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I. Srubar

Science and Development

During the past half-century, conventional understandings of science, development, and their relationship have changed radically. Formerly, science was thought to refer to a clear and specific variety of Western knowledge with uniformly positive effects on society. Formerly, development was viewed as a unidirectional process of social change along Western lines. Formerly, science was viewed as a powerful contributor to the developmental process. Each of these ideas has been subjected to insightful criticism. This article will examine science and development, concluding that the relationship between the two is problematic, partly because of the complexity of the concepts themselves. Three major theories of development are considered, together with the main types of research institutions in developing areas.

1. Science

Much of what is termed science in developing areas is far from what would be considered 'pure science' in the developed world. The 'root concept' of science involves *research*, the systematic attempt to acquire new knowledge. In its modern form, this involves experimentation or systematic observation by highly trained specialists in research careers, typically university professors with state-of-the-art laboratory equipment. These scientists seek to contribute to a cumulative body of factual and theoretical knowledge, testing hypotheses by means of experiments and reporting their results to colleagues through publication in peer-reviewed journals.

Yet when a new variety of seed is tested by a national research institute and distributed to farmers in Africa, this is described as the result of 'science.' When the curator of a botanical exhibit has a college degree, he or she may be described as 'the scientist.' When a newspaper column discusses malaria or AIDS, 'scientific treatments' are recommended. Seeds, educated people, and advice are not science in the abstract and lofty sense of the pursuit of knowledge for its own sake or systematically verified facts about the world. But they are science from the standpoint of those who matter—local people who spend scarce resources on their children's education, development experts who determine how and where to spend funds, politicians who decide whether to open a new university, corporate personnel who open a new factory in a developing region.

Perhaps the most important shift in recent thinking about science is a broadening of the scholarly view to include the ideas of science found among ordinary people. These are often *more* extended in developing areas, because of the association of science with 'modern' things and ideas. 'Science' in its extended sense includes technological artifacts, trained expertise, and knowledge of the way the world works. The importance of this point will be clear in the conclusion.

Given the fuzziness of the boundaries that separate science from other institutions, and the dependence of modern research on sophisticated technical equipment, the term 'technoscience' is often used to denote the entire complex of processes, products, and knowledge that flows from modern research activities. Even if we recognize that the term 'science' has extended meanings, it is useful to draw a distinction between (a) the institutions that produce knowledge and artifacts and (b) the knowledge that is produced. That is, on the one hand, there are organizations, people, and activities that are devoted to the acquisition of knowledge and things that can be produced with knowledge. These constitute the modern organization of *research*. On the other hand, there are *claims* involving knowledge and artifacts—often significantly transformed as they leave the confines of the research laboratory. What makes claims and practices 'scientific' is their association with scientific institutions.

Modern research capacity is concentrated in industrialized countries. Indeed, with respect to the global distribution of scientific and technical personnel, scientific organizations, publications, citations to scientific work, patents, equipment, and resources, scientific institutions display extremely high degrees of inequality. The most common indicator of scientific output is publications. In 1995, Western Europe, North America, Japan, and the newly industrialized countries accounted for about 85 percent of the world total. Leaving aside countries and allies of the former Soviet Union, developing areas contributed less than 9 percent of the world total. Much the same applies to technological output measured in patents and expenditures on research and development (UNESCO 1998).

Yet if we shift our focus from the question of inequality to the question of diffusion, an entirely different picture arises. To what extent have the *idea* *and practice* of research spread throughout the world? The main issues here involve who conducts research, on what subjects, and what happens to the results. Each of these topics is the subject of analysis and controversy.

Scientific research in developing countries began during the pre-independence era with the establishment of universities and research institutes. Research was conducted on crops and commodities for export as well as conditions (e.g., disease) that affected the profits sought by external agents from their control over the land, labor, and property of colonized peoples. Methodologies and organizational models for research were brought by European colonists to Asia, Africa, and Latin America. During the era of independence and throughout the 1970s, number of types of entities engaged in the generation of knowledge multiplied. The main scientific organizations now fall into five main types, or sectors: academic departments, state research institutes, international agencies, private firms and, to a lesser degree, nongovernmental organizations.

2. Development

The concept of development involves several dimensions of transformation, including the creation of wealth (that is, rapid and sustained economic growth) and its distribution in a fashion that benefits a broad spectrum of people rather than a small elite (that is, a reduction in social inequality). Cultural transformation (recognition of and attendant value placed on local traditions and heritage) has also been viewed as an important aspect of the process since the early 1980s. There is general agreement that development in the second half of the twentieth century is not a mere recapitulation of the process of industrialization that characterized Europe and North America in the eighteenth and nineteenth centuries.

Three theoretical perspectives, with many variations, have dominated development studies: modernization, dependency, and institutional. One way of distinguishing these theories is by their position on the ways in which relationships external to a country affect the process of change. Since scientific institutions and knowledge claims are of external origin, each of these perspectives views science and technology as important in the development process, with very different assessments of the costs and benefits.

2.1 Modernization

The oldest approach, sometimes called modernization theory, focused on the shift from a traditional, rural, agricultural society to a modern, urban, industrial form. Transformations internal to a country (such as formal education, a market economy, and democratic political structures) are emphasized, while external relationships are de-emphasized. However, science was the exception to this, available to benefit developing nations through *technology transfer* from Western sources. This idea relied on two assumptions. One was the 'hardness' of technological artifacts—their alleged independence from people and culture, their seeming ability to produce certain effects 'no matter what.' The second was the 'linear model' of technology development in which the (a) discoveries of basic science lead to the (b) practical knowledge of applied science and finally to (c) technological applications such as new products. In retrospect, both of these assumptions were simplistic in any context, but in the developing world they were especially problematic.

The assumption of 'hardness' has been replaced by the generalization that the uses, effects, and even the meanings of technological artifacts are affected by the context of use. First, effective technologies, from automobiles to indoor plumbing, do not typically stand alone, but are embedded in *systems* that provide infrastructure (roads, sewage treatment) which is often lacking. Second, the provision of artifacts such as buildings and computers is much easier than their maintenance, which requires both resources and knowledge. Third, introduction of new technology involves a multiplicity of consequences—positive and negative, short term and long term, economic and ecological. Many of these consequences are unpredictable, even in those rare cases where such foresight is attempted.

The case of the Green Revolution is illustrative. In the 1960s, widespread food shortages, population growth, and predicted famine in India prompted major international foundations to invest research and technology transfer efforts towards the goals of increasing agricultural productivity and the modernization of technology. What resulted were new kinds of maize, wheat, and rice. These modern varieties promised higher yields and rapid maturity, but not without other inputs and conditions. They were, rather, part of a 'package' that required fertilizers as well as crop protection inputs such as pesticides, herbicides, and fungicides—sometimes even irrigation and mechanization. Moreover, seed for these varieties had to be purchased anew each year.

The consequences of the Green Revolution are still debated, and there is little doubt that many of them were positive. Famine in India was averted through increased yields, but the benefits of the technology required capital investments that were only possible for wealthier farmers. Not only did the adoption of new technology increase dependence on the suppliers of inputs, but it was claimed to increase inequality by hurting the small farmer—one intended beneficiary of the technology. The actual complexity of the outcomes is revealed by one of the most sophisticated assessments—modern seed varieties do reach small farmers, increase employment, and decrease food prices, but the benefits are less than expected because the poor are increasingly landless workers or near landless farm laborers (Lipton and Longhurst 1989).

What is important for the question of the relationship between science and development is that the products and practices of the Green Revolution were research-based technology. This technology was often developed in *international* research institutes funded by multilateral agencies such as the World Bank and bilateral donors such as the US Agency for International Development. Since the combined resources of these donors dwarf those of many poor countries, their developmental and research priorities constitute a broad global influence on the nature of science for development. The largest and most visible of these organizations form a global research network, the Consultative Group for International Agricultural Research (CGIAR) which grew from 4 to 13 centers during the 1970s as support by donors quadrupled. The influence of this network of donors and international agencies was clearly evident in the early 1990s when environmental concerns led to an emphasis on 'sustainability' issues. This led to a change in CGIAR priorities, as the older emphasis on agricultural productivity shifted to the relatively more complex issue of natural resource management.

2.2 Dependency

Modernization theory emphasized internal factors while making an exception of science. Dependency theory and its close relative, world system theory, emphasized the role of *external relationships* in the developmental process. Relationships with developed countries and particularly with multinational corporations were viewed as barriers. Economic growth was controlled by forces outside the national economy. Dependency theory focused on individual nations, their role as suppliers of raw materials, cheap labor, and markets for expensive manufactured goods from industrialized countries. The unequal exchange relationship between developed and developing countries was viewed as contributing to poor economic growth. World system theory took a larger perspective, examining the wider network of relationships between the industrialized 'core' countries, impoverished 'peripheral' countries, and a group of 'semiperipheral' countries in order to show how some are disadvantaged by their position in the global system. Because of their overspecialization in a small number of commodities for export, the unchecked economic influence of external organizations, and political power wielded by local agents of capital, countries on the periphery of the global capitalist system continue to be characterized by high levels of economic inequality, low levels of democracy, and stunted economic growth.

What is important about the dependency account is that science is not viewed in benign terms, but rather as one of a group of institutional processes that contribute to underdevelopment. As indicated above, research is highly concentrated in industrialized countries. Dependency theory adds to this the notion that most research is also conducted for their benefit, with problems and technological applications selected to advance the interests of the core. The literature on technology transfer is also viewed in a different light. The development of new technology for profit is associated with the introduction and diffusion of manufactured products that are often unsuited to local needs and conditions, serving to draw scarce resources away from more important developmental projects. The condition of dependency renders technological choice moot.

This concern with choice, associated with the argument that technology from abroad is often *imposed* on developing countries rather than *selected* by them, has resurfaced in many forms. In the 1970s it was behind the movement known as 'intermediate' technology, based on the work of E. F. Schumacher, which promoted the use of small-scale, labor-intensive technologies that were produced locally rather than of complex, imported, manufactured goods. These 'appropriate' technologies might be imported from abroad, but would be older, simpler, less mechanized, and designed with local needs in mind. What these viewpoints had in common was a critical approach to the adoption of technology from abroad.

By the late 1980s and 1990s even more radical positions began to surface, viewing Western science as a mechanism of domination. These arguments were more closely related to ecological and feminist thought than to the Marxist orientation of dependency theory. Writers such as Vandana Shiva proposed that Western science was reductionist and patriarchal in orientation, leading to 'epistemic violence' through the separation of subject and object in the process of observation and experimentation (1991). 'Indigenous knowledge' and 'non-Western science' were proposed as holistic and sustainable alternatives to scientific institutions and knowledge claims. Such views had an organizational base in nongovernmental organizations (NGOs), which received an increasing share of development aid during this period, owing to donor distrust of repressive and authoritarian governments in developing areas. NGOs have been active supporters of local communities in health, community development, and women's employment, even engaging in research in alternative agriculture (Farrington and Bebbington 1993).

2.3 Institutional Theory

Institutional theory seeks to explain why nations are committed to scientific institutions as well as what forms these take. The central theme is that organizational structures developed in industrialized countries are viewed by policy makers, donors, and other states as signals of progress towards modern institutional development and hence worthy of financial support. Regardless of the positive or negative consequences of their activities, the introduction and maintenance of certain forms in tertiary education and government serves to communicate this commitment. Institutional theory provides an account of the growth and structure of the academic and state research sectors, as successful organizations in industrialized nations operate as models far from their original contexts.

Academic departments consist of researchers grouped by subject, each of whom is relatively free to select research projects. They bear the closest resemblance to the root concept of science introduced at the beginning of this article. But research requires time and resources. In areas such as sub-Saharan Africa, laboratories and fieldwork are poorly funded, if at all, since many institutions can barely afford to pay salaries. Professors teach, consult, and often maintain other jobs. Research is conducted as a secondary activity and professional contacts with other scientists in Europe and the US are few.

Equally important to the scientific establishment are state research institutes. These organizations are agencies of the state, they are charged with performing research with relevance to development, with health and agriculture the two most important content areas. They are linked to ministries, councils, and international agencies as well as systems (such as Extension Services in agriculture) that deliver technology to users—again based on a model from the developed world.

3. Relationships Between Science and Development

The popularity of dependency arguments and the resurgence of interest in indigenous forms of knowledge implies continued competition for older views of the uniformly positive effects of science. Institutional theory provides an alternative account of the spread of science and its organizational forms. But two features of current scholarship may prove more significant in the long run.

First, extreme diversity exists among developing areas in terms of their economic, social, and cultural patterns. It makes decreasing sense to speak of 'development' as an area of study. Latin American nations, for example, are generally far better positioned than the nations of sub-Saharan Africa. There is even wide variation within countries, as the case of India makes clear. While much of India qualifies as a developing area, it is among the world's top producers of scientific work, has a technically skilled, English-speaking labor force second only to the US, and is a leading exporter of computer software for corporations.

Second, 'science' is viewed as having many dimensions, many effects, and fuzzy institutional boundaries, but it is always a feature of the modern, industrial, interconnected world. Science cannot be the cause of modernization because, in its diverse institutional articulations and its evolving fit with society, science exemplifies the meaning of modernization itself.

See also: Biomedical Sciences and Technology: History and Sociology; Development: Social-anthropological Aspects; Development Theory in Geography; Innovation and Technological Change, Economics of; Research and Development in Organizations; Science and Technology, Anthropology of; Science and Technology: Internationalization; Science and Technology, Social Study of: Computers and Information Technology; Technology, Anthropology of

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W. Shrum

Science and Industry

The premodern industrial craft economy provided the initial intersection of industry with science through scientific instrument making. The development of scientific inquiry through craft-based production, and its effects, can be seen in Galileo and the telescope, chang-

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