THE COMMUNICATION OF IDEAS

Inaugural lecture
delivered at the College
on 5 December 1957

by

R. H. MACMILLAN
M.A., A.M.I.MECH.E., A.F.R.AE.S.
Professor of Mechanical Engineering

GWEDDW CREFFT HEB EI DAWN

UNIVERSITY COLLEGE OF SWANSEA

UNIVERSITY COLLEGE OF SWANSEA

THE COMMUNICATION OF IDEAS

Inaugural Lecture
delivered at the College
on 5 December 1957

by

R. H. MACMILLAN
M.A., A.M.I.Mech.E., A.F.R.Ae.S.
Professor of Mechanical Engineering

PRINTED IN GREAT BRITAIN

THE COMMUNICATION OF IDEAS

THERE is an old Spanish proverb that says 'En boca cerrada no entra mosca', or 'No fly enters a shut mouth'. This vivid plea for silence extols a course of action that many another in my position must at first have felt he would be willing enough to pursue, for the task of delivering an Inaugural Lecture must always be an arduous one, arduous both in the choice of topic and in the manner of presenting it. With a gathering such as we usually have here on these occasions, it is desirable to select a subject likely to appeal both to Town and Gown, and moreover one must attempt in ones observations to steer a middle course between the Scylla of vague generalities and the Charybdis of intolerable detail. Even if these waters can be successfully navigated, one must still try to resist the siren song of delightful but irrelevant digression.

It is the custom for those in my predicament to talk about an aspect of their particular branch of learning with which they have been specially concerned. But it so happens that two Inaugural Addresses have been devoted, in the course of the last year, to subjects very closely allied to my own special field, which is Automatic Control. Furthermore, I recently published a little book for the general reader dealing with Automation and, since I there set down in some detail my views on the technical, social, and economic implications of these new industrial methods, I felt I would prefer to avoid repeating them here tonight. Another topic I would like to have discussed is 'The place of Engineering in University education', but this was the subject of the Third Graham Clark Lecture, delivered earlier this year by Sir Ifor Evans, the

Provost of University College, London. As it would be superfluous for me to try to add to what he said on that occasion, I am still left without any obvious topic for this evening.

While casting around for a suitable alternative, I found myself wondering what purpose an Inaugural Address is intended to serve. Several possibilities immediately spring to mind. Could it be that it is simply a medieval survival from the times when it was in fact the *first* lecture given by the new occupant of a Chair, and was thus a sort of trial-by-ordeal, for initiation into the senatorial sphere? This seems hardly probable, in view of the fact that a sister University in England has only recently reintroduced the custom of having Inaugural Lectures, after it had been allowed to fall into abeyance. Perhaps, then, the object is to enable his contemporaries in University and Town to gauge the mettle of the person recently appointed as their colleague. But the capacities of a man are better judged by what he can achieve than by his ability to inspire confidence by plausible speeches, a feat that is part of the stock-in-trade of even the most perfidious politician. No: I think a truer view of the Inaugural Lecture would be to regard it as a privilege that is accorded to a new Professor, enabling him to ventilate among his associates some topic dear to his heart.

Since a number of those attending on these occasions only come out of a rigid sense of duty, the lecturer must do his best to ensure that the duty proves to be a pleasant one. Moreover, an audience that is not interested will not be receptive of any ideas that the lecturer may wish to impart. This, of course, is one of the time-honoured principles that are accepted by all who have examined the processes involved in the communication of ideas from one individual to another. Now, since the means of communicating ideas is a subject I have always found

intensely interesting, it seemed to me that it might be a suitable one to discuss tonight, particularly as the communication of ideas is the principal activity of a University teaching Department, though by no means its only one.

After a few general remarks, I shall restrict myself to discussing those features that are of importance in the communication of scientific ideas in particular, referring especially to some of the techniques that can be used in preparing technical reports and in writing about scientific matters for the general reader. It will, I hope, become evident that the problems do not arise solely from the matter to be communicated, but stem also from the educational backgrounds of both writer and reader. I shall wind up, therefore, by indicating how we in the Engineering Department at Swansea are hoping to contribute to their solution.

The ability to communicate by means of speech distinguishes man from the animals and the ability to communicate, through the medium of the written word, with the past and future is the key to civilization. Human knowledge, and particularly scientific knowledge, is cumulative: the present is built upon the past and the future upon the present; if each generation had to establish the fundamentals anew, only very limited progress would be possible.

Recently there has been an immense increase in the volume and importance of communication in the world. The number of learned societies multiplies and, with the rate of publication of all types of literature at a record level, the number of books in the world's libraries is doubling every fifteen years. The same is true of periodicals, both learned and ephemeral. Meanwhile, the number of documents that pass from hand to hand is mounting daily. This is so in all phases of modern life, but most particularly in industry, where even a minor executive finds his desk inundated with floods of reports, minutes, instructions for the use and repair of equipment, specifications, and publicity matter. It is small wonder he finds it hard to deal properly with this rising tide.

This situation, in which paper work occupies so much of an engineer's time, has come about because of the increasing complexity of industry today. Almost every activity is necessarily a co-operative one, calling for contributions from specialists in many fields, often remote from one another. To design a nuclear power station, or the launching rocket for a satellite, calls for co-operation between electrical and civil engineers, metallurgists, mathematicians, thermodynamicists, chemists, physicists, and instrument technologists; their activities may well be coordinated by a mechanical engineer. All these specialists inevitably come from different backgrounds, and to some extent use different technical vocabularies, yet they must communicate with each other concisely and without ambiguity if they are to collaborate effectively.

Ideas and information may be conveyed verbally as well as through the written word: in fact oral communication predominated until the invention of printing. Every industrial executive spends many hours each month in conference, and committee meetings of every sort, from the Cabinet through the College Senate to the Committee of the humblest student Club, wield an immense influence in the ordering of all our affairs. Is it not extraordinary then that so little thought is usually expended on the all-important problem of expediting committee business, by ensuring that ideas are expressed clearly and briefly? The reason for it lies, I believe, in a very general lack of appreciation of the existence and nature of the problems that face us.

Those ideas with which we are primarily concerned convey knowledge or information. Now knowledge is a basic resource of mankind, every whit as important to nations as are their natural resources of power. But unlike the fossil fuels such as coal and oil, knowledge is not consumable: it is available in unlimited quantities like thermonuclear energy, if only we can tap its sources. You will realize, then, how important is the issue at stake, and I hope you will agree that we ought to bestow on our means of communication the same care as we lavish on the design of a machine: a passage in a report, or a phrase in a discussion, that fails to convey its message clearly and concisely can be compared with a machine that is hard to use or control.

For a general statement of the correct principles of communication, I cannot do better than quote Professor Kapp, formerly Pender Professor of Electrical Engineering at University College, London. He wrote that

> The best expositor . . . designs [his vehicle of information] so as to ensure that the person addressed will remain receptive for the whole of the time that it takes him to impart the information, that this person may be ready to receive each point at the moment when it is presented to him, to see emphasis where it is intended. To do this the expositor must know, so far as it is humanly possible to know such things, what is likely to be happening in the recipient's mind from moment to moment; he must assess every passage for its characteristic qualities; he must recognize which of his statements will be difficult and which easy to understand, which will be known to the recipient already and which will be new to him, which items are for information only and which for action, which may safely be soon forgotten and which must be remembered, which will be welcome to the recipient and which highly unwelcome.

What I have been saying so far has applied generally to the communication of any sort of ideas whatever. Let us now, however, focus our thoughts on the communication of scientific ideas in particular and, since many of the problems of oral and written communication are similar, I shall restrict my remarks to discussion of the written word.

First of all, I feel we should be clear in our minds why it is that a scholar or research worker may wish to communicate his ideas. Presumably it will be for one of two reasons: either he thinks his work so interesting he is certain that others will wish to hear of it, or he believes it to be so important that they ought to know about it. In either case there is, or should be, an active desire on his part to communicate, and this, of course, is the first step towards success in its achievement.

It is important, when he comes to put pen to paper, for the writer to bear in mind his primary reason for writing and also the type of individual by whom he intends his words to be read, because scientific ideas are often complex and their proper understanding usually demands a certain background of knowledge. Naturally, this applies also in other fields; but with science a special difficulty arises in that very many persons lack almost entirely the necessary basic information, divorced from everyday experience as much of it is.

Because of the importance of scientific background, the communicator of scientific ideas must express them differently, according to the person to whom they are directed. His reader will probably be a member of one of four main classes. Firstly, there are co-workers in the same scientific field. It may be assumed by the writer that they are completely familiar with the special vocabulary that it is customary to use, and that they are aware of all important work that has been done in the field, apart perhaps from some of the most recent contributions. In many respects, writing for this group presents the least difficulties to the scientist.

The second group comprises other scientists, who have the necessary scientific background and outlook but are unfamiliar with the particular subject in question. I take it that a fair proportion of my audience tonight would fall into this category. In addressing this group, it is necessary to define carefully any peculiar vocabulary used and to fill in a certain amount of special background information. It must be remembered that because scientific knowledge is cumulative, any individual publication must fit into a general scheme.

The next class includes readers with intellectual capacity but without scientific training. This category would, I suppose, include the majority of those present. Although the writer may assume that a member of this group will be willing to read with care and concentration, making a real attempt to understand unfamiliar ideas, he must make a continuous and conscious effort to help this process of assimilation. It has been suggested that there are too few good scientists for us to expect them to spend valuable time in learning to write for the ordinary reader, and that we ought therefore to employ specially trained intermediaries to do this job. In the United States the 'technical ghost-writer', as he is called, has come during the last few years to fulfil just this function; but it is to be feared that the emergence of such an individual is a retrograde step and could lead to an even greater separation between the scientist or technologist and the ordinary man.

Finally, we must consider the type of writing needed to impart some grain of scientific truth to those who are either unable or unwilling to make any considerable effort at understanding difficult ideas and who read uncritically, if at all. This class unfortunately constitutes a very high proportion of the population, but I hope nobody here would be a member of it. Some decline in scientific accuracy is inevitable in attempting to communicate with persons from this group, and I would suggest that although such writing is of great importance, it should be the province of journalists, not of scientists.

It has been maintained that the difficulty of scientific communication rests principally, or even solely, upon the unfamiliarity of the language used to convey scientific ideas. Undoubtedly some authors load the scales against the comprehension of their work by the use of special and esoteric words that are often unnecessary. The pure scientists are more prone to this fault than are the technologists. Consider this authentic extract from a botanical source: 'The foliage is usually persistent. The leaves are linear, linear-lanceolate, acicular or squamiform and have simple venation. The leaf surface is often glabrous or lustrous.' Translated into plain words, by means of Flood and West's *Dictionary of Scientific Terms*, this becomes: 'The leaves usually last for several years. They are straight and narrow, thin spear-shaped, needle-shaped or scale-like and the veins are simply arranged. The surface of the leaf is often smooth or shiny.' This scientific habit of not calling a spade a spade has little to commend it, as it leads to a loss in clarity, and often in brevity too.

An incidental source of difficulty to the layman reading scientific material is the fact that a number of words in common use have a precisely defined scientific meaning that often differs somewhat from the popular usage. Obvious examples are such words as *power*, *work*, and *energy*. I have always found when lecturing that, without careful preparation, mention of an *impulsive couple* is apt to cause a disturbance, particularly if the problem is one of those in which *resistance* is to be ignored. The same situation arises with legal terminology, only in a far more acute form.

Nevertheless, I cannot support the view that we can lay the blame for the reader's lack of interest in, or comprehension of, scientific writing at the door either of the scientific vocabulary of the authors, or of their frequently obscure and sometimes even illiterate style. I have already stressed that the ideas to be conveyed are often new to the reader and they are set against an unfamiliar background—this is the fundamental difficulty. Doubt has lately been expressed as to whether it is really possible for scientists to put some of their findings into terms comprehensible to the ordinary man. Examples which spring to mind concern the radiation hazards attendant on the testing of nuclear weapons, and the precession of a satellite's orbit. And yet this same man is expected to take decisions, as a voter, on the assumption that he *can* understand these and related phenomena. My own view is that although a few issues of importance may not be entirely intelligible to somebody without scientific or mathematical background, their number at present is certainly small.

That the communication of scientific ideas to the layman *can* be achieved without a sacrifice in accuracy has been proved time and again, both by means of lectures and the written word. But we may be certain that success has only been attained because the author or speaker was aware of the problems he faced and exerted himself to make his meaning absolutely clear and his line of argument easy to follow. Among the successful exponents of scientific writing for the general reader one recalls such names as Julian Huxley and Fred Hoyle. Scientific talks and lectures that have been models of clarity range from the Science Lectures for the People given in Manchester, by the nineteenth-century chemist Roscoe, through the many illustrated lectures at the Royal Institution, to Science Survey and other scientific matter presented by the B.B.C. A proportion, though a regrettably small one, of the lectures at the annual meetings of the British Association match up to the standard I have in mind.

That there is a growing demand on the part of the public in this country for authentic and up-to-date information about current developments in both pure and applied science is proved by the appearance, and continued success, of periodicals such as *The New Scientist* and *Technology*. It is easy to be critical of some of the contributions to these publications, but for the most part they are adequately fulfilling a valuable and necessary function. *The Scientific American*, since its rejuvenation a few years ago, has gone from strength to strength, as is evidenced by the fact that some of the material published in it is now being made available in book form. From the point of view of production technique, our own popular scientific periodicals suffer by comparison with it.

We have seen, then, that the popularization of science has a relatively long and often honourable past, while there has recently been a greater appreciation of its importance and possibilities. Let us consider now how intelligible specialists succeed in being when they are addressing other scientists. Sir William Bragg, in his final Presidential Address to the Royal Society made a plea that contributors to the *Transactions* should make their summaries intelligible to all other Fellows of the Society. The proposal evidently fell on deaf ears, as the current summaries can still be understood only by specialists in the particular field. Again, it has been proposed that research workers seeking financial support be required to explain the objects of their work in plain words before being permitted to proceed. Since the men who fill the purse, even if they do not hold its strings, are scientific laymen, there is much to be said in favour of this suggestion, and I do not doubt that in all but exceptional instances the exercise would be entirely practicable. Furthermore, expressing his ideas in terms intelligible to the general reader can be a valuable experience to the scientist. In this connexion, Albert Einstein allowed himself to be quoted as having once made what he later described as a 'slightly exaggerated statement'. It was this: 'Whenever I get a new idea, I do not feel I fully understand it until I can express it in plain words.'

Only last week Sir Arthur Bryant had in *The Times* a letter that referred to writing intended for the general reader. These were his words:

> contrary to general belief a 'popular', that is, an easily readable history, if it is to be also an accurate work of scholarship, involves not less but more work than one compiled only for serious students, because one has first to collect, digest and arrange one's material and then, by constant re-writing and polishing, to present it in a form in which nothing is superfluous and tedious, in which every word, sentence, and paragraph leads naturally to the next.

What Sir Arthur wrote of popular history is equally true of popular science, especially regarding the very general ignorance of the problems it presents to the author who is determined to be scholarly as well as readable.

It is now time to be more specific about the means by which the scientific writer is to express himself, and I wish to detail a few of the principles that can be applied to help resolve the difficulty of communicating scientific ideas. For the most part my remarks apply equally to technical report writing and to scientific writing for the general reader. The techniques I shall advocate are generally accepted and have been described at length in such excellent books as *The Presentation of Technical Information* by Professor Kapp, whom I quoted earlier from another source.

Now, whether he is writing for colleagues or for the public, the scientist must always remember that communicating ideas demands the co-operation of the reader, if it is to be successful. In the process of transfer, the consumer of ideas is just as important as their producer, and the effectiveness of a document depends as much on the willingness of the reader to understand as on its own intrinsic clarity. It follows that ideas cannot be thrown out as though they were bullets that must meet their mark, when they are fired at a target, provided the aim is good. The process of communication has been compared more aptly with feeding a fastidious cat: only with skill and effort can the animal be persuaded to partake of the fare set before it.

The primary method of obtaining the reader's co-operation is to engage his attention by arousing his interest. If he can be persuaded that the matter before him contains material of importance to himself, he will take great pains to extract it, just as a detective is willing to spend hours deciphering the scribble on a charred scrap of paper, provided he is convinced of its value to his investigation. Once gained, the reader's attention must be held. Two factors are all-important in achieving this: pace and length.

The rate at which new ideas are introduced must not be too slow or the reader's attention will wander, nor must it be too fast or he may be unable or unwilling to follow the argument. Illustration and the use of simile and metaphor are means of varying the pace; and judicious repetition, combined with subtle variation, can also be invaluable in helping the reader to understand while giving him time to assimilate. I would not go quite so far as advising the writer to follow the dictum: 'say what you're going to say, say it, and then say what you have said', for he must guard against burdening his prose with 'vain repetitions', or he may appear to be over-fond

of the sound of his own phrases, like Browning's thrush that

> sings each song twice over,
> Lest you should think he never could recapture
> That first fine careless rapture!

Closely associated with pace is length. I have already pointed out that the amount of explanation needed must depend on the extent of the reader's background in the field covered. Naturally, any piece of writing should be as short as possible consistent with clarity and with covering all the ground. It will be more serviceable if it is like a ballet dancer's skirt, short but full: one that is long and voluminous is better adapted to conceal the subject than reveal it.

The process of assimilation, to which the reader must subject the new ideas presented to him, consists mainly in associating them with the framework of ideas already stored in his mind; the closer the association achieved, the greater will be his understanding of them and the more vividly will they be retained in his memory. To assist the reader's associative process, the writer must plan the logical framework—the skeleton—of his work with the utmost care. In the main argument of a technical paper, or in any piece of scientific writing for the general reader, this broad framework may vary so greatly that it is impossible to lay down a standard approach to the problem, except to stress that it is always desirable to proceed from the familiar to the unfamiliar—from the old to the new. This matter of organization is the main theme of that admirable book by Professor Nelson entitled *Writing the Technical Report*. The structure of a report should be planned not only to provide a balanced division into main sections and sub-sections, but also to have a suitable succession of paragraphs and sentences. Even the arrangement of the phrases and words within the sentences must be such that the whole forms a single logical unit. This is clearly a counsel of perfection, but it is always useful to have a target at which to aim.

Since the reader is not assisted by the variation in pace and emphasis with which the able speaker will naturally enliven his words, it is all the more important for the writer to marshal his ideas in the best possible sequence and to construct his sentences in such a way as to avoid all ambiguity. If a truly logical sequence can be achieved, the reader is led imperceptibly from idea to idea until the whole becomes plain and memorable to him, with the least conscious effort on his part. It would not be appropriate to attempt here to go into the detailed techniques that are useful in constructing the logical framework—such devices as comment words, logical bridges and theme sentences—as an adequate treatment would demand a whole series of lectures; so I must be content with the comment that, if carried out completely, the logical composition of any piece of writing calls for considerable ingenuity and effort.

A technical report must usually attempt to cater for two main classes of reader. There is the specialist in the same field and there is the busy man who wants to know the results and be persuaded of their accuracy, and who may also wish to seize the relevance of the work to other developments in the same field. Bearing these two in mind, a typical report will consist of the Title, a Summary and List of Contents, the Introduction and Main Argument, followed by the Conclusions, References, and Appendices. Many readers will study only the Title, Summary and Contents, the Introduction, and the Conclusions and Diagrams. To assist them, a special effort must be made with these parts, particularly in ensuring that the Summary, Introduction, and Conclusions are complementary rather than virtually identical, as all too often happens. The Introduction should be used to put the problem in perspective, and the Conclusions may point to further work. Care is always needed to decide what material should be included in the Main Argument, and what can be safely relegated to the Appendices: there is often a temptation here to allow the tail to wag the dog.

A typical argument in applied science runs somewhat along these lines. It starts with the basic equations, each expressing a physical relation or condition, or an assumption or approximation. These equations are then solved to express the unknowns in terms of known quantities, and a new formula is thus reached and interpreted physically. To develop such an argument one must start by stating briefly what is to be done, one must enumerate clearly all the assumptions and approximations that are used, one must show clearly the physical significance of each basic equation, and one must take particular care to explain any difficult steps in the analysis.

I have left till last a matter which, though of importance, is often given far too great prominence in discussions of scientific writing. I refer to its English style, a matter on which I can strongly recommend Sir Ernest Gower's book *Plain Words*. The object is to use those words that will best convey the ideas to the reader's mind. Such English has aptly been called Functional. Circumlocution is clearly not functional, it wastes the reader's time and dissipates his attention. To obtain brevity a sentence or paragraph may well need recasting. Jargon also must be shunned for the same reasons. To make writing vivid, the active is preferable to the passive and the concrete to the abstract.

Consider the following sentence, which perpetrates every practice that I have been warning you against, yet might well have appeared in a newspaper leading article.

'A comprehensive re-assessment of Collegiate financial policy is necessitated by the currently unsatisfactory economic situation and it is anticipated that during the forthcoming quinquennium there will inevitably be a consequent reduction both in recurrent and capital expenditures.' Some of you, through years of practice, may have understood this sentence; but I am sure that the idea it contains is expressed far more clearly and memorably, when it is rewritten like this: 'We fear events will force Colleges to spend less in the next five years, on both salaries and equipment.'

Of course, brevity can be overdone. Witness the celebrated headline in a New York newspaper: 'OYSTER BARS JAM PROBE.' Only an initiate could be expected to divine from this that the chief of police would not allow an investigation into traffic delays, but declined to give his reason. The English spoken by Russians often exhibits the same excessive terseness; this is because of the peculiarities of the Russian language, which omits some of the verbs and prepositions that are essential in English.

The growing practice of using strings of nouns as adjectives is ugly—and unnecessary, too, as the increase in brevity is negligible. Moreover, an addiction to this bad habit may antagonize sensitive readers. 'Oil storage tank depth measuring equipment', for example, is better written 'Equipment for measuring the depth in tanks for storing oil'. Note that the order of the words has been reversed, and that only now is it clear that the depth to be measured is that of the oil rather than of the tank.

It is during the process of revision that the writer must check that the structure of his work is really satisfactory and that only truly functional English is being used. Reading work aloud is a fine way of highlighting its faults, as they become magnified when spoken. If time permits, it is best to leave each draft for a few days after com-

pletion before undertaking revision, as a fresh eye will reveal faults that familiarity had concealed; it is even more valuable, when it is practicable, to enlist the help of an independent and critical reader, preferably drawn from the same category of person as that for whom the work is designed. While tediously revising, one realizes how true it is that only a genius could write successfully without taking great pains: but if writing is done carelessly, the reader must spend *his* time extracting the meaning, and it is arrogant of the writer to assume his own time is more valuable than his reader's. Anyway, the satisfaction to be had from a lucid piece of exposition amply repays the labour that must be expended upon it.

It is fitting to conclude my remarks this evening by indicating to you how I believe education can help us to ease the problems of scientific communication. There are two ways in which it can contribute to their solution: one is the direct approach, through courses of lectures and practical work devoted to teaching the expression of ideas in logical sequence and in functional English. The second approach is indirect and is concerned to bring the scientific writer and his readers intellectually closer together. Every reader of the future should have a rudimentary but accurate scientific background, while the scientific specialists must have their training and interests so widened as to reduce their difficulty in communicating with those outside their own specialism. I doubt whether a broad-based education helps, in itself, towards the lucid presentation of ideas: this is a separate problem. What it should achieve is to enlist the student's interest in topics outside his own field and so endow him with a greater ability to absorb others' explanations and to appreciate their ways of thought.

It is generally accepted that a high degree of specialization is contrary to the spirit of a University education, and I am glad to be able to say that, in striking contrast with some other scientific studies, Engineering in this country has had considerable success in avoiding the temptation to specialize too much. The reason for this is that most of our Universities still make no attempt to graduate fully qualified Engineers. The students leaving them can only become corporate members of the Chartered Institutions after at least two years of graduate apprenticeship in Industry. During this time they have the opportunity of acquiring special knowledge and skill in their chosen field of Engineering.

The applications of Engineering Science are so diverse that, even if it were desirable, it would be quite impracticable, in a relatively small University Department, to give vocational training in every one of them. This will be evident if I enumerate a few of the fields in which a mechanical engineer may find employment. They include Aeronautical, Automobile and Marine Engineering, Heating and Ventilating, Internal Combustion engine work—including Gas Turbines and Diesel Engines—Mining and Nuclear Engineering, Locomotive Engineering, Instrument Technology, and finally, Production Engineering. Perhaps I should not omit a field of endeavour now coming into prominence: Astronautical Engineering. It is clear that only great Institutes of Technology, such as are to be found in America and on the Continent, can possibly undertake to provide courses in all these fields. In this country, released from the necessity of providing specialist training, we are free to devote our attention in the Undergraduate Courses to studying those fundamentals of Engineering Science that are common to all, or anyway most, of the special technologies.

Lest you should think I am drawing an unduly rosy picture of the state of Engineering education in our

Universities, I cannot refrain from quoting some of Sir Ifor Evans's remarks in the lecture I mentioned at the beginning of my address. He said:

> In the past, among many of the dreary misunderstandings that have affected the history of engineering in our universities and in other places of higher learning, there has been too often a belief that the study of engineering is solely the study of technical expertness and of a professional practice. I doubt if this was ever true. It is certainly not true today. Engineering is a discipline as good as any other and better than some. Engineering, as it is studied in the universities, has taken over a substantial part of classical physics, makes heavy demands upon mathematics, and in its varied manifestations, employs these and other studies to its own purposes. . . . Such courses, based on fundamentals, constitute a full University discipline, and a very exacting one.

I hope you will be willing to accept the impartiality of this statement, coming as it does from a distinguished Welshman and one who is not even a scientist!

Let me now discuss briefly the lines along which University courses in Engineering are generally organized and refer, in particular, to our own new scheme of studies in Swansea, now in its second year. It is convenient, in practice, to divide Engineering Science into four main branches, each of which is served by one of the major Chartered Institutions. These are Civil, Mechanical, Electrical, and Chemical Engineering. Separate Honours courses are provided here in each of these branches. At the ancient Universities it is still possible to obtain an Honours Degree in Engineering without specializing even to this extent, whereas in many other British Universities the various courses are kept separate from each other throughout their duration.

Here we have a compromise, by which we hope to benefit from the advantages of both systems. In the first of the three years, a common course is pursued by Electrical, Civil, and Mechanical Engineers: Chemical

Engineers follow a number of the lectures but not all of them. At the end of the first year the student finally decides which branch of Engineering he wishes to study, and one choosing Mechanical Engineering will then devote his remaining two years to courses intended for his speciality.

But let it not be thought that this is narrowly interpreted, for we have borne in mind the half-jesting remark of Sir Charles Inglis, President of the Institution of Civil Engineers, and for many years Professor of Mechanical Sciences at Cambridge. He said that if a young man intends to become a Civil Engineer, then he should concentrate his studies at College upon Mechanical and Electrical Engineering, as these are the topics about which he will later learn less in the course of his normal experience. We do not go to quite that extreme here, as our third-year courses are to be devoted exclusively to subjects relevant to Mechanical Engineering, with an option of specializing either in Thermodynamics or in the Theory of Automatic Control.

In the second year of study, however, we are trying the experiment of requiring our Mechanical Engineers to attend, among their other courses, one on Electronic Circuits, a topic of prime importance to Mechanical Engineers, but one of which too many today are ignorant. Naturally, this work is done jointly with the Electrical Engineers: other courses in this year are taken jointly with the Civil Engineers, and yet others with the Chemical Engineers. You will agree, I hope, that the scheme I have outlined leads not only to a broadly based training, enlivened by contacts with the other branches of Engineering, but it also provides the maximum economy in the deployment of our inadequate numbers of lecturing staff.

By acting on the belief that only the basic principles ought to be included in our courses of Engineering

Science, the problem of the overcrowding of the syllabus is relieved for, except possibly in Electrical Engineering, the growth in the extent of the basic principles is relatively slow. It is in the special fields that the expansion is so spectacular and overwhelming. In addition to those features of our courses in Engineering that I have already mentioned, we are hoping to assist the student in broadening his outlook by including in the third year a course on General Engineering and Economics, that will be taken by all Engineering students.

This course will be to some extent a development of the existing one on Economics; the students enjoy this and we are certain it is valuable, because all engineering design is inevitably a compromise between scientific desirability and economic feasibility—between what you'd like to do and what you can afford—and a clear appreciation of this fact is basic to all successful engineering practice. We shall also require the students to do some background reading, setting them such books as *The Conservation of Natural Resources* published by the Institution of Civil Engineers, Norbert Wiener's *The Human Use of Human Beings*, and a few general technical texts such as Hayne Constant's *The Gas Turbine* or Shirley Smith's *The World's Bridges*.

In addition, we hope each year to organize a series of lectures covering broadly the various aspects of some wide technological topic, such as Power Production or Transportation. In this way we intend to help our students to appreciate more vividly how their own branch of engineering fits into the general picture. As these lectures are supposed to be couched in terms that can be generally understood, it seems to us that they might well be of value and interest to students of pure science, and possibly even to some non-scientists. We are therefore inviting the Heads of all other Departments to consider whether they would like to arrange for some of their students to attend this new annual series. I hope you will support any move like this that may tend to increase our understanding of each other's studies and should help to break down the division between the faculties in a University.

But it is not only between University faculties that barriers exist: there are those that too often separate the academic and the lay worlds. In his first Reith Lecture this year, Mr. Kennan listed the half-dozen most critical domestic problems now facing the United States; one of these he described as being 'the growing gap between specialized knowledge and popular understanding'. Unfortunately, his country has no monopoly of this problem, and the only hope of diminishing the gap in our own land is a sustained effort by each of us, directed towards mutual enlightenment. A necessary step towards this objective is to improve our techniques of communication. By emphasizing the existence of the difficulties involved, and by discussing their nature, I hope my remarks this evening may contribute in some measure towards attaining our common goal.

Particularly now that the public provides most of the money spent in Universities, I believe every one of us should regard it as an important part of his duties to inform the public of what passes within their walls, and to disseminate those concepts and discoveries that are nurtured there. Universities ought never to be Ivory Towers: they should attempt rather to serve as beacons, illuminating a patch in the limitless expanse of man's ignorance. Nor must we within allow ourselves to be dismayed by the thought that as the area of light increases, so also must its region of contact with the endless black beyond: thus, to learn more is only to extend the frontiers of the unknown.

But as, with each new discovery, the frontiers recede, the lines of communication between them become stretched and strained; and since the smooth operation of these lines is vital to our survival, keeping them intact is a challenge we cannot afford to ignore; but I am confident that, with a concerted effort, we can meet it successfully and our labours will serve, in addition, to enrich the lives of the whole community.

PRINTED IN
GREAT BRITAIN
AT THE
UNIVERSITY PRESS
OXFORD
BY
CHARLES BATEY
PRINTER
TO THE
UNIVERSITY