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The requirements for engineering education in South Africa*

by H.A.D. KIRSTEN

Written contribution by L.J. Besaans†

I am a Mechanical Engineering Technician (T3), and wish to further my education to at least NHD (T4) level.

I read your paper in the *Journal of The South African Institute of Mining and Metallurgy* with great interest, and must compliment you on its brilliance. However, there are some questions I should like to ask, and certain points I should like to highlight. I should appreciate your comments.

(1) You score a technologist (p. 126, Table I) as someone who has undergone a 4-year formal training period. This, to my knowledge, equates to a National Higher Diploma (T4), and not to a Masters Diploma (T5). Is this correct?

(2) At present, a candidate with a Masters Diploma (T5) can register as a Pr Tech Eng. What is the point in giving degrees at a technikon if the candidate can still register only as a Pr Tech Eng?

(3) To obtain a Masters Diploma at a technikon, one has to register a research project (which a lot of us cannot do) and one is then given certain subjects to do in parallel. Surely we, as engineers, obtain enough project experience from day to day, and would prefer to acquire what you call analytic- and synthetic-thinking skills instead?

(4) Where will the 'old-school' technologist and technician stand when the technikons introduce degree courses?

(5) No mention is made in the paper of Government Certified Engineers (GCE). Surely a person can write this examination with a college (N6), technikon (T4), or university qualification? Where do these people fit into your model?

(6) What is the real benefit of having an organization like The South African Council for Professional Engineers (SACPE), except that it has been forced on us by legislation? Surely we in South Africa have a free-enterprise system? I feel strongly that bodies like SACPE limit the availability of good people without qualifications and also frighten them away from the engineering industries. How many times have we seen people with, say, a T4 managing an ice-cream parlour?

(7) I feel that it is impossible to define the responsibilities and work profiles of the engineer, technologist, and technician. Once again, such a rigid classification will drive good people away from our industry. This should be prevented at all costs.

(8) My last comment, and I believe the most valid, is that a qualification does not mean that one can do the job at the end of the day. When I entered industry, I found that the Diploma I had obtained was worthless as far as working knowledge was concerned.

My comments may sound sceptical, but I believe very strongly that the universities and technikons should clean up their act, and not spoon feed their students for the sake of achieving a good pass rate.

I should also hate to see this worthwhile exercise not being implemented or, even worse, not having an effect on our economy and attitude towards the engineering profession and industry.

Author's reply to L.J. Besaans

Thank you for your contribution and complimentary remarks. As you have pointed out, there are certainly many aspects that will have to be addressed in the resolution of the crisis in engineering education. I trust that the following comments satisfactorily answer the queries you have raised.

The composition and relative weighting of mental skills and scientific techniques referred to in Table I in the paper are not proposed to equate to any of the present curricula pursued at universities and technikons. The information given in the Table is intended to indicate the relative make-up of the training programmes for the various engineering vocations with regard to basic skills and techniques.

For the proper execution of extensive engineering projects, it is generally necessary for the full spectrum of engineering vocations to be provided, each of which is unique in terms of the skills and techniques required. It is therefore necessary that each vocation should be separately but equally recognized. Separate recognition is already provided for in the Professional Engineer's Act. The awarding of degrees by the technikons is intended to introduce an equality of status that does not exist at present. Such equality of status should not be confused, as is often the case, with a similarity in educational curriculum. Engineers and Technologists should recognize that they are equal in status, albeit different in kind, and that each fulfils an important role in the range of engineering services.

The object at Master's level, both at universities and technikons, is not to add to the specific skills and techniques involved, but to enable the student to develop an ability to systematically solve complex problems through research and development. This is achieved mainly

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through the pursuit of research projects.

Special notice would have to be taken of existing qualifications in any new system that might be adopted. As indicated above, my object in the paper was not to specifically propose a new model, but merely to indicate that an educational system can be devised that would accommodate the requirements of the various engineering vocations.

SACPE is a statutory body in terms of the Professional Engineer's Act, 1968, and Amendments, 1972, 1979, 1983, and 1985. The Act was originally promulgated at the request, and was largely formulated with the direct assistance, of the engineering profession. Your suggestion that the Act, or the establishment of the body provided for in the Act (SACPE), has been foisted on the profession is therefore unfounded. The benefits of the Act are manifold, the most important being the registration and maintenance of a register of professionals; recommendations on professional fees; reservation of work of a professional engineering nature; protection of the public in their dealings with professional engineers, technologists, and technicians; maintenance of the integrity, enhancement of the status, and improvement of the standards of the relevant professional qualifications; and the encouragement of high standards of professional conduct. The loss of engineers, technologists, and technicians to the profession is certainly lamentable, but definitely cannot be laid at the door of any statutory body. It is simply a function of the forces at work in the economic environment.

In no other field of human endeavour is the required overall range of skills and techniques so wide, and is so much reliance placed on the team concept, as they are in engineering. Unless the various functions and responsibilities required in the engineering team are clearly identified, the work cannot be executed systematically, nor can the projects be managed properly with regard to time and budget. It is true that qualifications alone do not enable the work to be done, but it is one hundred per cent certain that, without qualifications, chaos will reign. I do believe that the tertiary educational institutions are performing very admirably under very trying circumstances.

Written contribution by J.F. Curtis†

The comprehensive and finely detailed survey of, and proposals for, engineering education in South Africa reflects the author's wide experience in the needs for, and the provision of, such education. This paper will make a major contribution to the enhancement of the profession of engineering and the improvement in quality of engineering activities in South Africa.

As a sometime academic colleague of the author, as well as a later professional adversary, I raise, not without some temerity, the consideration of three areas to which, in view of the great detail with which the subject has been treated overall, not enough attention has been given. They are:

(1) the determination of the entrance qualifications for the four named engineering vocational careers,
(2) validation of the student's educational attainments and/or inherent ability at the end of the course, and the determination of whether they meet the requirements of the qualification to be bestowed upon him, and
(3) the provision that, in the first three vocations named, 'management and organizational skills or techniques' should be 'acquired in practice'.

Determination of entrance qualifications

Under 'Education bias', the author notes, 'the career that may be required and suited to the individual, and for which there will be a demand, should be established at the start'; and, under 'Entrance standards', 'entrance standards are a basic instrument to ensuring the desired enrolment proportions between universities and technikons'.

It would be fair to say that, 'at the present time in South Africa', the factors that mainly determine the entrance of an aspirant engineering scholar into a university, a technikon, or neither, are:

(a) the material affluence of the student's parents or guardians, which enables him/her to attend a school where the facilities and teaching quality are of a standard that enables the student to obtain a higher matriculation qualification,
(b) the ability of the student to obtain a family, or other sponsor to meet the financial burden of his/her attendance at university, or the lesser one of his/her attendance at a technikon, and
(c) the absence of the need for the would-be student to take up immediate gainful employment.

Also, 'at the present time in South Africa', probably 75 per cent of all aspirants are disadvantageously affected by the absence of qualifications a, b, and c; therefore greater scope should be provided for entrants in the lower vocations, so that, as they demonstrate superior ability, they can move into the higher ones.

Napoleon's dictum that 'every soldier has a marshall's baton in his knapsack', may well be as apt in the 'new South Africa' as it was in Republican France. Any suggestion that an entrant to a lower function is indelibly wedded to it for his whole career must therefore be avoided.

Not only must mobility upwards not be prevented; it must be encouraged, and adequate provision should be made for it. The converse may, unavoidably, on occasion also apply.

Validation of the student's attainments at the end of the course

The author noted under 'General lapses in educational concepts and practice: Mental faculties' that 'Mental faculties, memory, and analytic- and synthetic-thinking skills are exploited in this order in the educational system. Teaching has, as a result, become answer-orientated, and education an exercise in spoon feeding and rote learning'.

The author has stressed the great need for 'analytic thinking' and 'synthetic thinking' in the higher vocations. The problem is: 'How is it to be taught?' and 'How is ability in these mental skills and scientific techniques to be measured at the end of the course?'

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It should be remembered that the great thinker Albert Einstein was an academic drop-out who, initially, because of the lack of a qualification, took up employment as a clerk in a Patents Office. Who was at fault: Einstein or the system?

It should also be remembered that the display of such skills in advance of that of the teacher, or of 'conventional wisdom', may not only be discouraged and discredited, but actually persecuted. In this connection, Galileo, Whittle, the Wright brothers, Semmelweiss, Nader, and others come easily to mind. The contributor himself has subjective experience of this tendency. This is a field that needs further attention.

Management and organizational skills

Because of the acknowledged shortage of graduate engineers and certified technologists in South Africa, persons so qualified are likely to receive promotion into executive positions in industry at a more rapid rate than they would in a country in which the supply and demand for their services is better balanced.

Management is a profession in itself and, even in the most abstruse fields of research, some grounding in its fundamentals is necessary. Engineers have to operate in a real world in which Murphy's law applies: 'If something can go wrong, it will go wrong'.

A potentially economically successful engineering venture that becomes a financial and operational disaster rarely does so as a result of errors in the 'activities of feasibility evaluation; design; specification and planning'. 'Resourcing and procurement of equipment, material, and labour', without which physical execution cannot even commence, are usually the factors leading to the failure of the plan. The first-mentioned activities are usually independent of time, or are given a generous time schedule for their completion. In the second, 'time is always of the essence'.

Time is money, and the timely and uninterrupted provision, and continuous smooth operation, of machines, materials, and men is the art and science of management. To send a graduate engineer or a certified technologist out into the real world without a grounding in this necessary adjunct to his engineering education, and expect him to pick it up by the wayside, is like 'sending a babe into the woods'.

During the last two decades in South Africa, the record of overruns in the estimated time of completion and over-expenditure on budget in major civil, mining, metallurgical, and building contracts has cost billions of wasted rands. Much of it has been cloaked under the all-covering garment of government administration. However, a sizeable proportion has come out of the pockets of private investors, as the stock-market discloses from time to time.

It would be perfidious and unprofessional of anyone to quote any such incidents—unless one were specifically retained to do so—but members of the Institute should have no difficulty in recalling a number of such incidents where not the concept, but the execution, was at fault; not the engineering, but the management; but where, alas, the chief executive was a Professional Engineer.

Author's reply to J.F. Curtis

Your comments and recommendations are appreciated, both as a personal compliment and as a complementary contribution to the paper. You raise some thought-provoking queries, to which I trust the following is a fitting response.

I share the sentiment that no one should be inextricably fettered to an undesirable situation, at least not as a result of circumstances beyond his or her control. My suggestion to avoid this problem is rather to provide the entrant—for whatever course he has the basic aptitude, however veiled it may be—with sufficient bridging education, including any financial assistance that may be required, to enable him to receive the education for his chosen career without delay.

A fundamental objective of the paper is the establishment of equality of status of the various engineering vocations, and escape from the present perceptions of subservience or inferiority of the technologist's and technician's roles compared to the engineer's. A provision for 'upward' mobility would defeat this objective. To provide for upward mobility is, with respect, a soft option to the solution of the problem. The hard option, involving provision of the proper training required by the aspirant student so that he can enter the career of his choice, will be more satisfactory and stimulating for the individual, and more cost-effective to the national economy, in the long run.

The various vocations referred to in the paper are not ranked vertically or laterally. Reference to 'higher' vocations is therefore, with respect, out of context. The basic tenet of the paper is the identification of the range of engineering vocations and the compositions of constituent skills required in each. Differences in the extent to which the constituent skills are required in the various vocations are therefore characteristic of the various occupations.

The acquisition or development of analytic or synthetic skills is a complex process. As with anything else, the acquisition of such skills starts with the basic mental abilities. It then proceeds with appropriately designed exercises requiring, in progressively increasing complexity, the application of analytic and synthetic processes. Most secondary and tertiary education in the basic sciences provide for such development of the analytic skills. Courses in design, in whatever field of endeavour, usually provide for the development of synthetic skills. The encouragement of young children in inquisitive and challenging mental pursuit also stimulates synthetic ability. Single negative- or affirmative-answer type examinations of knowledge and understanding are anathema to the development of synthetic-thinking skills. These are some simple examples of what clearly is a complex aspect of educational science.

The regularity with which the Engineer's design is challenged in our courts of law provides confirmation that lapses in management may not be the only or main causes of project overruns. Better formal training in management skills may solve the problem. However, it is difficult to know where to draw the line. Most professional engineers also require, particularly in the latter part of their careers, a better-than-passing knowledge of common and specific law, accounting, and economics.

Should courses in all these fields be included in the undergraduate curriculum? I think not; it is not feasible, and would make it even more difficult for the disadvantaged candidate. The real problem in this regard is the shortage of engineers and technologists. Once that problem is solved, the promotional path of the individual will be extended over a longer period of time, similar to the situation in Europe, and he will have the time available to acquire additional knowledge and skills on the floor.

Contribution by G.W. Annandale†

I have studied your paper in some detail, and am of the opinion that it makes an important contribution to the topic of the development of technological manpower, which is currently being debated in South Africa at all levels. Debate on this topic has risen above the level of academic discussion; it has been discussed by the Economic Advisory Council of the President, and is being considered at Ministerial level.

Your concise discussion clarifies various issues about the roles of engineers, technologists, and technicians, and makes an important contribution towards the development and utilization of a productive manpower base.

Although European nations have, in my experience, a better understanding of the roles of the different members of the engineering team, I believe that individuals in South Africa, the United States of America, and the United Kingdom do not generally share the same knowledge. This is possibly one of the reasons for the better economic performance of the European nations, particularly the West Germans.

This paper will play an important role in the formulation of policy as regards the development of technological manpower in the new South Africa.

Author's reply to G.W. Annandale

Your comments are much appreciated, as is your assistance in the preparation of the paper.

Author's General Comments

Since publication of the paper, attention has become focused on the provision of employment opportunities—an aspect not dealt with specifically in the paper. The following comments serve to indicate some of the directions in which job opportunities will have to be developed in the numbers that will be required.

The economy has developed in response to external influences instead of to a strategy based on internal objectives. It is still dependent on mining and the exportation of raw materials, for which purpose a readily available uneducated black workforce has been exploited. The country is richly endowed with mineral and human resources, but has neglected to develop the latter[1]. Unless this inappropriate allocation of resources is redressed, the concomitant socio-economic and socio-political forces will disrupt the economy and quality of life.

The remedial process will require that whites and blacks alike are given career-orientated education, and are provided with lasting employment in such careers in this regard. A very large numbers of jobs will be required at a greatly increasing annual rate. Employment opportunities will need to be stimulated on a national scale. This can be achieved, for example, by the establishment of a jewellery manufacturing industry, the extensive production and application of stainless steel, the production of refined base-metal products for industrial use, and the production of chromium chemicals. The potential impact of such initiatives can be gauged in terms of the value of imports that can be replaced with locally manufactured goods. Thirty-one billion rands' worth of goods are currently being imported annually, of which it is estimated that 20 per cent, or twenty billion rands' worth of goods can be manufactured locally. A considerable number of people with an extensive range of high-level technological skills will be required for the production of such a volume of goods. Further employment opportunities will arise from the concomitant construction and tooling of factories and the provision of infrastructural systems.

The production of jewellery by Taiwan, South Korea, Hong Kong, Singapore, Thailand, and Japan rose from 64 to 441 tons per annum in the period 1984 to 1988, of which gold's market share rose from 12 to 30 per cent[2]. In the same period, South Africa's production of gold jewellery increased from one to two tons per annum, that is, 0,1 per cent of world production. An increase to 10 per cent, which is achievable, would, at a modest added value of 25 per cent, earn an additional one-and-a-half billion rands per annum.

South Africa, as the world's largest producer of ferrochromium, produces only one per cent of the world demand for stainless steel. An increase to 10 per cent is feasible, and would yield an additional income equal to 50 per cent of foreign earnings on gold. New uses for platinum-group metals could generate additional earnings of two billion rands for every million ounces of platinum produced. New and expanded developments in applications involving the use of titanium, vanadium, and manganese could boost the country's income by a further one billion rands[2].

Australia and Canada are mineral-rich countries. In the fifteen-year period preceding 1985, the economies of those countries grew by 34 per cent, compared to 2 per cent for South Africa[2]. Taiwan does not produce raw materials to a significant extent, yet its foreign-exchange earnings rose twenty-seven times from $1,3 billion to $35,4 billion in the face of harsh international competition in the fifteen-year period referred to. In comparison, South Africa's foreign-exchange earnings rose only fivefold. Taiwan boasts a proliferation of small industries from which international giants have emerged. It has achieved remarkable industrial growth, and has created impressive new employment opportunities by importing raw materials and by turning them into sophisticated finished products of greatly enhanced value. In contrast to South Africa's huge debt, it has a considerable currency surplus.

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Edwards[2,3], Ford[4], and Gafner[5], have made extensive recommendations as to the actions that can be taken to induce the establishment of a thriving jewellery manufacturing industry. These generally amount to the removal of outdated restrictive legislation, the introduction of attractive incentives, and the judicious protection of local industry during the initial period of establishment.

Free enterprise in partnership with government should be encouraged. Government should adopt the attitude of a concerned and not a regulatory partner, and would, in such a role, provide an immeasurable stimulus—as it does in the Far Eastern countries referred to above. South African manufacturers should adopt a production-orientated, as opposed to the classically advocated consumer-orientated, approach. The country as a whole should also develop an outward-looking culture compared to the inward attitude that has been the result of the policies pursued in the past. These principles underlie the astronomic performances referred to above.

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