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Obtaining Results from Research and Development—Some Requisites

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Lest there be any misunderstanding, at the outset I would like to state that the remarks that what follows applies in my opinion, to the peculiar conditions existing in Pakistan. Are they not peculiar when we consider that, without additional training or education our professionally qualified when they go abroad are ever so much more productive than when at home. It appears they fit into the tactical level very well, albeit in accord with someone else strategy. This implies that even though the competence is there we have not found ways and means to convert this potential into something kinetic or something useful. This general statement indeed applied to the Research and Development efforts in the country also.

Organized research has progressed over the years in the last century in what is called the developed world, the various stages as follows:

1 Pure/Fundamental/Basic
2 Applied
3 Developmental

Basic research is concerned with original investigation and is primarily for advancement of knowledge. Applied research is similar to basic, but it is directed towards a practical purpose because of a current need. It is through technological transfer to produce, economically, prototypes or processes through an innovative approach that is characteristic of the developmental role. The basis lies in the spirit of enquiry which in turn is based on the

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empirical method which is a reality that we must recognize to ensure progress.

At the outset it may be mentioned that the longer than normally experienced time horizons in any R&D effort need careful consideration otherwise incorrect conclusions may be obtained because of the difficulty in establishing a relationship between resources expended and benefits obtained in a restricted fashion or in a short time. Certainly, the Japanese could not have quantified in advance that insisting on much more mathematics, amongst others, in their school education would help produce shop floor workers who are superior than their counterparts in the UK or USA. Japanese operatives i.e. ground floor workers are able to "stand up and give technical representations of their work and in the extent to which they were able to cope with high levels of automation and other sophisticated production methods". But how much less productive they would have been otherwise, no wiseacres could have predicted.

We move from the special to the general in a better understanding or in improving our methods where the physical transactions take place i.e. at the cutting edge of work. As a result of a lot of observations we build up hypotheses, theories or even laws. However, in the field of education we move from the general to the particular. The particular amounts to proving that the laws put forward by the teacher are correct, through examples. If divergencies are found, which a law cannot explain then we go through the loop again (if necessary again and again) to frame more general statements which can explain observed phenomena more satisfactorily.

In the process of such happenings considering the several sectors of knowledge which are being "looked into"

by thousands, in several countries we find that "pure" disciplines in themselves nowadays cannot explain many things. To study — as an example — the effect of industrial wastes on the environment, biology by itself insufficient. Most surely there has to be plenty of multi-disciplinary effort, hence biophysical ecology. The mechanisms to ensure that this approach multi-disciplinary is effectively used have to be worked out very carefully.

But this is but the beginning. We find that lateral movement is frequently required between the various main sectors of knowledge. Observe the utilization of electronics in medicine, for say steadying the heartbeats through a pacemaker, neurobiology cannot be far away.

A necessity for basic research is open communications, such an activity would usually be in the academic setting. Research of this type arises out of a desire to satisfy curiousity unlike applied or developmental research. The latter is technologically oriented and not science oriented. By this orientation I mean that there is an end product or result very much in mind. Further, the industrial setting does not always relish being openly communicative about what may be termed as trade secrets. However, it must be recognized that technological development is a very complex process and that it usually progresses through incremental improvements, if only on account of the high cost of failure.

Merely being ahead in scientific research does not mean that it follows that one would be ahead in its development or technology. Look at Great Britain and the USA. Again look at the USA and Japan, the latter are ahead in technology but behind in research.

One of the difficulties that we face is that neither the scientists or technologists are in a position

to express themselves in a fashion that the layman can understand. Techniques of presentation need to be radically improved. Problems that may also arise from the lack of simple clear expression include the difficulties that arise out of mixing up of the discussion of knowledge/science with the interpretation and possible actions arising out of the same. The inherent uncertainty of knowledge coupled with the injection of value judgements over a large canvas is bound to create situations "clear as mud". There is where compartmentalization is justified.

We must, therefore, have some comprehension as to how knowledge grows, how it is imparted, the problems of development and the obtaining of results coupled, of course, to the vitally important consideration of time. After all an essential feature of progress in our times is the harnessing of technology for improving the quality of life of the people. Because changes are taking place at a highly accelerating rate and with increasing sophistication, in many cases prior experience or tradition can be totally irrelevant or even dangerously misleading. This means that in order to arrive at conclusions that are consistent with:

1 The way we think and act organizationally including the way decisions are made so as to ensure work flows to obtain results and that
2 the type organizational set up required to be in conformity with the natural realities that have to be dealt with.

This means we must arrive at the requirements to satisfy the above criteria for which it is necessary to appreciate:

- the evolution and structure of scientific knowledge;
- the role of a central research organization;

- the relationship of research to the professions and industry

and only their can we arrive at a definition of a strategy i.e. policy. This approach may appear to be over-complicated. But has over-simplification ever provided an answer to complex problems? The baby is thrown out with the bath water, no problems therefore exist! If it were so easy as some make it out to be why is it that we find it so difficult to obtain out of our "well thought out plans" results that do provide satisfaction? Can it not be said that we are usually confronted by a series of crises of implementation? And it has to be admitted that there are so many failures that it can hardly be said they are exceptions in a general pattern of success!

Scientific knowledge has evolved over the years through the accumulation of individual observations made to solve immediate problems e.g. navigation at sea or in the desert lead to the beginning of astronomy, the requirements of dwellings/stores/places of worship lead to mechanics, the necessity for a proper definition of land holdings helped generate geometry. The movement in all cases was from the particular (problem) to generating general statements (theories or laws). Having arrived at a theory or law it was then possible to apply it to a wide variety of undefined situations and not reinvent the proverbial wheel again and again. How to systematize prior experience is, therefore, a necessity for progress. Systematization amounts to:

- Classification of observed phenomena (facts).
- The establishments of their mutual relationships leading to
- Increasingly general statements i.e. better theories or laws.

Masood Hasan

There are four agencies that can advance scientific knowledge:

- The professions and industries;
- The universities;
- Scientific/learned societies and
- Central Research Organizations.

There are several sectors in which knowledge, over the years, has conveniently broken itself into: including amongst others energy, transport, structures, communications, materials, earth sciences, agriculture, sociological and medical. Hence the approach to R&D should reflect this reality. In a way this amounts submission to evolved natural experience. Any policy and organization built on this conceptual foundation will indeed have the best chance of being effective.

The development of knowledge successively at each stage provides questions to be answered by the next and in the process one goes deeper and deeper into the more specialized aspects of what one is investigating. For example, in the manufacture of sugar, attempts are made to reduce the time between cutting cane in the field and processing it in the factory, because delays cause enzymatic action which converts crystallizable sugars into the non-crystallizable type. It may be added that only the crystallizable type can be recovered as a solid. Plenty of highly specialized work has been done to understand the biochemical microbiological changes that take place. After various types of processing such as extraction, clarification and bleaching the sugary syrup is concentrated and then seeded to encourage crystal growth. When studies are made to understand the crystallization process through an examination of the physico-chemical process we find that we move over, in this case, to a less specialized area of

knowledge because crystallization processes are common to several other operations (laterally) and a lot can be learnt from other branches of knowledge concerned with crystallization.

We must be careful to ensure that in our effort to specialize in a particular area, that we do not lose sight as to how the particular area fits into the larger picture. The view must not be obscured. Otherwise after obtaining the highest efficiencies in obtaining the maximum amount of crystallizable sugars in the extracted juice, to find that we lose out on account of an inefficient crystallization process. This happens many a time when the more generalized form of expertize required for investigations is forced to adopt the same means as in the case of the more specialized. The administrative structure must permit the right things to be done. After all administration does express itself through the types of organizations it devises. A proper structure can permit movement in the right direction. Just as law and order does not in itself generate development but is an essential backdrop. Hence there is a basic requirement for having a sympathetic structure which is an essential hygeine factor to provide the threshold to productive achievement.

In the more specialized case the more dependent we are on the natural environment both for the problems as well as data acquisition so as to build up a systematic body of knowledge. In the more generalized case we become more self-oriented and depend much more on manipulating data generated within the system for development.

The flow of work moves in this case mentioned above from immediate clinical on to the microbiological and thence on to chemical engineering in a kind of smooth continuum. Such continua will be found to exist in all the major sectors of knowledge development. We should recognize this reality.

The proof of the success or otherwise of any approach or plan lies in results achieved. Look at the early Muslims who were the forerunners of the scientific method i.e. of making observations and THEN arriving at conclusions -- but that was as long as ten centures ago. Did they obtain results? Observations of phenomena were made and patterns were established leading to hypotheses, theories and even laws. Progress followed in ophthalmology; in understanding reflection and refraction; in introducing the pendulum to determine time; in setting up hospitals; in determining the effect of the mind on the health of the body; in originating chemistry; in deveoping the laws of falling bodies in mechanics; in producing tables of specific gravities; in giving trigonometry its modern form; in ship-building; in developing commercial methods; in introducing the Indian system of arithmetic; in astronomy developing catalogues and ascertaining the earth's size, the length of the year, and publishing correct tables of the sun and moon along with verification of the accuracy of the equinoxes; in developing algebra (hisab al jabr wal muqabla) from the germ left by Diophantus, the word algorithm derives from one of famous mathematicians of Khwarizm. It would appear somewhere down the line the empirical method has been given an unceremonious burial. Hence when we talk of organized research it would better to now learn from the more recent past i.e. from the developed world of their approach.

In the seventeenth century a start was made to set up scientific societies e.g. in the UK the Royal Society was founded in 1663. As scientific knowledge progressed more societies came up and they advanced theoretical understanding of chemistry, of physics, of biology, both at the increasingly specialized level, as well as at the more general level which cuts laterally

across the various sectors of knowledge. This creates problems similar to coordinative problems between different departments of an organization, with one comment, that in the development of scientific knowledge the language can get most involved. This means if those involved cannot express themselves properly they must be trained to do so. This deficiency can be made good. Systems on the civil side of the governmental process are quite innocent of the requirement of the type of training to make such personal deficiencies. Elementary personnel administration admonishes us accordingly.

By the middle of the nineteenth century with the accelerating rate of scientific development the Universities came into the picture. Increasing compartmentalization of knowledge continued (in fact continues to this day). Just imagine we can be loaded with more than two dozen types of psychology or two dozen types of economics. The University's function is to find the underlying unity in this diversity. This had led to the creation of multidisciplines-- consider biopetrochemical engineering in which a number of disciplines attempt to understand better the processes of synthesizing proteins from petroleum fractions. Or cancer research involving epidemiology, experimental pathology, biochemistry, chemistry, radiobiology, virology, genetics and molecular biology.

Universities in UK are supported in two ways. The first is from their general funds and the second from outside bodies such as the University Grants Committee (who make block allocations without going into details that detract from independent action) and to a small extent by industry, to develop intellectual initiative. True this is becoming difficult in view of increasing

costs and increasing difficulty for anyone to keep up with progress in their field. But it is also true that the wider ones awareness of the extent of knowledge relevant to ones requirements, the more effective the research effort. Hence the necessity of a well stocked, particularly journal-wise, library. As also the opportunity to meet with ones peers frequently within the country and less frequently abroad.

In Pakistan, the necessity of bringing the Universities into the mainstream of activities concerning development of scientific knowledge requires more thought. What methods can help? What new organizational expedients are required to be experimented with? This needs discussion.

The three agencies involved are the Government, Industry (Public and Private) and the University. Some understanding of the proportioning of resources in basic and applied research and in development would be necessary. And when we talk of development, it will become ever so much more meaningful to talk of a development and acquisition policy. Otherwise with no commitment to acquire the results of developmental work, unproductive compartmentalization of effort will be intensified which is a bad thing. Hence it may make more sense to talk of a research, development and acquisition policy wherever possible. Projecting well ahead it will be necessary to understand the coming implications of the quality and quantity of the output of the educational policy's planning and more importantly its execution. Let us not forget that science is the main factor in national superiority. An educational system that cannot convey a general understanding of science condemns us to continuing ignorance of forces that are changing our future.

In the UK with the development of scientific knowledge over the years, in 1918 a committee was set up to report on the machinery of government. This committee concluded, in relation to research, that there were two types:

- research supervised by administrative departments;
- research for general use.

The former dealt with problems directly affecting the business of the departments - operational research. The latter the responsibility of organizations such as the Medical Research Committee and the then constituted Department of Scientific and Industrial Research (DSIR), which were concerned with advancement of knowledge.

Obviously the former would be concerned with the short term and the latter the long term aspects. The short term would be concerned with the immediate practical. Because science does not recognize as international boundary, leave alone a 'departmental barrier' it is the more general research organization (not responsible for implementation) that would further knowledge without having to look up to an administrative department for orders/guidance. This would indicate the requirements of a separate Ministry independent of departmental pressures. It is of historical interest to note that the British Medical Research Committee which was to have put under the new Ministry of Health (1919), was not. As a result Parliament and the UK were not deprived of a permanent source of informed opinion on a number of unexpected matters that cropped up, such as atomic fall out, safety of new vaccines, rationing in World War-II and the risks in smoking tobacco. This opinion was as unbiased as could be expected of any man-made system. Over fifty year later the "Committee of Enquiry into the

Organization of Civil Science" endorsed this separation which resulted in the setting up of autonomous Research Councils. In 1962 Sir Burke Trend in considering the organization of civil science supported from public funds took into consideration the fact that while certain departments had their own research establishments (for the more specialized work) that the DSIR had no Ministry hence the specialized work had to be set up by industry and DSIR encouraged it in the form of funding etc. The scope was obviously too broad an DSIR in course of time got over-loaded. The Trend Committee's recommendations was to dissolve the DSIR and to

- firstly, set up an authority to assume responsibility for research arising out of the specialist industrial experiences and
- secondly, a Science Research Council to be formed to promote unspecialized research in the Universities.

However, one authority, over the years would suffer the same fate if only on account of too broad a remit. This points to a break-up of R&D on a sectoral knowledge basis. The above is of interest to us in Pakistan because our sciendtific establishments have mirrored those in the early days of the UK.

Professions and Industry

At the provincial level a beginning will have to be made and ways and means found to encourage and motivate industry to go in for R&D. But we must recognize the following:

1- Why should industry to motivated to go in for R&D - no matter how well it is academically articulated - if the economic advantages do not promise to outweigh the costs of R&D?

2- For R&D to be really beneficial requires dissemination of the results so as to assist in an acquisition policy. What is to be done in a competitive milieu?

While it is true some exchange of views/information does take place in the Seminars/Meetings organized by Organizations such as the Institute of Engineers Pakistan (IE,P) or the Pakistan Institute of Chemical Engineers (PIChE) and several others including the platform I am speaking from. All these professional bodies (organized on a national basis) require financial support to produce something really worthwhile. Too much time is spent in working out the mundane mechanics of organizational day-to-day living to be really productive.

Since there is a continuum between research commencing with the

- pure/fundamental/basic and then
- applied thence
- developmental

leading on to full scale production, it is necessary to find ways and means to reduce the resistance between the interfaces. The pure scientist, the industrialist, the engineer. the bureaucrat are ALL cirizens of this country and there is no reason why a practicable line of action cannot be formulated based on an appreciation of reality.

The demands of technology centre around the government and industry and it is of interest to note that it has been estimated that in the early 70s governments spending in R&D in the national effort in

- USA/UK/France/Sweden was more than 50%
- West Germany/Holland/Japan was 33-40%
- Greece/Spain was greater than 75%.

It is vitally important not to forget that R&D requires not only scientists and technicians but managers apart from demand capital (from government and industry) to stimulate and support it. The national policy laid down by our President, when Dr. A. Salam return to Pakistan after becoming a Nobel Laureate, inter alia stated:

1- Scientific, technological and engineering knowledge both basic and applied - will be strengthened, acquisitioned and used for Pakistan's development at all levels. The resources of manpower and funding will accord with international norms. Pakistan's scientific and technological communities will not feel isolated from their international counterparts.

2- The decision-making process for development will have input from the local scientific and technological communities, at all levels and stages of discussion, advance and implementation.

3- Research and Development effort will be located with universities, industry or government laboratories, wherever it can make the maximum impact on the country's development.

4- Science and technology policy will endeavour to make the nation as a whole conscious of scientific and technological advances pertaining to the country's development.

From the above it is possible to work backwards and construct the policy, from which the four principles can be derived, as being "To deliberately promote the growth and utilization of science and technology as a means towards achieving, through self-reliance, the socio-economic well-being and security of the country". The President also laid down,

prioritywise the following areas that need to be attacked in this decade:

1- Agriculture (including water and allied resources);
2- Energy and Mineral Exploitation;
3- Science-based industry;
4- Population policies.

Generally, it is accepted that our difficulties have been in the implementation of policies rather than in their enunciation. In any case, we must give full credit to the President for his fortnight utterance as indicated above. The problem is how can the expressed intentions be converted into practical reality is how can results be obtained?

All creative workers, the world over, are distrustful of authority. Yet some form of control is necessary because the tax payers money is what is being used. However, freedom for scientific enquiry means it is necessary to put in simple language the requirements of science. That the scientific method must be used to do so, is to tell the scientists/engineers; physician heal thyself! But it can be done, provided the proper type of training is imparted at proper times during the professional advancement of individuals.

Further, in order to encourage creativity at the cutting edge i.e. the highly specialized end — the maximum amount of decentralization is required. Policy is expressed not through a definition of technical details but through the overall selection of investments in the varvious sectors of knowledge. There should be reasonable grounds for the attainment of results but the feasibility decision is an entirely scientific matter.

Two kinds of committees will be required the first

- to reconcile conflicting interests, hence representation of interested parties is required and
- secondly, an expert body to promote knowledge, the criterion of membership being PERSONAL MERIT.

While a member of the second committee can be a member of the first, but a member of the first would hardly know anything about the promotion of knowledge in a specialized field. What the implications of developing scientific knowledge are, the assessment of the feasibility of meeting a particular requirement through science or an objective appraisal of adopting a particular course of action involving scientific consideration is only for those who have been scientifically trained to go into such professional matters.

Those who seek to integrate scientific knowledge into social activity must not only be at home in the language of science but also at home in a comprehension of the administrative process. Administrative arrangements for collaboration between adjoining sectors of knowledge and the common problems of technical management need a cross-walks approach and can be done by having the proper representation on a relevant committee. The correct prescription for bringing together the researcher's search for more knowledge and the developer's desire to transfer theory into practice is the key to the successful harnessing of technology. In the USA in 1965 an investigation was made by the Department of Defence to determine what clicked (or didn't) in the 1945-63 era to bring in cost effectiveness in a range of 20 systems examined by 13 teams with mixed government, industry and nonprofit corporation scientists. They concluded that advancing

technology was much more in the area of minor improvements than in major scientific discoveries. This study concentrated on invention itself. Another study indicated that invention arose out of developing knowledge that had been generated 30 years or more ago including magnetic ferrites, the video tape, oral contraceptive pill, and the electron microscope. This certainly gives hope to an undeveloped country such as ours that properly organized R&D can help in achieving our national objectives.

Any approach to be successful to produce the proper climate combining the immediate results and medium/long term point of view will also require consideration of the sensitive human relationships also be included. Ultimately the limiting factor is human. Hence whatever can be done to improve the effectiveness of existing establishments should take priority, though it may mean making some changes. And any change, even for the better never has unanimous acceptance.

Since our economic development or increasing self-reliance depends on harnessing nature, which comes out of first discovering the natural laws which means a well directed multi-disciplinary effort is in order. As Lord Rutherford is reported to have said "We haven't the money, so we've got to think" so must we. Finally it is the management of any activity that determines its continued success. This depends on the administrative structure, the operating systems and procedures as well as the personnel involved. Finally it is results that matter. Looking at agriculture, about 70% of our population are involved in this activity yet we are heavily deficient in edible oils. Considering 12% of the population in Eire, 7% in New Zealand, 6% in France, 4% in Australia, 3% in Canada and 2% in USA generating surpluses for export. The necessity for

developing the infra-structure for R&D, then utilizing imported know-how leading on to effective R&D i.e. the output of R&D being converted into economic productive output will then provide the basis for indigenous design. The role of military procurement, particularly as a bridging mechanism, to support the short term negative cash flows of development projects must also be appreciated so as to permit activities that could otherwise not take off the ground. Civilian markets can be developed as one progresses.

Some mechanism must be found so as to tap the availability of knowledge from several institutions abroad say through directly accessing their computer files through telephone lines which must be "glitch free". This is one way towards free communications. Can our communication system dedicate a line or two to this activity? After all it was only 13 centuries ago that Muslims translated Greek, Indian and knowledge in other languages into Arabic in pursuance of popularizing the inductive method. Far easier now through communication via the satellite. One does not have "to go to China", China literally is in your room! Can our administrative methods, in keeping with modern day developments encourage this?

Modern day technology particularly software development can also be successfully implemented out here. Like all new activities it requires encouragement. However, our taxation laws do little to encourage this activity, as it appears so easy to equate an intangible i.e. knowledge with a tangible such as a brick, leading to similar methods of procurement! Yet it is agreed that knowledge is more important, yes without a doubt! It remains to be seen whether the recently announced Science and Technology policy achieves what it says it will. It is hoped that the essential difference between science

and technology is correctly understood in the application of the policy. Only time will tell and it appears we have a penchant of running out of time, not ideas.