Key Problems in Science and Technology in Thailand

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Summary. Science and technology can make substantial contributions to socioeconomic development in Thailand. In order to promote such contributions, problem areas and specific problems of high priority need to be defined, and possible solutions outlined. Important criteria for selecting priority areas and key problems include relevance to development, the availability of human resources and the possibility of their development, the cutting-edge advantage to be gained by development, the possibility of international collaboration, and the possibility of integration with culture and environment. These criteria suggest in Thailand a focus on the development of bioscience and biotechnology, materials science, electronics, and information science.

Thailand has been classified as a "middle-income emerging country" by a science adviser to the U.S. Agency for International Development (AID) (*1*). This optimistic assessment should, however, be tempered with the realization that Thailand is still a developing country with a rather poor socioeconomic status by world standards (*2*). In science and technology, various criteria also point to the status of Thailand as a middle, emerging country (*3*, *4*). Thus, existing indicators suggest a bright future, but not without a long, hard struggle.

Judgments about the relevance of development activities critically depend on such assessments of the present status of the country. Then a variety of external and internal considerations can be used to define broad priority areas and key problems with regard to relevance to development. External considerations, such as the emerging and maturing areas of science and technology, dramatically outlined as those constituting the "third wave" (*5*), must be taken into account. Crucially important as well are internal concerns over economic and social benefits and costs. The benefits should reach the people and contribute to improving the quality of life, especially that of the rural poor. They should be visible as substantial increases in value-added of the resources used, preferably in the form of products for export. The costs to be considered include not only capital, labor, and resources, but also social and environmental costs, which are difficult to quantify but often substantial. Furthermore, the distribution of benefits and costs must be carefully considered. The rule of thumb is to have, at minimum cost, optimum benefits reach large and varied groups of people. For large programs or projects, detailed research on policy, technology impact studies, feasibility studies, and case studies are called for; without these the developmental benefits and costs cannot be accurately assessed.

In terms of strategy for promotion of development, priority areas should (i) take advantage of existing special or abundant natural and human resources; (ii) preferably already be in a crucial stage of maturity so that progress is noticeable with a finite input; (iii) provide badly needed linkages among universities, government, and the private sector; (iv) form crucial links among various industries requiring a science and technology base; and (v) form the foundation for further development in science and technology. Fortunately, Thailand has a number of priority areas that meet these requirements. Once the relevance of a priority area to development has been established, then issues that must be examined include the availability of human resources, the particular technological advantage to be gained, the possibilities for international collaboration, and cultural and environmental concerns.

Human Resources

The major constraint on developing science and technology in Thailand is the lack of qualified manpower at all levels.

Thailand had, in 1980, a total of 55,790 scientists and engineers, 68,500 technicians, and 161,500 craftsmen—that is 12 scientists and engineers, 15 technicians, and 35 craftsmen per 10,000 population (*6*). In comparison with other Asian and Pacific countries, Thailand falls into the group with moderate scientific and technical manpower (*7*). Currently Thailand is producing annually between 1000 and 1500 college graduates with bachelor degrees in each of the fields of natural science, agriculture, and engineering, and the capacity for producing master and doctoral degree graduates is expanding. Doctoral degree programs in the life sciences have been in existence at Mahidol University for almost two decades, and a doctoral program for engineering is now getting under way at Chulalongkorn University. The Asian Institute of Technology in Bangkok has had doctoral and master programs for almost two decades, and King Mongkut Institute of Technology, Ladkrabang campus, is also starting a doctoral program. But, because no substantive grant funding is available, there is no effective postdoctoral system in Thailand.

With the present status of manpower, only a few selected areas in science and technology can be chosen for intense effort in advanced research and development. Educational values should guide choices in most other areas so as to build on the present moderate base. The choice of R&D topics should be modest and yet contribute to the science and technology base in particular and to development in general.

Agencies like AID can be especially important to development of the manpower needed to ensure that the transfer of knowledge and expertise can take

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place. The success of this transfer depends on the readiness of the developing country and an appropriate matching between donor and receiver. Thorough assessment of the manpower status in various problem areas is clearly essential to the transfer process.

Cutting-Edge Advantage and Local Character

Many characteristics of Thailand provide favorable opportunities for development of important areas of science and technology. Abundant biological resources, many of which are limited to humid tropical regions, for example, offer excellent materials for conversion to medicines, food, and other products through biotechnology. Because the manipulation of these resources often requires field experimentation and fresh materials, Thailand is in an advantageous position in this area. The long coast line and accessibility to two different sea environments provide opportunities for study and development of marine natural resources. The wild flora and fauna of the vanishing tropical rain forests challenge the scientific mind to study their nature, as well as invite efforts for their conservation. The abundant supply of solar energy calls for development of appropriate technologies to tap it for household and industrial use.

Its emergence as a new industrializing country also presents Thailand with special challenges. As developed countries move away from skill-intensive industries, new opportunities open for development in Thailand of science- and technology-based industries in which moderate cost for skill and labor is an advantage. The engineering industry is one example, with problems ranging from manufacture of mechanical machines and tools to electrical and transportation machinery. Food processing is another example, spanning technologies from fermentation to preservation. In agroindustries another advantage is conferred by the eminent status of Thailand as the fifth largest food exporting nation in the world.

Special local health problems, such as the high incidence of liver fluke disease in northeast Thailand, call for high priority and original research efforts within the country. Solutions to such a problem, be they in the form of new drugs or vaccines, may significantly contribute to the knowledge of other fluke diseases such as schistosomiasis, predominant in other regions of the world. The prevalence of thalassemias and the hemoglobin disorders presents an important and intriguing challenge for both basic science and its applications to medicine. Examples in other areas can be easily found.

International and Bilateral Cooperation

One of the most distinguishing features of science and technology is their international character. Scientists and technologists the world over share common interests and a common stock of knowledge in their professions. They build on this stock in a concerted effort and can often communicate with one another instantly. Therefore joint projects are relatively easy to establish and should form an important part of international and bilateral cooperation. However, matching of interests is a crucial feature for success of this cooperation, as is the basic strength of the developing country, so that it can share in the cooperation on a meaningful and equitable basis. Yet another important feature, especially for technology projects, is the degree of protection the technology is given by the developed countries. Clearly, for Thailand at present, collaboration with the United States on biotechnology would be more meaningful than on nuclear physics.

These considerations should not, however, be viewed so rigidly as to exclude international and bilateral collaboration where it may be warranted on the basis of other criteria. To continue with the example of nuclear physics, should a good group of scientists at, for instance, Chiang Mai University be on the threshold of doing good competitive science in this area, and would definitely gain momentum from collaboration with a leading university in the United States, the possibility of supporting this group should be seriously considered.

Industrial research in Thailand is still in its infancy but is increasingly needed to support the expanding industrial sector. The major difficulty for a country such as Thailand is limited access to industrial information, even at a basic level, since much of the information is not published. Furthermore, even when information is available, in patents or other sources, the lack of hands-on experience imposes severe restrictions on its use. Industrial rubber research is an example of an area where international and bilateral cooperation, involving industrial research institutes and the private sector, is essential in order to promote, with appropriate protective measures, exchange of privileged industrial information that will benefit Thailand and the cooperating countries.

Integration with Culture and Environment

The utilitarian aspects of science and technology have been much emphasized, often at the expense of cultural and environmental aspects (*8, 9*). Science and technology are integral parts of human culture and, in order to promote their long-term growth, they need to be integrated with the existing culture. Ideally, new science and technology and endogenous culture should interact synergistically. For example, the Buddhist teaching on the value of independent inquiry reinforces the scientific approach to problems. The Eastern concept of living in harmony with nature is in line with the principles of ecology and warns us against over-exploitation of the environment through technology.

Some traditional beliefs and practices deserve thorough investigation for the possibility of mutual reinforcement discussed above and also for further developmental purposes. The use of various herbs in traditional medicine, for example, is based on wisdom accumulated over many generations and, on thorough scientific investigation, some herbs may yield new pharmacologically active substances. Similarly, some traditional agricultural practices that conserve topsoil fertility may need to be reinforced through scientific investigation.

In many instances, traditional practices may need to be scrutinized or changed in the light of new scientific and technological information. Where uncertainty still exists, further investigation is warranted; where proof has been found, effective methods must be devised for modification of these practices. Problems of both types abound in the nutritional sciences, for example. The prevalence of bladderstone disease in Thai children in the northeast may be linked with nutritional behavior. Efforts at modification of food habits that cause deleterious health effect, such as eating raw fermented fish, restricting diet during illness, and so forth, although strictly not in the realm of science and technology activity, may require firm scientific information.

The environmental impact of technological change should by itself be an integral aspect of any major technological project, ranging from irrigation and construction of power stations to agricultural practice and health care. Too often, projects based on new science and technology have turned out to be of benefit only in some narrow aspects at the expense of the environment. Environmental impact studies should help in avoiding such mistakes.

The criteria discussed above can be used to identify a few broad areas of priority for science and technology in Thailand, such as biotechnology, materials science, electronics, and information science.

Biotechnology and Bioscience

Biotechnology and bioscience represent areas of high priority for development. Their relevance to agriculture, health, environment, energy, and industry (*10*) is obvious. In agriculture, benefits to be expected from utilization of biotechnology and bioscience range from development of improved crop varieties, fertilizers, and pesticides, to the introduction of new postharvest technology and processing techniques for agricultural products. In health, biotechnology and biomedical science should lead to the manufacture of human and animal vaccines, diagnostic agents, drugs from plants and microorganisms, and other health-related products. In environmental and energy fields, treatment and recycling of organic waste from industrial and household activities and the use of renewable biomass sources would be the focus. In industry, both traditional and new fermentation procedures can gain a great deal from development of new microbial resources or new bioengineering processes. Chemical, pharmaceutical, and food industries, based on fermentation technology or otherwise, increasingly rely on biotechnological processes, including those derived from genetic engineering. Even extraction of minerals and petroleum may, in the near future, be improved by new biotechnology.

Thailand, with its rich tropical resources, stands to gain tremendously from the development of biotechnology and bioscience and, in many cases, their development is optimally achieved in Thailand. For example, improvement of crop varieties through tissue and cell culture techniques must depend on techniques for plant regeneration best developed in their local habitat. An important fundamental problem, as yet unsolved, of introducing new genes into monocotyledonous plants (including rice, sugarcane, and maize) is likely to rely on discovery of gene transfer mediated by naturally occurring infective agents for these plants. Endemic diseases like foot-and-mouth disease or rabies, which must be wiped out eventually, provide materials essential for research and development on, and production of, vaccines, diagnostics, and drugs. These wide-ranging problem areas are of much interest to scientists throughout the world, and there will be no difficulty in expanding international and bilateral cooperation.

Development in biotechnology and bioscience can be easily integrated into other aspects of the Thai society, which has long had traditional technologies in fermentation, agriculture, and medicine, all of which can profit from interaction with the new technology and knowledge. Finally, development in biotechnology and bioscience can have a positive impact on environmental conservation by reducing pollution from agroindustrial waste and providing new methods of afforestation and cleaner methods for mineral extractions.

The present manpower with degrees in bioscience- and biotechnology-related areas, can be estimated from data of the National Research Council (*11*) as follows: biomedical science, 5781; chemistry, 2289; biology and agriculture, 8720; and engineering, 8525. The estimated number of scientists and technologists (at the master's level or above) active in R&D in biotechnology is approximately 400. However, many more are active in related areas, especially medicine and agriculture. There are approximately 20 institutions, mainly in universities, engaged in R&D in biotechnology. Of these, approximately 15 are in the Bangkok metropolitan area.

The private and public sector industry in Thailand has substantial interest and activity in biotechnology, although the focus is mainly technical service and quality control and not R&D. Public enterprises with some activity in biotechnology include Thailand Institute of Scientific and Technological Research, Pharmaceutical Organization of Thailand, and Thai Tobacco Monopoly.

Recently, the National Center for Genetic Engineering and Biotechnology (NCGEB) has been established, through the initiative of the Ministry of Science, Technology and Energy, to promote R&D and other activities in these areas in universities, government agencies, and the private sector. The NCGEB should play the key role in policy, planning, and support of biotechnology in Thailand.

The national budget for all R&D in Thailand is about $100 million per year, or about 0.25 percent of the gross national product (*12*). Approximately 40 percent of this budget is devoted to R&D in agriculture and related activities. The specific allocation for bioscience- and biotechnology-related activities has not been officially examined but can be roughly estimated as somewhere between 10 and 20 percent of the total budget for R&D. A special budget has been recently allocated to the NCGEB to support projects deemed to be of special importance to development.

Since the 1970's, the level of interest in bioscience in Thailand has been notable, but interest in biotechnology, as distinct from bioscience, has begun only recently. Most R&D activities in biotechnology are at present mainly confined to research in universities. Of the ten state universities that are involved in biotechnology research, Mahidol University, Chulalongkorn University, Kasetsart University, and King Mongkut Institute of Technology have major programs, while Thailand Institute of Scientific and Technological Research and Chiang Mai University have some specialized interests (*13*).

Metallurgy and Materials Science

By all the major criteria, metallurgy and materials science qualify as another broad area of high priority for development in Thailand. The importance of development in this area was stressed in the Fifth National Economic and Social Development Plan, and it was decided that a specialized R&D institute on metallurgy and materials science be established (*14*). Development in this area is of pivotal importance for industrial development. Furthermore, Thailand has rich deposits of metal and other mineral ores that are at present exported only as raw materials. Two main purposes are therefore served in development of metallurgy and materials science.

The importance of this area in industrial development stems from its role in the engineering industries, defined as those involving production of general industrial machinery, nonelectrical and electrical machinery, transportation machinery, and basic metal products. The engineering industries are important to industrial development because they furnish the machinery and components for factories and other production units. They also supply agricultural machinery as well as process machinery and design of factories for food processing and other industries. Finally, they provide parts and components for transport vehicles and electrical appliances, the local production of which can save a substantial amount of foreign exchange or even become a potential source of foreign exchange. Basic metal and nonmetal materials form the starting point of products of the engineering industries. Improvement in the R&D system, especially in the areas of metallurgy and materials science, has therefore been cited as of high significance in development of the engineering industries (*15*).

There is an urgent need for qualified manpower in this area at all levels. The current number of graduates, at both the degree and diploma levels, is not sufficient to meet the demand from industry, and many of the graduates lack appropriate practical training. There are shortages (*15*) in the areas of foundries, mold and dye design, and plastic technology. There is also a strong need for building up R&D personnel. The few highly qualified personnel in this area at present have been drawn, because of lack of incentives and infrastructure for doing R&D, into consulting, management, and other duties. It is essential to attract a significant proportion of this scarce personnel into R&D and education in order to build up new personnel. This will require good career structures and the provision of a viable infrastructure and sufficient incentives.

Many specific problem areas can be identified whose solutions would provide direct and relatively immediate benefits. Thailand has abundant high-quality dolomite, which can be developed for use as ceramic material. Rich deposits of tin, tungsten, and other valuable metals such as tantalum and niobium call for development of primary processing (conversion of ores into bulk industrial materials) within Thailand. Capability in secondary materials processing, including metal casting, cutting, forging, and machining, is highly desirable. Furthermore, combination of natural materials such as rubber with synthetic materials may yield products with new and superior characteristics. This and other examples clearly indicate the cutting-edge advantage to be gained from development in this area.

International cooperation in development of metal technology, and science and technology of materials in general, will be beneficial for local industry as well as for joint ventures in industry and trade related to the use of these materials. The United States, for example, relies on Thailand as a main source of a number of mineral ores (*16*) and both countries would gain from development of primary ore processing in Thailand.

Proper safeguards must be employed to ensure against over-exploitation of the mineral resources and against pollution resulting from extraction and processing of the minerals. Development and use of effective and clean procedures of materials extraction and processing should help in reducing conflicts between extractors and immediate users of material resources and those concerned with environmental conservation and pollution.

Electronics and Information Technology

As the world moves with a quickening pace into a postindustrial age that relies more and more on speed and capacity of information gathering, analysis, and transmission, so must developing countries prepare themselves to share in these powerful new technologies. However, there should be realistic and limited aims for developing electronics and information technology in Thailand.

In the area of computer technology, the purpose cannot be to achieve leadership, even in some narrow technological aspect. It should be to stay abreast of new developments in order to solve local technological problems and to contribute to the world market selected components of hardware and software that can be produced advantageously. The importance of computer applications in various aspects of trade, banking and finance, manufacturing, and university and civil service functions cannot be overemphasized, especially for a fast-growing country like Thailand. Telecommunication technology is equally important although the infrastructure for the telecommunication service is more under bureaucratic control. In the area of consumer electronics, there is now a budding industry with a good potential for both import substitution and export, and therefore strong scientific and technological support is needed. Finally, in the area of semiconductor technology, development is needed to support other areas of electronics and information technology as well as to build up capability in solar cell technology.

There is a shortage of manpower at all levels in electronics and information technology in Thailand (*17, 18*). The shortage is severe in both universities and the government, where salaries are not competitive with those in the private sector. Development of manpower in this area should be very cost-effective since the cost of hardware is so high. For example, it has been estimated (*18*) that in computer applications in Thailand the cost ratio of personnel to hardware is 0.67 to 1, whereas in the United States the ratio is 2 to 1. Many universities already have a capacity for postgraduate training and education programs, and there is great potential for training technicians and engineers as well. Better trained as well as more personnel in this area is essential and would not be difficult to achieve.

There are a number of areas in electronics and information technology whose development would be particularly advantageous in Thailand. Thai input-output devices, programs for utilities including word processing in Thai, voice input in Thai, and so on, are challenging areas of computer applications with immense developmental benefits. The relatively low cost of skilled labor is a favorable factor for development of software and the design and production of selected components for export. Furthermore, the local market is potentially large enough to absorb locally made consumer products.

Electronics and information technology represent areas whose development has immediate and dramatic impacts on society, especially an open society such as in Thailand. In this respect, the criterion for integration of technology with culture raises some problems. There is no doubt that traditional culture has been deeply affected by the products of electronics and information technology. However, this does not necessarily lead to disharmony, as can be seen perhaps from the example of Japan. Adaptation and selective emphasis on the harmonious aspects of the traditional culture and the new technology should benefit the society as a whole.

Development and Conservation of Land and Water Resources

The development and conservation of Thailand's natural resources fit our criteria for designation as a priority area. There is a continuing need to monitor our changing resources as well as possible hazards of geologic or atmospheric origin. There are potentially immense benefits to be obtained from the sea and inland waters through development of mariculture and aquaculture—benefits perhaps comparable to those expected from improvements in agriculture. Thailand is probably capable of developing shoreline and inland aquaculture to a much higher degree than at present, but incentives, more research, and adaptation of technology from more advanced countries are needed. Other areas of water resources management and use, requiring science and technology as integral components (*9*), include improvement in efficiency of water usage for irrigation (presently only 13 percent for Thailand), minimization of adverse effects from flooding and salination in large-scale irrigation and hydroelectric schemes, and appropriate technology for procurement of ground water.

In view of rapidly growing agroindustries and other industries in Thailand, the

need for monitoring and control of pollution is becoming acute. Development of material and energy resources must be balanced with the need for environmental conservation and pollution control. Overexploitation of forest resources in Thailand and other developing countries is an alarming example. Although the problem requires effective law enforcement and other nonscientific measures, science and technology can make essential contributions. For example, ecological studies comparing clear-cutting and selective cutting of forests can yield useful data for policy decision. Research on fast-growing trees and soil enrichment can help in afforestation efforts.

Conclusion

A number of problems related to promoting science and technology and their applications cut across all areas. Unless these problems are effectively dealt with, efforts to develop certain fields of science and technology are doomed to failure. These problems involve strengthening the infrastructure of science and technology, with emphasis on building up the quality and number of personnel at all levels. A climate needs to be created favoring the scientific and technological approach to solving problems in development, and public appreciation of the capabilities and limitations of science and technology needs to be cultivated. To do this, science education in the schools and through the mass media and other informal channels must be greatly improved and expanded.

There has been an alarming drop in the number of students pursuing careers in basic science (*19*). This trend needs to be reversed or capability in basic science in Thailand may become further diminished and unable to support applied science and technology. The lack of graduate entrants to departments of physics, despite the presence of high-caliber staffs, is an extreme example of the same trend at the higher level of education. Poor job opportunities are the most important reason, and the situation is likely to improve only when industrial development in Thailand progresses significantly. Meanwhile, it can be argued that only a few high-caliber graduates need to be attracted to a career of pure science. This situation calls for special measures in recruitment and support of gifted students, such as those recently initiated by the Institute for Promotion of Teaching Science and Technology.

As industry in Thailand becomes more sophisticated and more science- and technology-based, so is the need growing for technology transfer from abroad, R&D, better scientific and technical services, and better standards and quality control. At present, Thailand still lacks regulation on technology transfer and an effective system for its promotion, although cooperative efforts are being made by the Technology Transfer Center (Ministry of Science, Technology and Energy), the Board of Investment, and other agencies. Measures to promote R&D in the private sector are also needed because of the low activity there (*20*). The scientific and technical services required range from routine maintenance of instruments to analytical services and supply of scientific and technological information. These are essential for support of science and technology and, in view of the medium or small size of most industries, may require pooling of efforts. Promotion of standards and quality control also requires much more attention and systematic organization.

Finally, there is a great need for promotion of science and technology management and policy formation in Thailand. It has been argued that successful use of science depends on the overall quality of management rather than specifically on the degree of scientific knowledge (*21*). In Thailand, capability and personnel in policy and management are limited, but the Ministry of Science, Technology and Energy and the newly established Thailand Development Research Institute should play crucial roles in the future in the promotion of management and policy studies in science and technology.

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