ON THE ROAD TO WORLDWIDE SCIENCE

This page is intentionally left blank

ON THE ROAD TO WORLDWIDE SCIENCE

CONTRIBUTIONS TO SCIENCE DEVELOPMENT

MICHAEL J. MORAVCSIK

World Scientific

Singapore • New Jersey • Hong Kong

Published by

World Scientific Publishing Co. Pte. Ltd.
P O Box 128, Farrer Road, Singapore 9128

USA office: World Scientific Publishing Co., Inc.
687 Hartwell Street, Teaneck, NJ 07666, USA

UK office: World Scientific Publishing Co. Pte. Ltd.
73 Lynton Mead, Totteridge, London N20 8DH, England

**ON THE ROAD TO WORLDWIDE SCIENCE —
CONTRIBUTIONS TO SCIENCE DEVELOPMENTS**

Copyright © 1988 by World Scientific Publishing Co. Pte. Ltd.

All rights reserved. This book, or parts thereof, may not be reproduced in any form or by any means, electronic or mechanical, including photocopying, recording or any information storage and retrieval system now known or to be invented, without written permission from the Publisher.

ISBN 9971-50-617-3
9971-50-620-3 (pbk)

Printed in Singapore by General Printing Services Pte. Ltd.

PREFACE

The vagaries of history have cleft the world in twain. With many shades and nuances, there are developed countries (DCs), where the goods of this earth are distributed in reasonably generous and equal amounts, and the underdeveloped, or, to use an euphemism, less developed countries (LDCs), who suffer from many lacks, are heavily dependent and economically wanting. The fact that DCs possess a strong scientific and technological infrastructure and employ science and technology for their progress, and LDCs do not, or do so to a feeble extent, is certainly no random coincidence, since science, aided and abetted by social, economic and political forces, has been the most powerful instrument in catalyzing the process of development. The latter, incidentally, should include not only economic, but also social and cultural elements.

It is no wonder, then, that LDCs have wanted for some decades to “jump on the bandwagon” and to harness their progress onto science and, of course, technology. The results have not been terribly encouraging, and it is therefore opportune to analyze what are the elements in the subtle alchemy of the growth of science and technology which are lacking in some countries and abound in others. A corollary of such diagnosis is to establish a treatment for the disease. Michael Moravcsik undertakes this analysis and outlines therapy in the thirty-odd essays published here on the subject covering a twenty-five year span.

Mike Moravcsik's tall frame and his *simpático* demeanor have been frequently seen in developing countries, where he has acquired first-hand knowledge on science there. His understanding of, and in some mysterious way (he is a DC theoretical physicist) his affinity with, the problems of science and development have made him specially apt for the job. His articles, published at various times and in many journals, are at times repetitive, understandably, but there are many conducting threads which I shall try to uncover, adding my own comments, resulting from first-hand experience in a developing country, Venezuela, and from many contacts abroad.

At this point, some remarks may be made about the differences between basic science, applied science and technological research. Admittedly, they constitute nowadays a continuum of processes, with many grey areas between them, but the distinction is still useful as a basis for policy decisions. The fundamental difference lies in the *motivation* of the doers — to know nature disinterestedly *or* to act in a direct or indirect way upon it. Also in the *products* of each kind of research. Another difference, which I did not find mentioned by Moravcsik, is the *audience* at whom the research is aimed. This is constituted by scientific *peers* for basic science, with a paper as the chief formal means of communication, and the public in general for the technologist, when his work emerges, to be sold and judged on the market. This difference leads to marked divergences between

the *ethos* of both activities and the behavior of both groups. The first, as Derek de Solla Price humorously puts it, is papyrophilic (writes papers and books), and the second is papyrophobic (conceals his results until they find their way in the market).

While basic and technological research stand at both extremes of a spectrum, applied research, which shares some of the characteristics of both, is a special case. Like technology, it must be performed in economically or socially “relevant” areas, while it shares with basic research a degree of academic freedom and is usually promptly published in specialized journals. Actually, applied research in DCs is for the most part sterile. It is often “second class” science and seldom has any tie with production. And there is nothing sadder than “applied” science which is not applied. Basic science is a good *per se*, and technology gives rise to marketable goods, but applied science which remains fallow is a non-entity!

Science for whom? For all people and for all nations, of course, since I cannot conceive of a science whose dividends are not widely shared. *Science for what?* Economists, politicians and the public alike all agree that it should be for the material welfare of human beings, attained by the development and application of technology. With this we have no quarrel, but, in order to reach this desired end, one condition and one consequence must be accepted. The condition is that science (the *understanding* of nature) becomes part of each nation’s culture and the consequence is that, as this develops, the people’s view of the world and way of life will be modified.

What science? For both DCs and LDCs, not all science, or application of science if you so wish, is good, and the “perverse effects” of certain science and technology have often been commented upon (1). One of these “perverse effects” is research of new and more “perfected” weapons — and often their introduction into the Third World — which constitute a grotesque distortion of what development is meant to be.

Science in the Western sense — as contrasted with empiricism or with the so-called “ethnoscience”, no matter what Thomas Kuhn’s view on the subject — is a communal, cumulative, experimental and objective activity which, with Greek, Babylonian and other antecedents, appeared on the European scene some 400 years ago. It eroded mythologies and undermined religions, but gave man an instrument for controlling nature, for good or for bad. It demanded objectivity in its method, and humility in its gait. At the same time, technology — how to do — became dependent on science — how to know — specially in the last 100 years. It can be argued, and Moravcsik does it eloquently, that science, *in a cultural sense*, and technology go together and that, therefore, the first thing DCs must do, even at an early stage of their development, is to establish groups doing quality *basic* (so-called *pure, disinterested* or *academic*) science. This marriage works in a four-fold way: by satisfying the intellectual hunger of gifted members of the community — always an *elite*, let us not conceal it; by elevating the *morale* of nations; by serving as a basis for rigorous training of technologists and by

helping to make informed choice of technology to be transferred from other latitudes. It is Moravcsik's opinion, and my own, that, without such an indigenous base of quality science, independent technological research cannot grow. By "quality science", I mean obtaining reasonable results, starting from existing knowledge (the so-called "literature"), by means of observation, experimentation and logical thinking, subject always to facts, and publishing the findings in well-refereed journals, from where the generalized consensus of other scientists can be reached. At its best, "quality science" is moved by inspired theory. At an early — and also in later stages of growing science — the primary problem is then to identify talented individuals and give them the means to do research at the frontier of their specialties, rather than to build up grandiose and detailed plans that subsequently gather dust on the shelves of National Science Councils and the like. The choice of proper individuals as researchers can only be done by other researchers, who know best how to identify budding talent. Of course, the establishment of basic science in a country does not guarantee the growth of technology — other measures of social, economic and political nature, must be implemented — but it is a necessary background for the solid implantation of endogenous technological research.

Not that planning, in a general way, is superfluous. While science must be left free, technology, and even applied science, should be planned from the top, with scientists heavily involved in the process, in order to pinpoint areas where application is most likely to occur in a given country, and in order to promote production. Administratively speaking, this is a much more complex process than for basic science, since it involves complicated and widespread social and economic considerations.

From early schooling to University and, of course, post graduate education, an active and participatory knowledge, rather than rote memory and early specialization, as seems to be the case in Moravcsik's experience in other regions, and in our own Latin America, is to be emphasized. Science must be learned through a living experience; it is, as we say in Spanish, a *vivencia*. I have been asked many times by younger people to recommend to them books on the methodology of science, and have always refused to do so. While some ancillary methods — such as the handling of statistics — can be learnt in textbooks, the hard core of scientific behavior and *ethos* can still only be learned through contact, for many months or years, with experienced researchers, in a socratic, personal manner. Hence the need to send personnel abroad in the first stages of development. Specially in universities, the teaching of science should be done by people who perform active scientific investigation, so that their lessons are imbued with living, constantly changing theories, rather than by obsolescent textbook material. At the level of mass media, an aggressive information campaign should be encouraged in order to promote the population's "scientific literacy" which creates a proper receptive social *milieu* wherein both science and scientists can grow and prosper.

There is in developing countries a psychological obstacle to endogenous science progress, what I have termed elsewhere (2) “peripheral complex”. This consists of the general belief that scientists in LDCs cannot contribute effectively to the growth of knowledge, because of innate, or possibly cultural, “defects”. Such a fundamentally erroneous belief can be dispelled by scientists in LDCs contributing significantly to the growth of knowledge. This is another product of science, hygienic so to speak, and serving to give confidence to the public at large, and to developing scientists themselves.

Since science is a communal undertaking, isolation from other scientists is a common plight of LDCs scientists. Perhaps the chief task of a science administrator in such countries is to try to alleviate it. In the short term, well-stocked science libraries are indispensable, and frequent (at least once a year) trips abroad plus sabbatical leaves are useful. In the longer term the next step should be to form groups of scientists within the country who can talk to each other. It is well to bear in mind that this latter process may give results in no less than 20 years.

The practically unavoidable result of the mutation constituted by the growth in science in LDCs is the modification of their view of the world — the so-called *Weltanschauung* — with the destruction or change in their aspirations and habits. The late Argentinian scientist Jorge Sabato used to say: “Our aim in Latin America is to get the benefits of science and technology without giving up the *siesta*”. Probably a chimerical undertaking, since *siesta* is fast disappearing in our latitudes, as science and technology are making inroads, requiring new ways of living. Similarly, we Latin Americans must learn to abandon our traditional unpunctuality and to better value the importance of time. Unpunctuality in merely social events can be accepted as a form of agreed-upon behavioral convention, but it is deadly in science, constitutes a symptom of disorganization and can interfere markedly with the conduct of research. While we demand the fruits of science and technology, we continue at the same time to waste time, to act under no pressure, in a relaxed way. In brief, we want to have our cake and eat it too.

There are other illusions LDCs must dispel before they can make headways on the road to endogenous science. One is the belief that they must somehow invent a “new type” of science radically different from Western science. Yet, in the spread of science in the United States, Canada, and others, when they were LDCs, no such phenomenon emerged. And Western science has amply shown to be logically satisfactory, predictive, and practically efficacious.

Another illusion is that present “dependence” upon DCs is the only or at least the main cause of our backwardness. The existence of such dependence is real enough and I do not dispute it, but it is due mostly to the lack of science and technology in LDCs, and the root way to remove it is to do science, active and endogenous, of the highest quality.

Another notion is that the machiavellian action of multinational corporations prevents us from doing research in our own countries. There is some truth in this, at least for technological research, since multinational companies tend to do their most relevant research in their country of origin. Thus, for example, there was no research worth the name on oil in Venezuela (where 92% of foreign income comes from this commodity) before 1976, the year the oil industry was nationalized. In that same year, INTEVEP, the Venezuelan oil research institute, was founded and it has thrived ever since. But it must be added that the rapid success of INTEVEP was due largely to the previous existence in the country of basic chemists and physicists, who were able rapidly to take over the mostly applied and technological research carried out in the Institute. As Moravcsik aptly puts it: "It is much more comforting to believe that one's own failures are due to the conspiracy of external forces".

An indispensable item in science and technology policy is evaluation of the results of research. We have mentioned that from the administrative point of view planning was a simpler task for basic than for applied and technological research. In evaluating the results, the contrary is true. The aims of technological research are usually clear-cut and palpable. In the last resort, they consist of the marketability of a product and its benefits, which can be measured, although it may not be possible to unweave the respective contributions of research and technology and other factors, such as marketing. Not so for basic science: the goal here is, first, a published article and, two, the effect of this article on the state-of-the-art through its influence on the thinking of other scientists working in the area. One first step — highly unsatisfactory but often practiced — is simply to count the number of articles appearing in journals. The second step is to consider only well-refereed, usually international journals. The third step is to count in *Science Citations Index (SCI)* the number of references made to each article (its "impact"). This is not very satisfactory for LDCs, since only some 4000 journals, out of a possible 70000 existing in the world, are listed in SCI, most of them published in DC countries — the so-called (by DCs) *mainstream* of science. It remains that, for basic science, the old-fashion empirical approach is still the best, consisting as it does of evaluation made by knowledgeable directors of research, themselves scientists, of course, helped by committees of peers and also by the tools (SCI and the like) mentioned above.

There are many more detailed items, of course, which can be found in Moravcsik's useful collection of essays. The whole phenomenon of development through science if of extreme complexity — and, as the author states: "... our knowledge of how to formulate a systematic scientific and technological development program in any country, advanced or less developed, is extremely rudimentary". But we do know a good many things about the process, thanks to the efforts of people like Moravcsik. In addition, his book will come as a stimulus to other people to deal with the subject. In particular, scientists and writers from developing countries should address themselves to the

problem, with which they have a living experience, since "the literature dealing with problems of science in developing countries is being written primarily by people from the developed countries" (Moravcsik). Such bias must be corrected somehow.

References

- (1) ROCHE, M.: *¿Ha Contribuido la Ciencia al Desarrollo?*; *Interciencia*, 11: 216—220, 1987.
- (2) ROCHE, M.: *Early History of Science in Spanish America*; *Science*, 194: 806—810, 1975.

July, 1987

*Instituto Venezolano
de Investigaciones
Científicas, IVIC*

Marcel Roche

PREFACE

To the subject of scientific development in the Third World, Professor Michael Moravcsik brings the precision of a scientist, and the zeal of a missionary convinced of the virtues of modern science and modernity. There can be no question as to the author's qualifications as a physicist, or of his active involvement in numerous attempts to stimulate scientific growth in developing countries. The set of essays comprising this book are the clear and concise expression of a mind capable of choosing between facts, discerning those which conceal something and recognizing that which is concealed. To be sure, not every argument or conclusion reached herein will be popular with all readers. But even when the reader disagrees completely, the issues raised are so important and clearly posed that they shall surely force his gratitude.

"Scientific development" has come to be virtually an article of faith, and paying homage to it is a familiar ritual in Third World countries. The incense, however, is frequently burned at the wrong altar because it is only certain particularized applications of science—not the absorption and internalization of its other myriad aspects—which are really meant. It is, of course, perfectly natural that developing societies should seek modern agricultural techniques, factories for producing cement and steel, and so on, and identify these as "science". But, the author reminds us, there is far more to science than this. Indeed, science has as much — if not more — to do with philosophy and a world outlook as with industrial and technical production. As a methodological procedure, it combines observation, experiment, classification, and measurement to test various laws, hypotheses, and theories. Built on a great stream of thinkers and workers lies the vast cumulative tradition of scientific knowledge. And, in its philosophical dimensions, science is perhaps the most powerful influence moulding man's beliefs and attitudes towards the universe. Science lives in the minds of men and women, not inside equipment and machines.

The point, therefore, is that scientific knowledge cannot be simply bartered for material goods and services. In one of his essays, co-authored with John Ziman, the author attacks the notion that the advanced countries should somehow export the great surpluses of their knowledge factories in exchange for cocoa, bananas, oil, and copper. Quite apart from enhancing the relations of dependence, he argues, this transfer simply cannot be effected as a commodity exchange. A substantial indigenous scientific infrastructure is vital for any meaningful communication to occur between developing and developed countries in this sphere. This may well be a truism, but it is one which gets here the forceful emphasis it deserves.

In identifying the principal hurdles faced by Third World science, Professor Moravcsik articulates what is often felt but seldom stated. The problems are far more complex than

one might infer from the remedies that are usually suggested. In considering the issue of increased spending for science in the Third World, this immediately becomes apparent. There is no question that Third World countries, as a whole, spend much too little on scientific development. Considering the material and intellectual needs of such countries, one could easily argue for, say, a tenfold increase in the amount. There are definitely countries which would benefit immensely from some such change, and one could confidently predict a speedy transformation of their entire techno-socio-economic structure. On the other hand, there are also examples where, if all other factors are left constant, this change would probably do little. This is to be expected wherever the principal bottlenecks involve a rigid and irrational bureaucracy, or vital decision making powers are concentrated in the hands of an unsympathetic and non-understanding leadership, or when corruption pervades the entire fabric of society. In such countries, various externalities have a tendency for soaking up arbitrary amounts of funds. The creation of new scientific institutions on mere administrative impulse affords one such example. Bearing pretentious titles such as "Centre of Excellence" in this or that field, a veritable population explosion of new institutes and organizations has occurred. Formally, one is obliged to count this as progress. But, in real terms, notable success never occurs unless the new institution is endowed with a crucial, valuable, and scarce resource — the leadership of competent, imaginative, and dedicated scientists belonging to the country itself.

Living in the post-colonial era, but one in which the unhappy division between the metropolis and the periphery persists, the political, economic, cultural, and sometimes military, domination by the West inspires a reaction against the perceived instruments of domination. Modern science, sadly enough, has become increasingly an object of attack as well. One consequence is that, from time to time, there appears the notion of a science different from "Western science". There is no question that technologies differ from place to place. But is there such a thing as "Third World science" or "Islamic science" or "Marxist science"? The author takes an explicit and unapologetic stand: his answer is a simple no. One cannot agree more. The idea of any special science in this sense negates the concept of science as a universal, independent, rational human endeavour which can transcend divisive national and ideological boundaries. Upon examination, one is struck by the fact that such constructs derive from passionately held beliefs of how matters ought to be, rather than what is required by the imperatives of logical and empirical enquiry. Neither the premises, or the conclusions, of any "special science" are the least bit in doubt. It seeks to reaffirm what is already known, not search into the unknown. No new mathematical principles are sought, no experiments will be designed for its verification, and no new machines will be built on account of it. Like creationism in the West, the numerous varieties of "special science" are a reaction against modern science, and not a new direction of science. Their pursuit is nought but a fruitless chase.

And now to move on to more delicate, controversial, and perhaps irresolvable matters. The need for such a discussion is forced by the value structure implied by science and modernity, and by the explicit positions taken on this in the book.

Science has evidently prospered in some Third World environments. In others it has not. Why? Access to financial and material resources certainly cannot be the whole story, even though these are universally emphasized and are undoubtedly essential. This question forces upon us the importance of considering the overall idea system of society, and how it influences the acquisition of positive, rational knowledge. Overall idea systems — by which shall be meant beliefs, attitudes, social mores, general assumptions, and specific religious and ideological positions — are of the profoundest importance in human history. Julian Huxley compared them to skeletons in biological evolution: they provide the framework for the life that animates and clothes them, and in large measure determine the way it shall be lived. Embodied within an idea system, to an extent which may be greater or lesser, is rationality — by which is meant that matrix of connections assigning cause to effect. Rational thought and science have their origin in man's drive to have power over events in the external world. Without this impelling Nietzschean obsession, humans become mere buoys that float on the waves. A society oriented towards fatalism, or one in which an interventionist Deity forms part of the matrix of causal connections, is bound to produce less individuals inclined to probe the unknown with the tools of science.

So let us accept, at least as a provisory hypothesis, that the idea system of a society has more to do with its scientific advancement than any other factor. Combine this with the fact that a great revolution took place in Europe some 400 years ago as a consequence of which experimentation, quantification, prediction, and control became the paradigm of a new culture. It was only after this that a mysterious and capricious universe could be understood as mechanical, orderly, and in which "number holds sway over the flux". Add to all this the continuing scientific and technological pre-eminence of the West. What emerges? That the Western idea system, based on a Greco-Roman legacy and Christian ethic, is superior to any of its contemporaries?

The author's position on the merits of European civilization is perfectly explicit. His essay, authored jointly with John Ziman, begins thus:

"With European industrial civilization comes European science. It is a package deal. The question whether a culture thus superseded or repressed had its own form of science has become purely academic: the process of economic growth and social development is entirely predicated on the "rational materialism" of post-Renaissance Europe and its North American colonies . . . In the present discussion, it is taken for granted that European science should become a dominant cultural force throughout the world."

Whether or not our reaction to this is typical of a person from a country with a colonial past, we cannot tell. But, inspite of having sworn allegiance to both the techniques and philosophy of scientific rationality, and though sadly aware of the shortcomings and defects present in our environment, we must nevertheless confess that such explicit Eurocentrism makes us deeply uncomfortable. Presuming that the book seeks to spread science rather than “civilization”, such a position does harm to its mission by introducing an extraneous issue. The temptation for retort becomes irresistible: Do the contributions of the Chinese, Islamic and Hindu civilizations warrant such a peremptory dismissal? Were not Auschwitz and Hiroshima consequences of a supposedly rational and scientific European culture? How should we assess a civilization which has created the concept of “megadeaths” and “mutual assured destruction”?

Personally, we feel that such divisive issues should, and could, have been avoided. Instead of tracing the roots of science to narrow geographical or cultural domains, it would be infinitely more preferable, and also more accurate, to regard the development of modern science in a universal context — as a collective effort of mankind in which different civilizations have contributed their share. One can persuasively argue that science is the natural outcome of human intelligence. Rational man has emerged from the realms of biological evolution endowed with innate mental structures capable of abstract thought. Epistemological and linguistic research bring evidence that humans are intricate “pre-wired” computers needing only external stimuli to set cognitive and creative processes into operation. Regarded in this manner, science pretty much had to develop sooner or later in the course of man’s progress. That it should have developed over the last few thousand years is probably quite accidental. There were countless ages before that during which there was no knowledge, and there may be countless ages without knowledge in the future. On a cosmic scale, the history of knowledge and science is profoundly irrelevant, reminding us of the futility of parochial pride in the historical cultures which we accidentally happen to be associated with.

Differences aside, one must acknowledge this book as a valuable manual on science development. It sets out the role of science in technology transfer with unusual clarity, identifies both the immediate and long term needs of science institutions, discusses the role of scientists as science managers, brings to attention the importance and feasibility of scientometric studies, emphasizes the need for communication among scientists, analyzes the problems and potentialities of overseas university education, and much more. One hopes that it will be widely read, and with care.

Pervez Hoodbhoy
Physics Department
Quaid-e-Azam University
Islamabad, Pakistan

Abdus Salam
Director
International Centre for Theoretical Physics
Trieste, Italy

ACKNOWLEDGEMENT

The Publisher and Editor wish to thank the authors and the following publishers/institutions for permission to reproduce published papers in this volume:

American Association for the Advancement of Science
American Association of Physics Teacher
American Institute of Physics
Association of Geoscientists for International Development
Council on Foreign Relations, Inc.
Department of Biochemistry, Mahidol University, Thailand
Educational Foundation for Nuclear Science
Elsevier Scientific Publishers B. V.
Indian Science News Association
Interciencia
International Council on the Future of the University
International Commission on Physics Education
International Science Policy Foundation
IOP Publishing Ltd
Macmillan Journals Ltd
Ministry of Education, State of Bahrain
Ministry of Science, Technology and Energy, Bangkok
National University of Malaysia
North-Holland
Organisation for Economic Co-operation and Development
Pergamon Press
Rijksuniversiteit Gent
Society for Social Studies of Science, Illinois Institute of Technology
The University of Michigan
United States Advisory Commission on Public Diplomacy
Universite Libre de Bruxelles, Institut de Sociologie

While every effort has been made to contact the publishers of reprinted papers prior to publication, we have not been successful in a few cases. Where we could not contact the publishers, we have acknowledged the source of the material. Proper credit will be given to these publishers in future editions of this work after permission is granted.

This page is intentionally left blank

CONTENTS

Preface	v
<i>Marcel Roche</i>	

Preface	xi
<i>Pervez Hoodbhoy & Abdus Salam</i>	

I. THE TASK AND ITS FRAMEWORK

A. The Task in a Context	3
1. "Paradesia and Dominatia: Science and the Developing World" (With J. M. Ziman) <i>Foreign Affairs</i> 53 (1975) 699	5
2. "The Context of Creative Science" <i>Interciencia</i> 1 (1976) 71 [Reprinted in <i>Everyman's Science</i> (India) 11, No. 3 (1976) 97]	31
3. "What is a Developing Country" <i>CASME Journal</i> 2:1 (1981) 16	39
4. "Developing Countries and the Fruits of Science" <i>Leonardo</i> 11 (1978) 214 [Reprinted in <i>Int. Dev. Rev: Focus</i> 20:1 (1978) 27]	51
5. "The Two Ways of Mountaineering" <i>Phys. Bull.</i> 29 (1978) 249	54
6. "Two Perceptions of Science Development" <i>Research Policy</i> 15 (1986) 1	55
B. Research in the Third World	67
1. "Technical Assistance and Fundamental Scientific Research in Underdeveloped Countries" <i>Minerva</i> 2 (1964) 197 [Reprinted in Edward Shils (ed.): <i>Criteria for Scientific Development: Public Policy and National Goals</i> , (MIT Press, 1968) and in A. B. Shah (ed.): <i>Education, Scientific Policy, and Developing Societies</i> , Manaktalas, 1967]	69
2. "Scientists and Development" <i>J. Sci. Soc. Thailand</i> 1 (1975) 89	82
3. "Do Less Developed Countries Have a Special Science of Their Own?" <i>Interciencia</i> 3, No. 1 (1978) 8	89
C. The Bridging of the Gap	95
1. "A Chance to Close the Gap" <i>Science and Culture</i> 39, No. 5 (1973) 205	97
2. "The Transmission of a Scientific Civilization" <i>Bull. Atom. Scientists</i> 29:3 (1973) 25	104
3. "Intercultural Transmission of Science" <i>Civilizations</i> 29:1/2 (1979) 127	108
4. "Preparing the New Pioneers" <i>Bull. Atom. Scientists</i> 36:10 (1980) 56	118
5. "The World in the 21st Century — The 2020's in the Context of Education" <i>Proceedings of the Symposium on the Future of the Arabian Gulf Universities</i> , Bahrain (1983)	120

D. The Personal Angle	127
1. "What Motivates the Developing Countries to do Science and Technology?" <i>Communication and Cognition</i> 13:2/3 (1980)	129
2. "The Scientist in a Developing Country and Social Responsibility" <i>Interciencia</i> 4 (1979)	140
E. Some Benefits	145
1. "Science and a Crucial Stage of Economic Development" <i>Bull. Inst. Phys. Singapore</i> 7:1 (1979)	147
2. "The Role of Science in Technology Transfer" <i>Research Policy</i> 12 (1983)	149
3. "Who Benefits from International Scientific and Technological Cooperation?", published under the title of "Global Scientific and Technological Co-operation", <i>Bull. Res. Inf. (Tanzania)</i> 1:3 (1981)	159
F. Research on Science	163
1. "Science in the Developing Countries — An Unexplored and Fruitful Area for Research in Science Studies" <i>4S Review</i> 3:3 (1985)	165

II. THE PROBLEMS

A. The Nature of the Problem	179
1. "Dependence" <i>Human Systems Management</i> 2 (1981)	181
2. "Relevance: An Analysis Illustrated on Science Education in the Third World" <i>Interciencia</i> 10:1 (1985)	188
3. "Generating Innovative Capabilities in Science and Technology in Developing Nations", address at the Woodrow Wilson International Center for Scholars, Washington, D.C. (1982)	194
4. "Science Development — A Network of Vicious Circles" <i>Approtech</i> 5 (1982)	198
B. Research and Its Applications	205
1. "Applied Scientific Research and the Developing Countries" <i>Science and Public Policy</i> 5 (1978)	207
2. "Everyday Science in Developing Countries", published under the title of "Third World Needs 'Barefoot' Science" (With R. H. B. Exell) <i>Nature</i> 276 (1978)	218
3. "Scientific Output in the Third World" (With John Blickenstaff) <i>Scientometrics</i> 4:2 (1982)	220
4. "An Analysis of Citation Patterns in Indian Physics" (With P. Murugesan and E. Shearer) <i>Science and Culture</i> 42 (1976)	255
C. Communication	263
1. "Communication Among Scientists and Its Implications to Developing Countries", in <i>Management of Research and Development</i> , OECD, Paris (1970) pp. 224—237	265

2. "In the Beholder's Eye: A Possible Reinterpretation of Velho's Results on Brazilian Agricultural Research" *Scientometrics* 11 (1987) 53 279

D. Managing Science 285

1. "Local Institutions for the Building of Science and Technology in Developing Countries", address at the Building National Institutions for Science and Technology in Developing Countries, Washington, D.C. (1979) 287
2. "Scientists as Science Managers" in S. Joffily *et al.* (eds.), *Leite Lopez Festschrift — A Pioneer Scientist in the Third World* (World Scientific, Singapore, 1988) 293
3. "Priorities and Decision Making for Science in Developing Countries" *Interciencia* 11 (1986) 90 302
4. "Special Obstacles in the Organization of Science in Developing Countries" *Approtech* 4: 1/2 (1981) 1 307
5. "The Missing Dialogue — An Obstacle in Science Development" *Int. Dev. Rev.: Focus* 18:3 (1976) 20 310
6. "The Incomplete Alliance", Newsletter of the Asian Physics Education Network 1 (1982) 7 316
7. "Las Responsabilidades del Hombre de Ciencia en Calidad de Estadista Científico", in *La Participación de la Comunidad Científica Frente a las Alternativas de Desarrollo*, ASOVAC, Caracas (1982) p. 67 318

III. ACTION

A. Directions 331

1. "New Directions in Scientific and Technological Assistance" *Science Policy* 2:6 (1973) 179 333
2. "Scientific and Technological Assistance and the Challenge of the 80's" *Science and Public Policy* 8 (1981) 40 343
3. "The Role and Function of a Scientific and Technological Infrastructure in the Context of Development Policy" in V. Urquidí (ed.), *Science and Technology in Development Planning*, (Pergamon, Oxford, 1979), p. 149 350
4. "Mobilizing Science and Technology for Increasing the Indigenous Capability in Developing Countries" *Bull. Sci. Tech. Soc.* 1 (1981) 355 360
5. "A Map of Science Development" *Sci. Eng. Soc. Dev.* 3 (1982) 5 383

B. Latent Opportunities 387

1. "Some Practical Suggestions for the Improvement of Science in Developing Countries" *Minerva* 4 (1966) 381 [Reprinted in Edward Shils (ed.): *Criteria for Scientific Development: Public Policy and National Goals*, (MIT Press, 1968)] 389
2. "Some Modest Proposals" *Minerva* 9 (1971) 55 399

3. "The Committee on International Education in Physics"	
<i>Am. J. Phys.</i> 41 (1973) 309 and 608, and <i>Phys. Teacher</i> 11	
(1973) 82	410
4. "The Research Institute and Scientific Aid" <i>Int. Dev. Rev.</i> 13:3	
(1971) 17	419
5. "Science and Scientific Higher Education in Developing Countries	
or Seven Tasks for Geoscientists", contribution to the Symposium	
on Opportunities in Geomagnetism and Aeronomy for Developing	
Countries, University of Washington, Seattle, 22 August 1977	425
C. Human Resources	431
1. "The Physics Interviewing Project" <i>Int. Educ. Cult. Exchange</i>	
8 (1972) 16	433
2. "Foreign Students in the Natural Sciences: A Growing Challenge"	
<i>Int. Educ. Cult. Exchange</i> 9:1 (1973) 45	440
3. "Observations on an Obstacle Course" (With F. Dart, A. deRocco,	
and M. Scadron) <i>Int. Educ. Cult. Exchange</i> 11:2 (1975) 29	454
4. "American Universities and the Science Education of Third World	
Students" (Submitted for publication, 1986)	458
5. "Postgraduate Education for Developing Countries" <i>Proceedings</i>	
<i>of the International Conference on Postgraduate Education of</i>	
<i>Physicists</i> , eds. P. J. Kennedy and K. Vacek, Prague (1980) p. 222	468
6. "Some Off-beat Suggestions for Software Teaching Aids" <i>Proceedings</i>	
<i>of the International Conference on Teaching Aids in Physics Education</i> ,	
Kuala Lumpur, 1982, p. 30 [Reprinted in <i>Physics Education</i> (India)	
1:4 (1985) 19]	479
7. "How to Pick the Right Person (The Choice of Personnel in the	
Building of Science)" <i>Science and Culture</i> 44 (1978) 339	488
8. "The Mobilization and Utilization of Scientific and Technological	
Human Resources in Developing Countries" <i>Asean J. Sci. Tech. Dev.</i>	
3 (1) (1986) 1	496
D. Science and Technology	511
1. "Linking Science with Technology in Developing Countries"	
<i>Approtech</i> 2:2 (1979) 1	513
2. "Creating an Effective Applied Scientific Research Program in a	
Developing Country" (With W. Pardee) <i>Bull. Sci. Tech. Soc.</i> 2	
(1982) 135	517
E. Measuring Science	523
1. "Practical Problems and Steps of Implementation in the Application	
of Scientometrics in the Third World" <i>Proceedings of the First Pan</i>	
<i>American Workshop on Quantitative Methods in Science Policy and</i>	
<i>Technological Forecasting</i> , San Jose, Costa Rica, 1983, Vol. II, p. 30	525
2. "Applied Scientometrics: An Assessment Methodology for	
Developing Countries" <i>Scientometrics</i> 7 (1985) 165	540