation with educational institutions, government and industry, whose role is to recommend and implement policies on matters including: definition of 'engineer' and of various engineering categories; professional registration and its relationship with legal regulations in force; minimum requirements of the profession with respect to the qualifications and training.
of engineering graduate and registered engineer; professional standards and ethics.

(b) Advisory board of an educational institution. The representatives of faculty administration, professors and students should take the primary responsibility, with the co-operation of the professional engineering bodies, in expressing views and in making recommendations concerning: the qualities of the future engineering graduate; the curriculum; the teaching methods; the desirable examination controls.

(c) Advisory board for professional and institutional co-ordination. The professional engineering bodies should equally share representation with the faculty, government and industry on boards for the purposes of: recommending and implementing policies on continuing education; recommending and implementing policies on practical training to be undertaken during courses of studies; funding of special practical training programmes; general cooperation; reporting of a minimum of useful statistical and related information; joint meetings, major development seminars, etc.

D. RECOMMENDATIONS TO GOVERNMENTS

1. That governments' policies in technological training should be carefully formulated in the light of the state of development of the educational sector. Particular attention should be given to matching in a quantitative and qualitative sense the education of engineers and technicians with the actual and foreseen requirements of industry.

2. Governments should facilitate and encourage co-operation between industrial enterprises and educational institutions for the training of engineers and technicians for industry, providing any necessary incentives to ensure that such co-operation is effective.

3. In countries where it is appropriate a special body should be established to advise the government on the training of engineers and technicians in both educational institutions and industry.

4. That research and development institutes, either autonomous or attached to educational institutions, be used as effective links between education and industry.
Appendix 4


CONCLUSIONS

1. There is in general a serious lack of co-ordination between higher educational institutions and industry in all the scientific and technical professions whose task it is to stimulate the technological development of the industrial section in Latin America.

2. The training of engineers calls for the co-operation of the scientist. The latter is a universalist and he idealizes certain types of fact. It is hard for him to understand the pragmatic, down-to-earth mentality of the industrialist. Likewise, the university, as a centre of knowledge, is independent of society and often critical of it, but it should collaborate as closely as possible with industry, in its own particular fields.

3. Latin American industry has to a large extent developed without regard for engineering ability, so that interest in the training of engineers has only recently been aroused in some countries of the region. The causes of this lack of interest in engineering include:

   Over-dependence on foreign technology (economic and cultural dependence).
   The fact that the driving force in industrialization has been provided by more or less recent immigrants who, by dint of sustained personal effort and owing to the low technological standards of Latin American countries, feel technically self-sufficient. The result has been the development first of a great many small industries, and later of medium-sized and large ones, which supply the various markets.
   Excessive protection, by high tariffs, of industries which have come into being as a result of the import-substitution policy.
   Lack of confidence in a university system which is frequently at loggerheads with the most 'established' part of society, that is, industry and commerce.
   The reluctance of many industrialists to admit that technological

1. This seminar brought together engineers and engineering educators from seventeen countries in Latin America. It was arranged by the Unesco Field Science Office for Latin America and was financially supported by the United Nations Development Programme.
development today is so rapid that an industry which does not constantly renew its plant and processes and bring its knowledge up to date soon lapses into obsolescence and inefficiency.

The fact that Latin American society has no real scientific and technological tradition, so that people are often suspicious of creative innovation.

4. In Latin America there is very little practical, official, sustained or successful action in the field of co-operation between industry and institutions of engineering education. On the other hand, there are channels for informal, sporadic and chance communication which, in some countries, amount to a system of de facto co-operation between industry and institutions of engineering education:

Practical training courses, in which final-year students spend a certain amount of time working in industry, seem to have been built up by almost all institutions of engineering education into an education method of acknowledged value.

Industries and institutes of engineering education collaborate to some extent and in various ways in planning and conducting courses of further education for engineers. These experiments are definitely beneficial as regards the qualification, suitability and personal satisfaction of engineers fortunate enough to have attended these courses.

A large proportion of engineering teachers and research workers do work related to their particular field of study in public or private industry. This means that industrial concerns in fact take part, albeit indirectly, in planning the educational, scientific and technical aspects of the work of educational institutions.

The fact that graduates of Latin American institutions of engineering are working in industrial posts in their own countries means that there are centres of understanding which lead to agreements, research and technical assistance contracts, invitations to lecture and conduct seminars, donations of equipment, awards of fellowships, and so forth.

5. It is felt to be most important that educational institutions should give technical assistance or professional advice to industries as a means of communication and mutual information, so that apprehension and distrust will by replaced by contact, understanding and collaboration. But at present it is only in exceptional cases that institutions of engineering education carry out technological research or provide highly scientific advisory services for industrial groups, the majority of which do not see the point of this kind of consultation. However, these groups expect to receive the scientific and technological support they need from numerous well-equipped institutes, which in turn have tenuous or non-existent links with institutions of engineering education.

6. As regards institutions, public bodies and legislation to promote co-operation, the following may be stated:

The National Councils of Science and Technology are playing an increasingly important part in the co-ordination of institutions of engineering education and industry.

Bodies in which industry and educational institutions combine to stimulate and channel co-operation between both parties have not yet been established in Latin America.
The region has no legal enactments to promote co-ordination between the industrial sector and institutions of engineering education.

7. The many instances of co-operation between industries and institutions of engineering education in Latin America are as yet isolated and makeshift arrangements, but they do show the feasibility of reaching a profitable understanding between the two, and they open up the possibility that the cooperation mechanisms referred to will be extended throughout the region and will be placed on a legislative and institutional basis.

RECOMMENDATIONS

Support by industry for institutions of engineering education

1. The participants in the seminar, mindful of the problems arising from an atmosphere of mistrust and mutual distrust between educational institutions and industry, which is prevalent in most Latin American countries, taking into account that academic circles are anxious that their right and duty to decide independently on their teaching and research activities should be preserved, considering the experiments described, which show that the industrial sector can and should take action of various kinds to support academic activities in the training of engineers,

And with a view to:
increasing the participation of industries in the training of engineers, particularly when the students have reached the stage of applied engineering and are doing highly specialized work; and
keeping educational institutions informed as to the technical skills required by industry, direct transfers of technology from other countries and the problems of adaptation or further training that they raise,

Recommend:
(a) That industries, in agreement with educational institutions, facilitate the systematic and extensive introduction of professional experience as an integral part of curricula.
(b) That industries make their facilities available so that refresher courses can be provided for the teaching staff of institutions of engineering education.
(c) That industries, through those of their members who have the closest links with education institutions, participate in the governing boards of the latter, in the elaboration of research policies, particularly the selection of priority fields for applied research, in the preparation of syllabuses for the various subjects, in the planning of lifelong education programmes, in the organization of postgraduate engineering courses.
(d) That industries give financial support to academic research activities as a means of improving the specialist training of engineers.
(e) That industry establish the procedures and technical facilities required for the management of technology, allocating resources for the introduction of
the country's own technology and the adaptation of imported technology. It should plan the effective and systematic replacement of foreign engineering advisory services by national services.

(f) That industries make arrangements for educational institutions to be represented in their organizations and for them to be members of governing bodies concerned with industrial development and planning.

(g) That international organizations concerned with industrial development programmes bear in mind the general spirit of this recommendation in their activities to support and guide the industrial development of the countries of Latin America.

Improvement of institutions of engineering education in order to foster industrial development

2. The participants in the seminar, considering that recent trends, in the countries of Latin America, towards the development of a large-scale basic and manufacturing industrial sector necessitate radically changing both the numbers of engineers to be trained by educational institutions and their subjects of study,

mindful of the new educational methods which have been tested in various countries with a view to making the services of engineers immediately useful and permanently effective in a world in which technology is changing at an ever-increasing rate,

And for the purpose of:

making the industrial sector aware of the advisability of introducing technology on a permanent basis and training all workers, in close co-ordination with the rate of industrial growth and improvement called for by technological progress throughout the world;

making the industrial sector aware of the desirability of having permanent access to national sources of technological support, because that would enable decisions regarding transformation, extension, diversification, re-conversion, etc., to be taken independently;

impressing upon educational institutions the desirability of evaluating their educational activities by keeping the public informed of what is taught and by making services available to the industrial sector;

stimulating the development of real engineering ability at national and regional levels so that engineers can carry out the most important stages of industrial projects either on their own or with the advice of national or foreign experts,

Recommend:

(a) That special attention be given to the establishment of flexible educational structures which can be adapted to suit the multidisciplinary character of most technological problems met with in the region today. Furthermore, these structures should be compatible with the need for effective action regarding the conclusion of labour contracts or engagements, which may include financing and the power of inspection on the part of industry.

(b) That the development of advanced studies connected with specific industrial problems be promoted by keeping in touch with industry. In some cases
highly innovatory studies could be carried out in this way. Such participation by students in technological research activities should ultimately become one of the main features of their training.

(c) That contributions to applied research and technological innovation contained in the syllabuses followed by teachers should be appraised at their true worth, so that the value of their work is recognized by the public at large.

(d) That each institution of engineering education publicize, by means of publications, brochures, and so on, the facilities it possesses for research or the provision of services and the specialist staff whose services it can enlist for the purpose, and that each institution set up a body to be responsible for promoting the provision of services and administering them and adopt regulations regarding this activity, and that part of the resources thus obtained be used to remunerate the staff of the institution who have to perform additional work in order to render such services.

(e) That in its programmes of assistance designed to improve institutions for the training of engineers Unesco consider a policy of providing services as one of the factors that contribute to the development of an institution and keep in touch with industry.

(f) That institutions of engineering education, in conjunction with industry, the state and professional associations, organize and implement lifelong education programmes, so that any engineer who wishes to may bring his knowledge up to date, at any stage of his professional career.

(g) That the adoption of legislation and of internal regulations for educational institutions be encouraged, and that the support of industrialists be sought to assist the worker to gain access to higher education and continue to enjoy its benefits, either in conjunction with his industrial activity or for periods alternating with it.

(h) That institutions of engineering education take part in the formulation of national policies for technological development, and that industry and the state should recognize the fundamental part played by such institutions in framing these policies.

(i) That engineers trained in educational institutions be taught in such a way that they develop a critical spirit and the ability to use the available resources of their country creatively.

Government action to encourage co-ordination between institutions of engineering education and industry

3. The participants in the seminar,

Considering the ever-increasing role of states in the large-scale industrialization of their countries and in the process of training the technologists required for such industrialization,

Taking into account the fact that there is practically no legislation to promote co-ordination between the industrial sector and institutions of engineering education and that there are very few institutions conducted jointly by these two sectors for the purpose of channelling collaboration between them,

Recognizing the increasing responsibility for this co-ordination assumed by the national councils of science and technology, effectively backed up by such international organizations as Unesco, OAS and IDB,
Mindful of the diversity of situations of the different countries of the region as to degree of industrial development, degree of dependence on foreign investment, and age and degree of development of educational institutions,

Recommend:

(a) That the framing of technological policies for each country, sector and branch of industry be speeded up, the efforts of the industrial sector (and of its higher authorities) being combined with those of the education sector and with the activities of the National Councils of Science and Technology, and that all bodies or individuals able to contribute information on the matter should participate in this process.

(b) That suitable instruments and mechanisms for the application of such policies be set up. These should, in particular, enable small- and medium-sized concerns to have access to the most up-to-date technology available in the world.

(c) That regional co-operation between engineering groups in the countries of Latin America be encouraged with a view to promoting a degree of technological specialization by countries, that support be given to regional industrial planning and to innovation in drawing up curricula for engineering schools in the region.

(d) That state-run industrial research institutes be increasingly used as an effective link between institutions of engineering education and industry. In particular, that ways of organizing the exchange of staff between these institutes and the universities be investigated, so that research workers from institutes take part in teaching activities (especially postgraduate) and university teachers take part in the activities of institutes.

Participation of engineering societies in co-operation between institutions of engineering education and industry

4. The participants in the seminar,

Considering that the engineering profession as a whole, organized at the regional or national level in accordance with corporate or technical arrangements, is the most suitable institutional mechanism for promoting contact and true understanding between institutions of engineering education and industry,

Taking into account the concern expressed by Latin American engineers, at meetings of their professional bodies and councils in Lima and Santiago, and in various documents of UPADI, etc., regarding their seriously decreased participation in the most active bodies working for industrialization and the technical advancement of the economic life of the countries of Latin America,

Recommend:

(a) That engineering societies take steps to bring industry, governments and institutions of engineering education closer together in order to achieve the aims of technological policy.

(b) That engineering societies assume their responsibility in the matter of national technological development through the active participation of their members in the formulation of policies and in the promotion of engineering activities.
(c) That the international organizations which are associated with the engineering societies of Latin America or have close relations with them (UPADI, WFEO, Unesco, UNIDO, OAS, etc.) act as depositories for the conclusions and recommendations of this seminar and promote the institutionalization of all the arrangements for co-operation between institutions of engineering education and industry which have been proposed and the adoption of legislation relating to them.
References


1. References shown with an asterisk are publications or reports of United Nations agencies.


69. Science Research Council. The Teaching Company Scheme Leaflet. Swindon, SRC.


