Technological Semantics and Technological Practice: Lessons from an Enigmatic Episode in Twentieth-Century Technology Studies

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This paper is a review of words and their meanings in the field of technology studies, and an analysis the semantics of an idealistic international technology-related social movement that flourished briefly during the second half of the twentieth century. Sloppy nomenclature employed by proponents and observers of the movement led to people with opposite views appearing to agree (and vice versa), with the consequence that the movement's valuable policy insights exerted only marginal influence on mainstream technology policy. I conclude that poor technological semantics may undermine effective technological practice. Suggestions for a constructive technological nomenclature are presented.

The core thesis of this paper is that, in the sphere of technology, good semantics can lead to good practice and, conversely, poor semantics can lead to poor practice. This claim will be supported by some analysis of the semantics of an international technology-related social movement that rose to prominence in the 1970s and 1980s. Before addressing my thesis and its supporting evidence directly, however, it will be helpful to reflect briefly about the prominence of technology and technological semantics in contemporary industrialized societies.

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The Ubiquity of Technology

Technology has become the *leitmotif* of the modern world and a linchpin of the international economy. Businesses, governments, community organizations, and individuals, seemingly everywhere, look to technology as a key to attaining their goals. In opposition, there are those who are reluctant to adulate technology, and who point to the technological causes of human and environmental problems. Even these unbelievers, however, seem unable to avoid becoming embroiled in the new polemics of technology and to escape the technological milieu against which they protest. In short, during the twentieth century technology has become ubiquitous.

The ubiquity of technology has at least two important dimensions: the rise of technology itself as a part of society and the rise of human concern about technology.

The first dimension, the rise of technology itself, means that the practical functions of society and the economy (such as agriculture, transportation, building construction, manufacturing, the fighting of wars, communication, health care, and even analysis of problems) are increasingly carried out in a technological manner. Whereas these functions used to be carried out *directly* by people, sometimes aided by technological artifacts, they now tend to be *mediated* by technologies or technological systems.

For example, whereas most people used to have a *direct* role in the cultivation and preparation of food, in urban-industrial societies this relationship is now *mediated* by household appliances for reheating factory-processed foods, bought from supermarkets that have technologically sophisticated food storage and distribution systems; and the raw food itself is normally produced in technologically complex ways, such as by mechanized farms producing genetically-engineered crops. Even functions that used to be thought of as intimate and personal activities between individual people, such as producing children, may now be conducted artificially, by the application of techniques such as in vitro fertilization, embryo transplants, artificial insemination, and embryo storage.

Of course, technology has probably always been present in human society, perhaps in the form of simple hunting, farming, cooking, food preservation, or fire-making implements. Its pervasiveness appears to have increased so much, however, that it may no longer be thought of only as a collection of "things" to help people do a better job of whatever they want to do. Rather, technology has become an integral part of the environment in which people live, form their values, and make decisions.

For example, while the automobile may still be quite legitimately described as "a machine to get me from *point A* to *point B*," it is more than that. The shape of the landscape in modern cities, such as Los Angeles, is molded by the requirements of car travel: new technologies such as cellular phones have emerged as a means of coping with time spent in automobiles; "drive-in" convenience outlets now exist for almost any service such as banking, takeout food, and consumer goods sales; and businesses restructure their organizational form to take advantage of the opportunities for decentralizing certain activities to "back offices" in the suburbs, to which employees may travel by car. The automobile becomes part of the *context* that determines where *point A* and *point B* are, and how frequently the driver needs to travel between them; it is no longer simply a means for connecting *point A* and *point B*.

The general point here is that the ubiquity of technology in society transforms technology from simply being a collection of *means* for making human actions easier into a force for framing the *ends* that human actions serve. It is this phenomenon that was popularized through Jacques Ellul's writings during the 1960s and that helped make the phrase "the technological society" (Ellul, 1964) common.

The second dimension of the ubiquity of technology, the rise of human concern about technology, has no doubt been fed by popular perceptions of the emergence of the technological society. Until recently the general public in the now industrialized societies tended to relegate technology to the professional domain of the engineer or technologist, or take it for granted as the benevolent provider of material wealth. While turbulent responses to the introduction of new technology did occur during earlier periods, it would appear that popular attitudes towards technology *per se* are now more intense and deeply rooted. This insight is probably readily apparent to the casual observer, but a number of serious studies have now been published that confirm such observations about public attitudes to technology (and science) (Pecotich and Willoughby, 1989; Beveridge and Rudell, 1988; Postman, 1988; Kuhlman, 1987; Williams, 1986; Miller, 1983; Yankelovitch, 1982; Pion and Lipsey, 1981; Maderthaner et al., 1976; Mazur, 1975).

The normative status of technology is now contentious. Some view it as a savior, capable of solving most of the perennial problems of human existence; others view it as a demon that threatens the health of human society and the environment. Some argue that a felicitous future will only be possible with continually increasing technological growth; others plead for the rejection of technology, arguing that it is intrinsically destructive. It is not the purpose of this paper to explain the details of public disagreements over the normative status of technology, as this has been explored elsewhere (e.g., Willoughby, 1990; Yearly, 1988; Frankel, 1987; Borgman, 1984; Braun, 1984; Mazur, 1981; Nelkin, 1981; Gendron, 1977; Schuurman, 1977; Ferkiss, 1969; Marcuse, 1964; Mumford, 1963; Jünger, 1956). Rather, my purpose is to recognize the contentious role of technology in society and to explore some of the implications this has for semantics in the field of technology studies.

The ubiquity of technology in contemporary society means that most social, political, economic, and environmental problems have a technological dimension to them. This means that most political, administrative, or judiciary functions of society that at one time might have been relatively free of technological considerations must now carefully incorporate such considerations. Thus, political debates about whether a country's energy policy ought to emphasize nuclear energy, energy conservation, fossil fuels, or renewable energy sources revolve around highly *technical* disputes over the relative safety of alternative waste disposal technologies. Likewise, debates about the ethical legitimacy of military action may hinge on *technical* disputes about the ability of the attacker to deploy the latest military technology to win a strategic target without hurting civilians. Or, debates on whether to introduce a national identity card may hinge on the possibility of providing technological assurance of confidentiality of information about citizens.

In summary, the ubiquity of technology *within* society has meant that human society *itself* has become more technological in character.

The Importance of Technology-Practice

A consequence of society becoming more technological is that a particular sphere of human endeavor—what will be labeled here as "technology-practice"—has become more important. The meaning of "technology-practice" will be explained later (see Glossary at end) in more detail, as will be the meaning of "technology." Basically, however, what this means is that technological competence has become a prerequisite for competence in other spheres of human endeavor.

It is now commonplace for relative technological prowess to be seen as a measure of relative economic competitiveness between nations, or relative commercial strength between business enterprises. Competency in the sphere of technology-practice is important not only to economic competitiveness, however, but also to a community's capacity to solve problems in spheres of human endeavor such as political conflict resolution, human resources development, health care, environmental management and remediation, social service delivery, household management, or interpersonal communication. Two examples will illustrate this.

First, the importance of competence in technology-practice vis-à-vis political conflict resolution may be illustrated by the role of technological change in the timber milling industry. As logging and timber milling have become more capital intensive, small towns throughout the world with economies based around these industries have experienced economic problems connected with rising unemployment among timber workers. This creates political pressures to intensify logging as a means of maintaining employment levels. At the same time, the growth of environmentalism means that logging companies also experience political pressures from the opposite extreme, aimed at reducing the intensity of logging operations. This may lead to political conflict between families and sympathizers of loggers and those people in the community who have a strong concern for environmental preservation.

Viewed from one perspective, technological change may be legitimately described as a source of such political conflict. From another perspective, however, it may be viewed as a potential source of rapprochement. The application of micro-computer control systems to a small-scale sawmill can make it possible to increase the efficiency of finished-timber output from a given log input, and improve the commercial competitiveness of these normally labor-intensive operations. By such means it is possible to both reduce the amount of logging required for a given level of timber production, and increase or maintain local employment levels. Thus technological competence (of a more sophisticated kind than that which is aimed simply at the automation of large-scale mills) may help appease the fears of both environmentalists and timber workers. This, in turn, may assist resolution of conflict between social groups in timber towns.

A second example may be drawn from the spheres of interpersonal communication and household management. A person who travels frequently in his or her profession, or who operates a business in more than one location, may have troubles maintaining contact with family, friends, and colleagues, and may have trouble managing household practicalities such as paying bills on time, ensuring bank accounts are balanced, or ordering household services efficiently.

There are many electronic systems now available to help solve these kinds of problems, e.g., facsimile machines, touch-tone telephone services, electronic funds-transfer networks, computerized electronic mail systems, modems to connect personal computers with telephone systems, cellular telephones, voicemail services, telephone answering machines, and digital paging services (you know ... the kind designed to sound-off during a performance!). Anyone with the above kind of lifestyle, and who has tried to use such technological aids seriously can readily relate anecdotes of frustrating experiences where "the system was down," "the software had a bug," "the networks were not compatible," "the computer malfunctioned," "the instruction manual was ambiguous," "the file was corrupted with a virus," "I eventually got through, but it took me until 1:00 a.m.," "I forgot the commands," "Somebody else got credited with my payment," "I gave up after the voicemail computer asked me to press '9' if I wanted to leave a message for the operator," or "the computer system's firewall wouldn't allow a file of that format to enter the network."

The point here is not that all of these communication and computing technologies are not useful (to the contrary), but rather that their usefulness depends upon a certain degree of *mastery of the technology-practice*, even by "dumb users." For such technologies to actually help an "average" business person or householder, that person must expend a considerable amount of effort both to evaluate options in the technology before buying or subscribing, and to become proficient in the practical operations of the technology. This level of competence in technology-practice is normally not as high as the level of competence required of engineers, technicians, and systems managers, but it is still technological in nature. Thus, in the technological society, lay people (i.e., non-technicians) need to develop a degree of comfort in technology-practice in order to cope with the practicalities of modern life. Technology can no longer be left only to the experts ... well, not unless you don't care if it doesn't work properly.

Human competence in technology-practice is not just a matter of technical experts designing a more powerful machine than their competitors. Rather it involves at least two other important processes. First, it is important that *technologies* and technological systems be designed and constructed so that their use is convenient and efficient for non-experts. An example of this phenomenon in the computing market would be the emergence of the Apple Macintosh group of personal computers and software.

Second, *institutions* need to emerge which make it easier for non-experts to manage technology "as it is." Once again, in the computing market, an example of this would be the emergence of organizations such as the Berkeley Macintosh Users' Group (an independent community organization that runs meetings, newsletters, magazines, and advisory services for users of Macintosh computers). The various consumers' organizations that publish magazines that evaluate alternative brands of consumer products, or even the companies that publish automobile magazines that may be found in newsagents' stands, may also be examples of the phenomenon.

To summarize thus far, the ubiquity of technology in society, which has given more importance to technology-practice as a sphere of human practice, indirectly creates the need for both more sophisticated approaches to technological design and new types of technology-related institutions. This is partly expressed in the growth of technical training institutes and technical universities, but also in the growth of special technology-related organizations and services for lay people, as well as academic programs in technology management at universities.

The Problem of Technological Semantics

As the practicalities of human society and governance become increasingly entwined with technology, human language increasingly contains references to matters technological. Whereas the work of a scholar at a desk might once have been described as "writing a paper," the activity might now be described as "working at a computer" or "editing some files on disk." In the area of banking, "I wonder whether the teller will recognize me well enough to give me the money?" might be replaced by a phrase such as "Will the Automatic Teller Machine accept this card if I type that PIN?" Put simply, "tech talk" has become an important part of everyday language.

An essential dimension of technology-practice is the development and use of technology-related language. Developing competence in technology, and in solving practical human problems linked with the application of technology, requires the assignment of words to technological objects and processes, and to concepts about the human use of technology. Without such language, problem solving in technological-practice becomes difficult because problems become hard to define, clarify, and communicate. With new technology, however, new phenomena in technology-practice emerge. These require new terms. Human language must therefore adapt, and this process is necessarily experimental, complicated, ambiguous, messy, and problematical. Nevertheless, the process is inevitable.

Words carry meanings, and the meanings associated with a set of words may be quite different for one person compared with another. Semantic problems are therefore a normal part of human society. When technological language becomes prominent in a society, concomitant with a rise in the importance of technology-practice, technological semantics become more significant. Thus, the ubiquity of technology in society raises the importance of technology-practice as a sphere of human competence, and raises technological semantics as an element of human practice. This leads towards the main concern of this paper: What is the relationship between technological semantics and the familiar stuff of contemporary human life?

The core argument of this paper, as mentioned earlier, is that in the sphere of technology, good semantics can lead to good practice, and, conversely, poor semantics can lead to poor practice.

A corollary of this argument is that because technology-practice has become a prominent part of human affairs, good technological semantics is becoming a prerequisite of effective performance in many fields of human endeavor. Another way of putting this is to say that technological semantics have become a problem for society.

Before the above argument is presented in detail, the meaning of "good semantics" and "good practice" should be explained. Here, "good semantics" means language that involves richly textured nomenclature with internally consistent definitions; it also refers to a system of words that is not only capable of neatly and consistently describing phenomena but that is capable of helpfully elucidating critical contemporary issues. "Good practice," in the sphere of technology, refers here to technology-practice in which technology effectively meets the primary objectives which it is intended to serve without creating significant negative side effects, or without negating secondary objectives intended for the technology.

Identifying, as abstract principles, some of the general parameters of good practice in technology is one of the central challenges of technology studies as an academic field. This challenge will only be met if an orthodox language of discourse is established, at the center of which is a lucid concept of technology. Presently, however, the field of technology studies appears to be stuck in a semantic quagmire.

The trend in the literature and in the conference circuit to describe almost anything as "technology" (it seems easier to get a paper published that way!) means that, because technology is everything, it is also, in effect, nothing! Consequently, the word "technology" is used by commentators with such a wide variety of meanings that it is exceedingly difficult to know whether two people saying ostensibly similar things about "technology" have even remotely similar meanings in mind. The word "technology" can mean anything from "organization" (Hibbard and Hosticka, 1982: 4), "a human activity" (Goldhaber, 1986: 4) or "routineness" (Miller, Glick, Wang, and Huber, 1991) to a "form of life" (Winner, 1986); and for some (e.g., Reinecke, 1982) it means little more than "computers!"

One reason to be concerned about this trend is that it degrades language and makes it difficult to talk coherently about matters technological. For example, at an international meeting on large-scale technical systems attended by the author of this paper a whole session was devoted to discussing cities as large-scale technical systems because they are large and may be construed as systems. A debate about whether or not they are really "technical" systems could not be resolved because of lack of agreement about the meaning of "technical." The inability of the meeting to agree on the meaning of technological nomenclature meant treating a city as a similar system to a telecommunications network.

This kind of situation, while probably quite familiar to scholars, may be passed off as of no real importance because it is only of relevance to academic pedants. Confusion about the nature of technology, however, has very practical ramifications for governments (who may allocate funds to technology programs in the belief that economic benefits will ensue) or businesses (who may invest in the stocks of "high technology" companies in the belief that they will yield high returns on investments). Does investment in technology mean investment in people, education, science, skills training, the purchase of machines, the purchase of intellectual property, the reform of organizations, or the provision of higher salaries for engineers? It is difficult to make informed decisions about such matters without a clear idea of what we have in mind by the word "technology."

A case study of one episode in the history of technology studies may be instructive here. An example of where poor technological semantics has led to inadequacies in technological practice may be found in the "appropriate technology" movement that emerged in the mid-1970s. This movement, popularized through the use of E.F. Schumacher's emblematic phrase, "small is beautiful" (Schumacher, 1973), provided a lively stimulus to the emergence of technology studies as a field, yet the sloppy use of language, apparent in the movement's literature, meant that people with opposite views frequently appeared to be saying the same thing. One result of this sort of confusion was that many of the important policy insights of this movement were overlooked in mainstream technology policy debates that took place during the closing two decades of the twentieth century.

While a certain fluidity in the use of language is probably an essential part of a living academic discipline, some kind of semantic orthodoxy at the core of a field is nevertheless necessary to facilitate orderly policy analysis and debate. In this paper I therefore hope to assist the emerging formation of a core nomenclature to unify discourse in the general field of technology studies. My intention is not be to set definitions in concrete but rather to outline a workable nomenclature that will, no doubt, evolve over time.

By reviewing the semantic dimensions of the appropriate technology social movement I hope to elucidate a general approach to semantics for the broader field of technology studies. Before outlining suggestions for a preferred approach to technological semantics, a range of existing approaches to defining technology will be examined.

The Semantic Problems of Appropriate Technology

By drawing upon a particular sub-field within the technology studies literature—the debate over the appropriateness of technology—the following analysis illustrates how a more coherent approach to semantic conventions might enhance scholarship and policy analysis in technology studies.

Comprehensive Definition

The concept of Appropriate Technology was first synthesized by the British economist E.F. Schumacher, drawing upon important foundations laid by

Gandhi and others (Schumacher, 1962a; Schumacher, 1965; Hoda, 1976). Drawing upon the ideas of that pioneering literature, an appropriate technology is defined here as a *technology tailored to fit the psychosocial and biophysical context prevailing in a particular location and period* (Willoughby, 1990: 37). This definition does not completely embrace all the viewpoints that have emerged under the rubric of "appropriate technology," but is comprehensive enough to incorporate most of the credible definitions in the literature, and it accords closely with the original ideas of Schumacher. Nevertheless, as the following discussion shows, despite the fact that the primary progenitor of the appropriate technology literature commenced with a coherent set of ideas, and despite the fact that a simple and cogent expression of those core idea can be articulated, the pertinent literature has been plagued by inconsistency in the application of the "appropriate technology" concept and rubric.

Definitional Problems

During the 1970s and 1980s the rubric of "appropriate technology" was taken up by a plethora of organizations, interest groups, individuals and schools of thought, and its usage consequently became loose and confusing. It was used variously to refer to particular philosophical approaches to technology (Drengson, 1982), to ideologies (Morrison, 1978), to a political-economic critique (Lodwick and Morrison, 1982), to social movements (Winner, 1979), to economic development strategies (Robinson, 1979; Diwan, 1979), to particular types of technical hardware (Canadian Hunger Foundation, 1976; Darrow, 1976; Magee, 1978), or even to anti-technology activities (Office of Technology Assessment, 1981: 18). The diffuse nature of the Appropriate Technology movement during that period was illustrated by the comments of one of its veteran practitioners and critics who described Appropriate Technology (dubbed "AT" by many of its proponents) as being part lay religion, part protest movement, and part economic theory, and who censured it for the "bandwagon" effect that it produced. He wrote as follows (Rybczynski, 1980: 28-29):

> AT was a protest movement and for many it also became a True Belief. But it was more than that; AT developed into a bandwagon of Pullman-car proportions. And what a strange set of travelling companions one found: well dressed World Bank economists rubbing shoulders with Gandhians in metaphorical, if not actual *dhotis*; environmentalists, Utopians, and bricoleurs; conventional politicians like President Jimmy Carter and less conventional politicians like Governor Jerry Brown of California who had both met E. F. Schumacher (himself recently made a Companion of the British Empire by Queen Elizabeth II).

In practice the term "appropriate technology" was used to describe far more than just technology and, as Rybczynski's comments indicate, it was a symbol for a heterogeneous social movement that had not itself reached universal agreement on what the notion meant. Any concise definition (such as the one I have provided above) must therefore be stipulative and not merely descriptive.

After Appropriate Technology was first publicly promoted by Schumacher and colleagues at a conference at Oxford University in 1968, and following its subsequent popularization through the publication of Schumacher's seminal book, *Small is Beautiful: A Study of Economics as if People Mattered* (Schumacher, 1973), many related terms came into widespread use. Examples include: "alternative technology" (*Undercurrents*, 1972-1985), "appropriable technology" (de Pury, 1983), "community technology" (Hess, 1979; Wade, 1975), "convivial tools" (Illich, 1973), "eco-technology" (Bookchin, 1977; Boyle, 1984), "humanized technology" (Fromm, 1968), "intermediate technology" (Schumacher, 1962), "liberatory technology" (Bookchin, 1971), "light-capital technology" (Long, 1977), "modest technology" (Vacca, 1980), "participatory technology" (Carrol, 1971), "progressive technology" (Marsden, 1970), "radical technology" (Boyle, 1976), "soft technology" (Clarke, 1972), "technology with a human face" (Dunn, 1978), "utopian technology" (Dickson, 1974), "vernacular technology" (Illich, 1980), or "village-level technology" (Lutheran World Service, 1977). Each of these terms reflected their author's particular viewpoint, and consequently exhibited considerable diversity in the meanings attached to them. This led to some confusion and unproductive polemic. The definition stipulated in this paper, in contrast, is intended to be consistent with the original ideas of Schumacher, to be comprehensive enough to embrace the majority of the credible ideas implied by the terms just listed, but yet specific enough to be of practical use.

In addition to the diversity of ideas associated with Appropriate Technology and the diversity of terms related to the concept, a variety of definitions of the term itself also appeared. Considerable discussion of the definitional problems appeared in the technology studies literature, and two contrasting approaches emerged: these may be labeled here as the *specific-characteristics* approach and the *general-principles* approach. The stipulative definition proposed in this paper is of the latter type, the *general-principles* approach. Both approaches to defining Appropriate Technology have their own advantages and disadvantages, as discussed below. Definitions of the former type tended to predominate within the Appropriate Technology movement itself; and among those people outside the movement who were familiar with its main ideas, a concept of Appropriate Technology in keeping with the specific-characteristics approach also appeared to predominate (e.g., Cooper, 1979; Stewart, 1983; Reddy, 1979; Thomas, 1979; Jéquier, 1976; Jéquier, 1979; Miles, 1982).

General-Principles Approach

The general-principles approach has the advantage that it abides by the normal conventions of language by keeping to the commonly accepted meaning of words. The word "appropriate," employed as an adjective, conventionally means that something (technology, in this case) is specially fitting, suitable, proper, or applicable for or to some special purpose or use (Murray, 1933; Skeat, 1910; Sykes, 1976). Used in this way, the adjective places emphasis on technology as a means to certain ends and on the importance of articulating the ends in each case. It raises the question, "Appropriate to what?" The general-principles approach to defining Appropriate Technology contains no specific and tangible content. Rather, it emphasizes the universal importance of examining the appropriateness of technology in each set of circumstances.

A difficulty with this type of definition is that it is very formal. While this fact gives it validity, its all-embracing nature makes it somewhat vague and amorphous. Consequently, it is possible for opposing interest groups in a community to adopt the rhetoric of Appropriate Technology while in practice promoting radically different types of technology. This was demonstrated, for example, by the difference of approach between Roby and Swinkels, who both participated in a session of an international conference of the Australian and New Zealand Association for the Advancement of Science on "appropriate levels of technology for Western Australia." Roby (1979) argued the case for low-cost, small-scale technology, while Swinkels (1979) argued the case for costly, large-scale technology—both speakers employing the same rubric. A further example was Robertson's use of the term "appropriate technology" as part of his advocacy of the CANDU nuclear reactor system (Robertson, 1978; Institute for Local Self Reliance, 1981), in stark contrast to the pronounced anti-nuclear stance of the Appropriate Technology movement in general (Bender, 1975; Lovins, 1975; Merrill, 1977; Schumacher, 1973: 24-135).

The lack of specific criteria and parameters leaves the abstract type of definition open to diverging interpretations at the practical level. This is because all technology must be "appropriate" for something—irrespective of the possible absurdity of that "something." A further problem with the general-principles type of definition is that the widespread usage of the term "appropriate technology" during the 1970s and 1980s in fact invoked connotations of specific characteristics, even when it was defined in general terms—this led towards trivial and sometimes fatuous usage of the term, as illustrated by the article entitled "Pen registers: The 'appropriate technology' approach to bugging," which appeared in the journal of the American Association for the Advancement of Science (Shapley, 1978).

Specific-Characteristics Approach

The specific-characteristics approach avoids the above difficulties by assigning specific and tangible operational criteria to the definition. In this way the specific-characteristics definition is more than a concept about the nature of technology and the way it relates to ends. It is simultaneously a normative statement (because it assumes priority for certain ends rather than others) and an empirical statement (because the practical criteria of appropriateness must be based upon some assessment of which technical means generally best serve the ends in question). Whereas the general-principles approach tends to leave the evaluation of ends and means relatively open, the specific-characteristics approach embodies the results of previous efforts to evaluate both of these factors. The specific-characteristics type of definition is therefore of more immediate practical use because it contains various signposts for planning and decision making. It contains substantive judgments about the real nature of particular technologies in particular contexts.

Despite these advantages, the rhetoric of the specific-characteristics approach has been employed for trivial and misleading purposes as much as that of the general-principles approach. For example, in deference to the reputed advantages of small-scale and low-cost technology, Schumacher's phrase "small is beautiful" has become something of a symbol of the Appropriate Technology movement; the phrase has now been used with reference to the possible emergence of smaller and cheaper fusion reactor technology—despite its unproven nature and its high cost relative to other forms of energy technology and its inability to measure up easily against most of the commonly accepted criteria of Appropriate Technology (Waldrop, 1983).

Comparison of Definitions

Some examples from the literature will illustrate these two approaches. The following three quotes from an analyst of Third World affairs (Harrison, 1980: 40), a report from a United Nations Industrial Development Organization conference (United Nations Industrial Development Organization, 1979: 4), and a philosopher of technology (Drengson, 1982: 103), respectively, are examples of the general-principles approach to defining appropriate technology:

> "Appropriate technology" means simply any technology that makes the most economical use of a country's natural resources and its relative proportions of capital, labour and skills, and that furthers national and social goals. Fostering AT means consciously encouraging the right choice of technology, not simply letting business men make the decision for you.

> The concept of appropriate technology was viewed as being the technology mix contributing most to economic, social and environmental objectives, in relation to resource endowments and conditions of application in each country. Appropriate technology was stressed as being a dynamic and flexible concept which must be responsive to varying conditions and changing situations in different countries.

> "Appropriate (technology)" here refers to the right and artful fit between technique, tool and human and environmental limits.

The next three quotes, from an O.E.C.D. economist (Jéquier, 1983: 1), a brochure from an American Appropriate Technology organization (National Center for Appropriate Technology, 1981: 1), and from a science journalist (Wade, 1980: 40), respectively, illustrate the specific-characteristics approach:

> Appropriate technology (AT) is now recognized as the generic term for a wide range of technologies characterized by any one or several of the following characteristics: low investment cost per workplace, low capital investment per unit of output, organizational simplicity, high adaptability to a peculiar social or cultural environment, spar-

> ing use of natural resources, low cost of final product, or high potential for employment.
>
> An appropriate technology is relatively inexpensive and simple to build, maintain and operate; uses renewable resources rather than fossil fuels, and does not require high energy concentrations; relies primarily on people's skills, not on automated machinery; encourages human scale operations, small businesses and community cohesion; is protective of human health, and is ecologically sound.
>
> Appropriate technology differs from the other kind in being labour-intensive, accessible to its users, frugal of scarce resources, unintrusive on the natural ambience, and manageable by the individual or small groups.

The first three definitions were generalized formulations emphasizing the achievement of a good fit between technology and its context, and they avoided explicit normative assertions. The latter three clearly exhibited elements of advocacy and stipulation and they also gave the reader a better comprehension of the actual type of technologies that were typically associated with the Appropriate Technology movement.

In some cases, as illustrated by the following quote from a study of the commercial prospects of "AT" in the United States (Magee, 1978: 2-3), the specific-characteristics approach was taken to extremes by defining appropriate technology in terms of specific tangible features of the hardware involved:

> In order to concentrate on specific aspects of small AT businesses, the author is defining appropriate technology in terms of products and technical systems—solar collectors, composting toilets, recycling, organic agriculture, wood stove manufacturing, small-scale hydropower, energy conservation, methane, greenhouses, adobe, and so on.

While the author of the study just mentioned provided reasons for taking such an approach in that particular case, the definition exemplified a fundamental problem with the specific-characteristics definitions. They broke the conventions of normal language by giving the word "appropriate" a substantive meaning it did not have in general usage. The phrase "appropriate technology," a noun preceded by a qualifying adjective, became a compound word "appropriate-technology," which amounted to being just a noun but with the adjectival connotations associated with the word "appropriate." The semantic confusion resulting from widespread adoption of the specific-characteristics approach was significant for at least two reasons.

Firstly, it resulted in a lack of rigor in the analyses and action programs of people within the Appropriate Technology movement, leading to considerable waste of scarce resources. Secondly, it did damage to the way in which the general-principles approach to Appropriate Technology was received by policy makers and the broader public—who may have ignored its value as a policymaking tool because of its association with some community activities and technical experiments with very limited applicability or isolated relevance.

In addition to the above problems, the adoption by a country or political group of policies for the promotion of Appropriate Technology, where such policies were based upon a specific-characteristics definition, could lead to the adoption of technology that was in fact inferior or did not best serve stated social, economic, or environmental objectives. The more specific the characteristics in the definition became, the more static the definition became, with the result that the responsiveness of the associated policies to the dynamic environment (both natural and human) may also have been reduced. When discussing this problem, a scholar of technology and development economics demonstrated the semantic dilemma that had been created by the wide usage of the specific-characteristics approach within the Appropriate Technology movement. By adopting the terminology of this approach in her analysis she was forced to state that, in effect, "inappropriate" technology might sometimes be the most "appropriate!" (Stewart, 1983: 280, emphasis added):

> This (i.e., the adoption of so-called "appropriate technology" which does not serve a region's actual needs) might arise because the technology with appropriate characteristics was very inefficient in a technical sense (of low productivity) compared with one with inappropriate characteristics. In some cases, the technology with appropriate characteristics might still be the best choice if its effects on some objectives ... outweighed its low productivity. But in others this might not be so, and therefore the technology with inappropriate characteristics should be preferred.

Despite its attractiveness to engineers and practitioners who may have desired straightforward technical design criteria, the specific-characteristics approach to defining Appropriate Technology exhibited severe shortcomings. The semantic difficulties, which created problems in themselves, illustrated that the specific-characteristics definition was only valid when applied to specific circumstances. The general-principles approach, in contrast, was suitable for universal application; it provided a basis for the development of a specific-characteristics definition within specified circumstances.

Preferred Type of Definition

As has been argued elsewhere (Willoughby, 1990), the substantive ideas of the Appropriate Technology movement, of both the normative and empirical kind, may make a valuable contribution to policy formulation and action. As the foregoing discussion reveals, however, the lack of consistency in the literature of the movement created obstacles to the achievement of this goal. Consequently, the general-principles approach to defining Appropriate Technology therefore appears preferable over the specific-characteristics approach. Nevertheless, the insights and practical ideas that emanated from the specific-characteristics approach still represented some important insights and principles.

The theory, policy and implementation of Appropriate Technology during the last few decades of the twentieth century would have been enhanced by employing only the general-principles approach for general definitions and by restricting the use of a specific-characteristics approach to specific contexts for which the circumstances had been clearly defined.

If more attention had been paid by participants in the Appropriate Technology movement to technology-related lexicography and formal technological semantics, could such problems have been avoided, or at least significantly mitigated? Let us now review some of the formal literature about technological semantics in an attempt to cast light on this matter.

Existing Approaches to Defining Technology

Dictionary Definitions

Providing a consistent and workable definition of technology is fraught with difficulties. The *Concise Oxford Dictionary* (Sykes, 1976: 1188), in a similar manner to other dictionaries, defines technology as the "(science of) practical or industrial art(s); (the) ethnological study of the development of such arts; (the) application of science." Definitions of this type are of limited value, however, because the meaning and use of the word "technology" has changed over time, it is used differently by different schools of thought and between different languages, its common use is haphazard, and the definition does not convey much of the complexity of meaning attributed to the term in the literature. A number of different approaches to defining "technology" should therefore be examined.

Historical Approach

Technology evolves historically and may therefore only be fully understood from an historical viewpoint. Technology is not static and many different technologies have been developed and superseded in a variety of times and places. This has led many scholars (e.g., Landes, 1969) to adopt an historical approach to the study of technology and has encouraged others to speak only of technologies and groups of technologies in the conviction that it is not possible to discern such a thing as technology itself (Bresson, 1987; Rapp, 1981: 24-25). This view has received considerable criticism in the literature (Ellul, 1980: 23-33). It reflects the eighteenth- and nineteenth-century perspectives, as embodied in the dictionary definitions. Referring to this period Winner (1977: 8) has written:

> Technology, in fact, was not an important term in descriptions of that part of the world we now call technological. Most people spoke directly of machines, tools, factories, industry, crafts, and engineering and did not worry about "technology" as a distinctive phenomenon.

Despite the criticisms it has received, the perspective of those in the historical school lends itself to an approach that gives preference to the historiography of tangible technological change, and that avoids the awkward task of defining technology in systematic or philosophically precise terms. This approach also has a certain attraction to contemporary technologists and business people who are disinclined to “waste” time on abstract academic discussions of technological theory.

While it is true that an historical study of technology would be required to do justice to its diversity and complexity, it does not follow that some common elements may not be observed throughout that diversity, thereby justifying the place of a systematic analysis of technology in addition to an historical analysis (Rapp, 1981: 24-25). Evidence for the continuity of technological phenomena throughout history has been surveyed elsewhere (David, 1975; Mumford, 1963; Pacey, 1975; Singer, 1954-1958; Schuurman, 1977) and need not be duplicated here. It should be stressed, however, that the validity of Appropriate Technology as a theoretical category depends itself upon the validity of *technology* as a theoretical category. In short, if taken to extremes and embraced in isolation, the historical approach to defining technology militates against effective treatment of the Appropriate Technology idea.

Ambiguity of English Terminology

“Technology” is employed in the English language to denote and connote a mixture of phenomena and concepts. It is therefore impossible to provide a precise and universal definition of the term without it becoming specialized jargon. Some other languages, in contrast, are less ambiguous. French, for example, distinguishes between *“technologie”* and *“technique”* (Ellul, 1980: 23-33); *technologie* is the science of analyzing and describing *technique* or *techniques*, whereas the latter are the object of study of the former. A similar distinction is made in German (Ströker, 1983) between *“technologie”* (technological science) and *“Technik”* (technology, or technical things). Thus, *“technologie”* (French) conforms to the dictionary definitions of “technology” (English) but not the common English-language usage of the term.

Techniques (French) are the individual technical means, either processes or objects, and *technique* (French) is the general phenomenon of which *techniques* (French) are particular examples. English, in contrast, uses the word “technology” to denote both the science and its object of study. This lack of discrimination in the English language usage of “technology” may partly explain why technology is so frequently defined as applied science—rather than as technology *sui generis*. It may also explain why “technics” has become popular among some sophisticated American commentators (e.g., Winner, 1977) as a general term for all things technological.

The rapid expansion of the role of technology in modern society, both in the level and scope of its deployment, has led to a closer integration of technological phenomena with other factors and to the spread of new phrases such as “the technological order” (Ellul, 1963), “the technological society” (Ellul, 1964), “the technocratic society” (Roszak, 1969), “technological man” (Ferkiss, 1969), “the technostructure” (Galbraith, 1972), or “the technetronic age” (Brzezinski, 1970). In the rhetoric of the counterculture of the 1960s and early 1970s the ubiquitous influence of technology was symbolized in an extreme form simply as “the system” (Guiness, 1973). One scholar has observed that there is a tendency among those who write or talk about technology in our time to conclude that "technology is everything and everything is technology" (Winner, 1977: 9-10). It appears that during the previous century the term "technology" grew from something with a quite limited meaning to become an all-embracing symbol. For the purpose of analysis a more discrete definition of technology is required; but such a definition must of necessity be stipulative rather than merely descriptive, due to the lack of uniformity in general usage.

Broad Scope of "Technology"

A selection of definitions will now be considered so as to establish consistent terminology for analyzing the Appropriate Technology movement. One important observation that may be made of the definitions that are propounded in most studies is that they tend to portray technology as something much more than the hardware, machines, or individual apparatus normally associated with "technology" in popular thinking.

The dictionary definitions refer to technology as a group of arts or as the science of such arts—in other words, as a form of human skill or activity. This concurs with the main etymological root of the term, the Greek *techné*, which denotes art, craft, skill, or practical knowledge (Burnet, 1930; Heidegger, 1977; Koenker, 1980; Runes, 1962: 93, 183-184, 314). *Techné* was used by the Pre-Socratics to denote a process, rather than a set of objects, and in such a way as to emphasize the unity of action and knowledge (*epistémé*, Greek). The other main etymological root of "technology" is the Greek word *logos*, which denotes the ideas of word, reason, or principle.

The modern usage of the term "technology" normally embraces some reference to social or cultural institutions. This is illustrated by the term "technological society," a phrase first coined in France (*societé technicienne*) in 1938 by Georges Friedman (Friedman, 1956; Friedman, 1961).[1] There is a growing trend in the serious literature for technology and society not to be viewed as discrete phenomena that interact, but rather as overlapping and mutually determining phenomena: society becomes technologized and technology reflects the structures and interests of society. The debate over this issue is complex and a thorough discussion may not be properly conducted here, but we may concur with Johnston and Gummett (1979: 9) who have concluded: "Technology is not merely a matter of physical and social hardware, but a force which permeates our political, economic and social systems." Recognizing the broad scope and influence of technology does not, however, guarantee us a clear grasp of its distinguishing characteristics. Further discussion is required.

Technique and Structure

Galtung (1979: 15) has produced a formula that echoes some of the above observations and draws upon the distinction, as stressed in French, between *technologie* and *technique*: technology = technique + structure. He describes *technique* as the "visible tip of the iceberg": the tools and the know-how (or, skills and knowledge). The structure is defined as the social relations or "mode of production" within which the tools become operational, and the cognitive structure within which the knowledge becomes meaningful. Galtung's notion of *structure*, while narrower and differing from it in a number of ways, corresponds to the notion of *psychosocial and biophysical context* in the comprehensive definition of appropriate technology that I proposed earlier. While it usefully emphasizes the social context of *techniques*, Galtung's formula uses the English "technology" with a broader and more equivocal meaning than the French *technologie.* The term *technique* is given a broader meaning than is normal in English by including technical apparatus as part of the concept; it thus accords closely with the French usage of the term.

Galtung's approach helpfully stresses how the social relations surrounding the application of technical knowledge substantially determine the nature of the resulting technology. Nevertheless, the formula does not provide us with an actual definition of technology.

Humanity, Nature, and Economics

In addition to the foregoing formula Galtung provides a functional definition of technology as the modification of natural or ecological cycles into economic cycles (Galtung, 1979: 5, 29). In this way he appears to define technology as a *process* (for modifying cycles) rather than as *apparatus*; he also portrays technology as a form of mediation between people and nonhuman reality, drawing upon a conception of people as primarily economic beings. This theme of the modification of nature by people is also emphasized in the following paraphrase[2] of Rapp's definition of technology:

> Technology is the refined totality of procedures and instruments which aims at the domination of nature through transformation of the outside material world, and which is based on action according to the engineering science and on scientific knowledge.

While Rapp chooses to limit the definition of technology to those things that affect "the outside material world," he does this simply out of a desire to limit the scope of his analysis and to approximate certain popular viewpoints, rather than on etymological or logical grounds (Rapp, 1981: 35-36). There appears to be no reason for not applying his notion of "procedures and instruments for the domination of nature" to the transformation of the "inner world" of human experience.

For Karl Marx also, technology concerns the interaction of people with nature. In *Capital* (Marx, 1954: 352) Marx writes:

> Technology discloses man's mode of dealing with nature, the processes of production by which he sustains his life, and thereby also lays bare the mode of formation of his social relations, and of the mental conceptions that flow from them.

Marx relates technology here to what he viewed as a definitive characteristic of human existence, *production*. This perspective appears to undergird

Galtung's emphasis on economic cycles vis-à-vis technology. A striking feature of Marx's conception is his idea that technology *reveals* things.

The German metaphysician Martin Heidegger, along with Marx, has also emphasized technology's capacity for revealing things—nature in particular. In fact, he describes technology as *a mode of revealing*. By taking this approach Heidegger contrasts certain modern technology that, in revealing nature, works *against* it by dominating it and transforming it (to echo Rapp's terminology) and certain pre-modern technology that tends to reveal nature by working *with* nature's inner principles and by cultivating it. An example of such pre-modern technology would be a windmill that causes very little apparent disruption to nature, while an example of the other type would be a nuclear fission reactor that, according to Heidegger, works by "extracting from" nature. Heidegger's perspective is important to note here because it illustrates how domination is not the only mode of relationship between people and nature that may be invoked by the term "technology" (Heidegger, 1977: 12, 15-16).

Despite their differences, the thinkers just considered each emphasize the role of technology in *mediating* human relationships and activities, both in relation to nature and as part of economic life. It is still necessary to inquire, however, what special characteristics technology gives to this mediating role.

Efficient Means

The reference to "the engineering sciences and scientific knowledge" in Rapp's definition is meant by him to indicate that technology always involves efficient goal-oriented activity (Rapp, 1981: 32). Accordingly, Skolimowski (1966) has noted how an increase in the efficiency of technological procedures has been a defining characteristic of technological progress since the industrial revolution. The French sociologist Jacques Ellul has been among the strongest proponents of the view that efficiency has been the overriding feature of technology (*La Technique*, French) since its origins (Ellul, 1980: 26):

> [Technology is] the ensemble of the absolutely most efficient means at a given moment.... Wherever there is research and application of new means as a criterion of efficiency, one can say that there is a technology.

This emphasis on *efficient means* as the distinctive feature of technology accords with Habermas' view of technology as purposive-rational action (Habermas, 1971), accords with theoretical conceptions of technology that emphasize technology's mediating role, and either amplifies, or is consistent with, the other definitions and formulae outlined above. It therefore appears that such an emphasis should be used to provide substantive content to the definition of technology adopted earlier.

Knowledge

Other scholars choose to emphasize knowledge as the defining characteristic of technology—an emphasis that, as previously indicated, is consistent with its etymology. MacDonald (1983: 27), for example, writes:

> Technology is really the sum of knowledge—of received information—which allows things to be done, a role which frequently requires the use of machines, and the information they incorporate, but conceivably may not.

He argues against those who treat technology's characteristics as no more than those of the machine. He employs the term "techniques" to denote what he refers to as the tools of technology (e.g., machines). This emphasis on technology as knowledge has grown with the widespread deployment of technologies for processing and transmitting information (Stonier, 1983); the term "technology" has even come to be used as a synonym for "information technology" (e.g., in Reinecke, 1982). The literature on the "sociology of knowledge" (e.g., Jagtenberg, 1983; Knorr-Cetina, 1981) also tends to view technology as a special form of knowledge.

While knowledge is, with some justification, recognized by this school of thought as an essential aspect of technology, the tendency by MacDonald and others to define technology as a particular category of knowledge *per se* may be questioned. Firstly, popular English language usage of "technology" normally refers to tangible manifestations of technology—machines, apparatus, tools, and technical artifacts, etc. Secondly, MacDonald's definition does not fit easily with the dictionary portrayals of technology as a category of human activity; the "sum of knowledge" is surely a product of human activity rather than human activity as such.[3] Thirdly, by limiting "technology" to mean knowledge, we are forced to use the English term "technique" to denote artifacts as well as human skill and method—which sits rather awkwardly with common English parlance. Fourthly, any approach that separates the knowledge aspects of technology too rigidly from its operational and tangible aspects runs the risk of over-emphasizing the role of explicit knowledge as opposed to implicit knowledge in the historical development of technology. The development of technology from predominantly explicit, scientific knowledge (e.g., the nuclear fission bomb) is historically far less common than the development of technologies from the gradual accretion of practical experience (e.g., indigenously developed efficient agricultural implements such as the Mexican *sembradora* [Walt, 1978]) and from the practical innovativeness of technology-users and engineers (Ihde, 1979; Ihde, 1983; White, 1962; McClellan and Dorn, 1999). Fifthly, as I will subsequently attempt to demonstrate, it becomes difficult to discuss the problems of "appropriate" versus "inappropriate" technology in a given context if technology is viewed simply as knowledge to the exclusion of artifacts or to the exclusion of the tangible embodiment of knowledge.

In conclusion, there are some etymological reasons and some indications from other languages besides English that may provide a *prima facie* case for defining technology as a particular form of knowledge; and, it appears possible, in principle, to construct an internally consistent taxonomy based upon such an approach. This approach will not be adopted in this paper, however, because to do so would *inter alia* break with certain entrenched conventions of the English language, and would also depart from the common use of "technology" in English-language literature on technology. In raising a definition of technology it is nevertheless still important to incorporate the useful insights of the "technology-as-knowledge" school of thought, but with a different semantic convention.

Artifacts

Some commentators avoid the difficulties of the "technology as knowledge" precept by emphasizing *artifacts* as characteristic of technology. Scriven (1985: 25), for example, defines technology as "the systematic process, and the product, of designing, developing, maintaining and producing artifacts." Artifacts, according to the *Concise Oxford Dictionary* (Sykes, 1976: 52), are the products of human art and workmanship.

This approach avoids the semantic problems cited above; it includes much of the meaning attributed to *technique* (French), *technik* (German) or "technique" (English,[4] as per Galtung, MacDonald, etc.) under the rubric of "technology." Scriven (1985: 40) qualifies his definition with the comment that "technology is artifacts *and* knowledge [implicit or explicit] in the service of artifact production," and makes the distinction between the *application skills of technology* (meaning roughly equivalent to "technique" [English, as per the *Oxford English Dictionary*]), the *embodiment of technology* (artifacts), and *technological theory* (either explicit or implicit) (1985: 27). He avers (1985: 39) that techniques (English) may be thought of as technology when they are employed in using or creating artifacts.

Scriven's definition is a useful advance on some of the artifact-free definitions of technology within the English language, but it exhibits a weakness. The part of his definition that refers to technology as the *product* of producing artifacts in effect makes "technology" equivalent to "artifacts." This gives technology the ubiquitous status of being all things produced by human art and workmanship. Given the meaning of the term "artifacts," the other part of his definition (i.e., the *process* of "designing, developing, maintaining and producing artifacts") may be logically reduced to mean, roughly, "systematic human art and workmanship." Such a formula would include crop rotation and modern managerial practice, but Scriven (p. 26) explicitly rules these out as examples of technology (interestingly, MacDonald [1983: 26-27] includes these activities as part of technology). Scriven's definition does not provide a sufficiently clear indication of the distinguishing features of technology, in addition to those of artifacts. His emphasis on the *process of producing* artifacts does however imply concurrence with the Marxist economic depiction of technology as the means of production.

Technology-Practice

Most discussions of technology in the English language technology studies literature are consistent with Galtung's formula of technology as technique plus structure, in that they consider other factors in addition to specific technical means themselves. Some scholars have attempted to maintain this syncretic approach and strengthen it with more precise definitions, thereby incorporating both the knowledge emphasis and the artifacts emphasis while hopefully avoiding semantic ambiguity. For example, Winner (1977: 12) includes the following under the rubric of "technology": *apparatus* (the physical devices of technical performance); *technique* (human activities characterized by their purposive, rational, step-by-step manner); and, *organization* (social arrangements of a technical form).

The Dutch engineer and philosopher, Schuurman (1977: 377), makes a broad distinction between *practical activity* (*techniek*, translated from Dutch as *technology*) and *theoretical activity* (*technische wetenschap*, translated from Dutch as "technological science" or "technicology").[5] He also (1977: 8-50) divides *technology* (i.e., *techniek*) up into three categories: *technological objects* (things or processes that are put to use in technology); *technological form-giving* (the execution and operation of technology); and *technological designing* (the preparation for technological objects and form-giving). Schuurman's taxonomy brings helpful precision and semantic consistency to the task of explicating the scope of technology. It does so, however, at the price of introducing new jargon that may be cumbersome and have difficulty becoming adopted beyond the confines of specialized scholarship.

Pacey has coined the compound word *technology-practice*, and in doing so he has managed to synthesize the various perspectives on technology illustrated by the above examples. He defines technology-practice as "the application of scientific *and other knowledge* to practical tasks by ordered systems that involve people and organizations, living things and machines" (Pacey, 1983: 6, emphasis added). In doing so he has managed, we might add, to achieve semantic consistency without giving the word "technology" a meaning it does not possess in popular usage. Pacey outlines three aspects of technology-practice: the technical aspect (equivalent to technique in Galtung's formula), the cultural aspect, and the organizational aspect (which together correspond to structure in Galtung's formula) (1983: 4-7). The concept of technology-practice covers all the content normally indicated by "technological" in both popular and specialist discourse. While technology-practice corresponds closely to some usages of "technology" it should nevertheless be viewed as possessing a broader meaning than is normally given to "technology" in the English language.

Pacey's schema is not very precise for analytical purposes and it contains a number of problematical elements but it illustrates the diversity of factors associated with technology-practice and provides a convenient starting point for the development of a more effective nomenclature. It may act as a kind of map for locating technology-related concepts. For example, *Appropriate Technology* (as generally understood throughout the literature) may be viewed as a particular type of technology-practice, while a particular *appropriate technology* would be included as part of the Pacey's technical aspect; Schuurman's *technological objects* would fall within the technical aspect of technology-practice, while his *technological form-giving, technological designing* and *technicology* (or technological science) would embrace the organizational and cultural aspects as well; Winner's notions of *apparatus* and *technique* would fall within the technical aspect of technology-practice, while his notion of *organization* corresponds to the organizational aspect of technology-practice; and, the definitions of both Heidegger and MacDonald, different though they are, embrace all three aspects of technology-practice.

Pacey's notion points clearly to the cultural and organizational context that always surrounds the technical aspects of technology. By including the cultural aspect as a fundamental component of technology-practice Pacey focuses attention on the normative dimension of technology. While normative factors may have been implicit in the other definitions considered here, his concept encourages explicit examination of such factors.

Pacey's concept of technology-practice accords with the reference by European critics to the notion of *technical praxis* (favored by European scholars [e.g., Ströker, 1983: 323-331]) and to the use by American writers of the term "technics" (Ihde, 1979; Winner, 1977) in discussing the general subject of technology. His emphasis on "the application of scientific and other knowledge," however, while not strictly at odds with it, does not appear to adequately address the growing emphasis among theorists of technology on the distinction between science and technology (see, e.g., Agassi, 1966; McLellan and Dorn, 1999). Despite the usefulness of "technology-practice" for discussing technological matters in general, Pacey's notion does not provide substantive content to the term "technology" itself. An informative and reliable *definition* of technology (in addition to *statements* about technology) is still needed here.

Preferred Nomenclature

Need for a Stipulative Definition of Technology

There is no universally agreed upon definition of technology in the technology studies literature, although, as the foregoing discussion indicates, there is much overlap in the definitions raised and there is a general consensus that a field of study may be identified under the rubric of "technology." It is therefore necessary in this paper to stipulate a definition, rather than adopt a single definition from elsewhere that is widely in use. The semantic rules outlined below could be debated at some length, but an exhaustive analysis of all relevant issues is beyond the scope of this paper. The conventions advocated below, although based upon an extensive survey of the literature extant during the period when the Appropriate Technology movement was at its peak, ought to therefore be viewed as stipulative.

Technology has relevance to most fields of human endeavor and appears to be deeply enmeshed in most aspects of modern society. It is important that this be recognized; but, at the same time, it is important to avoid adopting a definition that is so general as to render the concept indistinguishable from other concepts. A spectrum exists in schools of thought vis-à-vis technology between those who adopt a broad, all-inclusive definition and those who adopt a narrower, more discriminating definition. The narrower approach is adopted here. The main reasons are that this sits more easily with popular English usage, it assists in resolving some of the confusion in the technology studies literature, it allows a more lucid discussion of the relationship between technology and other factors, and it is to some extent a necessary condition for a fruitful analysis of problems that have plagued some of the policy literature on technology.

"Technology"

Technology is defined here as the *ensemble of artifacts intended to function as relatively efficient means.*[6]

This definition has the advantage of resolving the difficulties that result from reducing technology to a category of knowledge alone and it also goes beyond the limitations of the artifact-based definition discussed earlier. By including "the function of being relatively efficient means" it is possible to distinguish between artifacts-*qua*-technology and artifacts-*qua*-artifacts. The word "artifacts" denotes the products of human art and workmanship, and hence does not necessarily refer only to physical apparatus and machines; my stipulative definition is therefore capable of embracing such less tangible technologies as computer software or cybernetic control systems. My emphasis on artifacts incorporates the knowledge aspects of technology but stresses that such knowledge needs to be realized, incarnated, embodied, or objectified if it is to be deemed "technology." The inclusion of "artifacts" in the definition also indicates the human or social element of technology, but without reducing technology to being simply an aspect of society.[7] In this way it is possible to avoid treating technology as being either entirely discrete or autonomous, at one extreme, or as lacking endogenous characteristics and a dynamism of its own, at the other extreme.

The use of the term "means" as part of the definition emphasizes technology's instrumental function, and the inclusion of efficiency as part of the definition makes possible a distinction between means-*qua*-technology and means-*qua*-means. The term "*relatively* efficient means" is used in preference to "efficient means" only in acknowledgement that: the efficiency of technology may vary geographically and over time, due to innovation and other factors; perfect efficiency may in fact never be attainable[8]; and, the degree of efficiency also relates to such things as the degree of specialization of the technology's function, the nature of the task for which it is in fact used, and the manner in which it is used. It also reflects the recognition that although technical efficiency may be an important factor for technologists and others it is not the only factor influencing the adoption of technology. In accordance with the above definition, individual technologies, in contrast to technology in general, may be defined as *artifacts intended to function as relatively efficient means*.

There are other characteristics of technology that deserve attention, such as its systemic tendencies, but the restriction of space means that a discussion of these will have to be left for further writings.

"Technological" and "Technology-practice"

"Technological" may be used to qualify all operations, activities, situations, or phenomena that involve technology. "Technological" should be distinguished from "technical," which has a more specific and concise content. "Technology-practice" is the noun equivalent of "technological," and covers the scope of meanings expressed by Pacey; i.e., "technology-practice" denotes all things technological, and possesses a scope of meaning similar to that associated with Galtung's use of "technology." It may be used on occasions when, as in many (if not most) popular discussions of technology, an all-inclusive meaning is intended and semantic precision is not considered to be a top priority.

"Technical" and "Technicity"

"Technical" may be used as the adjective or adverb to qualify phenomena (either human or non-human) dedicated to efficient, rational, instrumental, specific, precise, and goal-oriented operations. Unfortunately there appears to be no commonly used English word suitable to be employed unequivocally as the noun corresponding to "technical"—i.e., to denote the factor or quality itself which makes something technical. I therefore propose the term "technicity" for this purpose.

"Technicity" exudes specialized jargon but, unfortunately, for the purposes of scholarly rigor and to enable adequate differentiation of technology-related concepts, there appears to be no alternative here to the introduction of a rarely used word.[9]

Technicity is thus a defining feature of technology; but technology, as I have defined it, and as generally understood, may involve features other than technicity (in the same way, for example, that "humanity" is not an exact substitute for the noun "human"). Accordingly, some technologies may be more technical than others—i.e., the degree of technicity may vary between different technologies.

The crucial importance of this observation becomes more apparent following detailed analysis of the topic of technology choice (Willoughby, 1990), but an example here may help. Horticulture may be considered to be a technological activity because it involves the use of technology (e.g., drip-trickle irrigation systems or rotary hoes) but it might not always generally be conducted in a highly technical manner. Some aspects of modern horticulture (e.g., cloning of hybrid plants, or automated computer control of temperature and fertilizer levels in hydroponic systems) may, however, be highly technical. Nevertheless, just because some horticulturalists do not employ highly technical procedures or highly technical apparatus—preferring instead to work with so-called "low" or less complicated technologies—it does not follow that their operation is therefore not technological.

"Technique"

"Technique" may denote *human skill* that involves a significant technical element. Used in this way the term therefore corresponds closely to the meaning of Scriven's term "application skills of technology." It should be realized, however, that not all skills in *using* technology involve a significant degree of technicity (e.g., storing food in a refrigerator). The normal English meaning of the word "technique" may therefore be adopted here, and other terms such as "technology," "technicity," or other phrases, may be used when appropriate to denote the meaning given to *technique* in French (or to equivalents from other languages). In contrast to the tendency of some thinkers who employ "techniques" to denote particular examples of technological artifacts, I propose the use of "technologies" for this purpose. As implied above, and in parallel to the situation of "technology," some techniques may be more technical than others.

"Technological Science"

As discussed earlier, *technologie* is used in continental European languages (e.g., in French, German, and Dutch) to denote an essentially scientific or theoretical activity, but in such a manner as to avoid confusion between the science itself and its object (i.e., *technique* [French], *technik* [German], or *techniek* [Dutch]). English language theorists should therefore avoid using the term "technology" in this sense, and instead consistently employ "technological science" as the English equivalent of *technologie.* The term may denote either the scientific study of technological matters or scientific practice that involves a significant amount of technology.

"Mode of Technology-Practice"

By defining technology as the ensemble of artifacts intended to function as relatively efficient means, I have adopted a narrower and more precise formula than is often found in the technology studies literature. For example, Hibbard and Hosticka (1982: 4) write:

> Technologies are thus not only objects and material processes, but also organizational forms, methods of knowledge production, decision-making techniques and so on. For example, the common organizational form of the pyramidal bureaucracy is as much a technology as the word-processors, microcomputers, filing systems and calculators which facilitate the work of the organization. One only has to consider the current search for more effective and efficient organizational forms to appreciate this.

To help them address broad issues of technology and society, the authors of this statement have defined technology to incorporate factors normally considered to be part of the environment of the technology, rather than technology itself. In other words, they have fallen into the logical trap of including something other than the thing being defined in the definition of that thing.[10]

The intellectual and practical issues addressed by the field technology studies are quite eclectic. Questions of organizational form, social relations, political bias, and human experience, amongst others, are integral to the field. It does not follow, however, that in order for these factors to be adequately addressed they must be included by definition as part of technology. It also does not follow that because, logically, they ought not to be included as part of technology, they do not exhibit some intrinsic relationship to technology. I therefore suggest that technology should be construed within the academic field of technology studies as technology *sui generis.* A corollary of this principle is that factors or phenomena related to technology should be referred to in their own right and not as part of technology. For example, organizational structure should be denoted by the term "organizational structure" (or something similar) rather than by the term "technology."

So that we will be able to simultaneously account for both the "narrow" aspects of technology, as implied by the definition stipulated in this paper, and the "broad" aspects, as referred to in quotes such as the one by Hibbard and Hosticka above, I suggest that we adopt the term "mode of technology practice." This term embodies the recognition that specific technologies may be employed as part of technology-practice in a wide variety of ways, and that technology-practice itself may take a variety of forms. Recognizing the possibility of a variety of modes of technology-practice will enable us to break away from the absurd impasse of the "pro-technology" versus "anti-technology" debate that has dominated much of the technology studies literature. Much of the public debate in western industrialized countries about technology has centered on whether or not technology as a whole is "good" or "bad," or on whether or not technology ought to be "accepted" or "rejected." The nomenclature I have proposed above allows careful discussion of the types of social, cultural, political, and environmental issues that motivate critics of technology, in such a manner that the normative concerns of the critics may be embraced, but without the necessity of thereby also embracing an anti-technology attitude. Thus, the important issues in contemporary policy debates over public acceptance of new technology may be approached as problems of choosing between alternative modes of technology-practice, rather than being about rejecting or accepting new technology.

Conclusions

While much of the above discussion may appear somewhat pedantic when compared with seemingly more practical analysis of technology-studies topics, such as technology and employment, computers and productivity, biotechnology and environmental safety, etcetera, I would argue that poor use of language has led to many of the more "practical" debates in technology studies having less policy impact than they might otherwise have had. The apparent failure of the Appropriate Technology movement—that flourished worldwide during the 1970s and 1980s—to exert significant influence on mainstream debates in technology policy, illustrates this theme. Poor technological semantics can lead to poor technology-practice. Hopefully, however, the converse is also true. The definitions I have stipulated above (and as are summarized in the Glossary) are proposed at this stage as starters for an ongoing debate about semantics in technology studies. I welcome criticisms and suggestions for improvements.

TABLE 1

Technology-Related Nomenclature

Term	**Definition/Explanation**
technology	The ensemble of artifacts intended to function as relatively efficient means.
technology-practice	The ensemble of operations, activities, situations, or phenomena that involve technology to a significant extent.
technological	A term used to qualify operations, activities, situations, or phenomena that involve technology to a significant extent (i.e., the adjectival form of "technology-practice").
technical	The adjective or adverb used to qualify phenomena (either human or non-human) dedicated to efficient, rational, instrumental, specific, precise, and goal-oriented operations.
technicity	The distinguishing factor or quality that makes a phenomenon technical (i.e., the noun equivalent of "technical").
technique	Human skill that involves a significant technical element.
technological science	The scientific study of technological matters, or scientific practice that involves a significant amount of technology (i.e., the English language equivalent of the European word *technologie*).
appropriate technology	Artifacts that have been tailored to function as relatively efficient means and to fit the psychosocial and biophysical context prevailing in a particular location and period (i.e., technology that is compatible with its context).
Appropriate Technology	A mode of technology-practice aimed at ensuring that technology is compatible with its psychosocial and biophysical context. The term may also be used to denote the general concept, social movement, or innovation strategy associated with this mode of technology-practice.

Source: The author.

Notes

1. Jacques Ellul (1980: 12) acknowledges Friedman as the progenitor of the term *societé technicienne*.
2. This paraphrase is the present author's and draws upon several partial definitions provided by Rapp (e.g., Rapp, 1981: 33-36) See also (Tondl, 1974).
3. Some commentators resolve this particular difficulty by referring to technology as the *application* of knowledge rather just as knowledge. Schaiberg (1980: 278), for example, drawing on the work of Schooler (1971), defines technology as the "application of knowledge in the processes of social production," and in doing so he links the knowledge aspect of technology with the economic and political aspects emphasized by Galtung (1979), drawing on Marx (1954).
4. When used in this sense "technique" ought perhaps to be labeled as pseudo-English rather than English in the strict sense.
5. These notions correspond to the notions of *technique* and *technologie*, respectively, in French.
6. This definition of technology belongs to the author of this paper.
7. Many writers in the political-economy tradition (e.g.: Bresson, 1987; Levidow, 1983; Thompson, 1980) strongly resist discussing technology *sui generis* because of a fear that this would amount to reifying or "fetishing" particular technologies.
8. An amusing survey by Papanek and Hennessey (1977), entitled *How Things Don't Work*, of technologies that are poorly designed and ineffective, illustrates how in the "real world"—as opposed to the "drawing board"—efficiency in technology-practice is elusive.
9. "Technicity" has been used elsewhere in an attempt to translate some of Heidegger's ideas into the English idiom (see Schuurman, 1977, pp. 87-95).
10. Jacques Ellul (1964, p. xxv) has coined the term *La Technique* to denote "the totality of methods rationally arrived at and having absolute efficiency [for a given stage of development] in every field of human activity." This is a much broader concept than that of technology, as defined in this paper, and it does incorporate such human products as organizational forms; however, *La Technique* (as per Ellul), although related to it, is different in meaning than *technique* as normally used in French. Ellul thereby accomplishes what Hibbard and Hosticka appear to be seeking but without falling in to the logical trap into which they fell.

References

Agassi, J. (1966). "The Confusion between Science and Technology in the Standard Philosophies of Science." *Technology and Culture*, 7(3), 348-367.

Autrement. (1980). "Technologies Douces." *Autrement,* Special Edition, 27.

Bender, T. (1975). *Sharing Smaller Pies*. Portland: RAIN.

Beveridge, A.A. and Rudell, F. (1988). "An Evaluation of 'Public Attitudes toward Science and Technology' in Science Indicators; The 1985 Report." *Public Opinion Quarterly*, 52(3), 374-385.

Bookchin, M. (1971). "Toward a Liberatory Technology." In *Post-Scarcity Anarchism*. San Francisco: 83-119.

Bookchin, M. (1977). "The Concept of Ecotechnologies and Ecocommunities." *Habitat*, 2(1/2), 73-85.

Borgman, A. (1984). *Technology and the Character of Contemporary Life: A Philosophical Inquiry*. Chicago and London, The University of Chicago Press.

Boyle, G. (1978). *Community Technology*. Milton Keynes: Open University Press.

Boyle, G. (1984). "A.T. Is Dead—Long Live E.T.!" Paper presented to "A.T. in the Eighties," Conference. London, 16 June 1984.

Boyle, G. and Harper, P. (Eds.). (1976). *Radical Technology*. Ringwood, Australia, Penguin.

Braun, E. (1984). *Wayward Technology*. Frances Pinter, London.

Brzezinski, Z. (1970). *Between Two Ages: America's Role in the Technetronic Era*. New York, Viking Press.

Burnet, J. (1930). *Early Greek Philosophy*. London, Adam and Charles Black.

Canadian Hunger Foundation & Brace Research Institute (1976). *A Handbook on Appropriate Technology*. Ottawa, Canadian Hunger Foundation.

Carrol, J.D. (1971). "Participatory Technology." *Science*, 171, 647-653.

Clarke, R. and Clarke, D. (1972). "Soft Technology: Blueprint for a Research Community." *Undercurrents* (2).
Coe, G. (1979). *Present Value: Constructing a Sustainable Future*. Friends of the Earth, San Francisco.
Cooper, C. (1979). "A Summing Up of the Conference." In A. Robinson (Ed.), *Appropriate Technologies for Third World Development*, London, Macmillan: pp. 403-409.
Darrow, K., Keller, K., and Pam, R. (1976). *Appropriate Technology Sourcebook*. Volunteers in Asia, Stanford, CA.
de Pury, P. (1983). *People's Technologies and People's Participation*. Geneva, World Council of Churches.
Dickson, D. (1974). *Alternative Technology and the Politics of Technical Change*. London: Fontana/Collins.
Diwan, R.K. and Livingstone, D. (1979). *Alternative Development Strategies and Appropriate Technology: Science Policy for an Equitable World Order*. New York, Pergamon.
Drengson, A.R. (1982). "Four Philosophies of Technology." *Philosophy Today*, 26(2/4), 103-117.
Dunn, P.D. (1978). *Appropriate Technology: Technology with a Human Face*. New York, Schocken.
Ellul, J. (1963). "The Technological Order." Paper presented to the Encyclopaedia Britannica conference on the technological order, March 1962, Santa Barbara, California. In C.F. Stover (Ed.), *The Technological Order*, Wayne State University Press, Detroit: pp. 10-37.
Ellul, J. (1964). *The Technological Society* (J. Wilkinson, Trans.). New York: Alfred A. Knopf.
Ellul, J. (1980). *The Technological System*. Continuum, New York.
Ferkiss, V. (1969). *Technological Man: The Myth and the Reality*. London: Heinemann.
Frankel, B. (1987). *The Post-Industrial Utopians*. Polity Press in association with Basil Blackwell, Cambridge and Oxford.
Friedman, G. (1956). *Problêms humains du machinisme industriel*. Paris: Gallimard.
Friedman, G. (1961). *The Anatomy of Work: The Implications of Specialization* (W. Rawson, Trans.). London, Heinemann.
Fromm, E. (1968). *The Revolution of Hope: Toward a Humanized Technology*. Harper and Row, New York.
Galbraith, J.K. (1972). *The New Industrial State* (2nd ed.). Harmondsworth: Penguin.
Galtung, J. (1979). *Development, Environment and Technology: Towards a Technology for Self-Reliance*. United Nations, NY
Gendron, B. (1977). *Technology and the Human Condition*. New York: St. Martin's Press.
Goldhaber, M. (1986). *Reinventing Technology: Policies for Democratic Values*. Routledge & Kegan Paul, New York and London.
Guiness, O. (1973). *The Dust of Death: A Critique of the Counterculture*. Inter Varsity Press, Downer's Grove, IL.
Habermas, J. (1971). "Technology and Science as "Ideology." In *Toward a Rational Society*. Heinemann, London: 81-122.
Harrison, P. (1980). *The Third World Tomorrow*. Harmondsworth, Penguin.
Heidegger, M. (1977). "The Question Concerning Technology," translated from the text of a lecture delivered before the Bavarian Academy of Fine Arts, 6 June 1950, entitled "Die frage nach der technik." In W. Lovitt (Ed.), *The Question Concerning Technology—And Other Essays*. Harper Colophon, New York: 1-35.
Hess, K. (1979). *Community Technology*. Harper and Row, New York.
Hibbard, M. and Hosticka, C.J. (1982). "Socially Appropriate Technology: Philosophy in Action." *Humboldt Journal of Social Relations*, 9(2), 1-10.
Hoda, M. M. (1976). "India's Experience and the Gandhian Tradition. In N. Jéquier (Ed.), *Appropriate Technology: Problems and Promises.* Organization for Economic Cooperation and Development, Paris: 144-155.
Ihde, D. (1979). *Technics and Praxis*. D. Reidel, Dordrecht.
Ihde, D. (1983). "The Historical-Ontological Priority of Technology over Science." In P.T. Durban and F. Rapp (Eds.), *Philosophy and Technology*, D. Reidel, Dordrecht: 235-252.
Illich, I. (1973). *Tools for Conviviality*. London, Calders and Boyars.
Illich, I. (1980). "Vernacular Values." In S. Kumar (Ed.), *The Schumacher Lectures*. London, Blond and Briggs.

Institute for Local Self Reliance. (1981). "Appropriate Nukes?" *Self Reliance*, (25), 2.
Jagtenberg, T. (1983). *The Social Construction of Science*. Dordrecht, D. Reidel.
Jéquier, N. (1976). "The Major Policy Issues." In N. Jéquier (Ed.), *Appropriate Technology: Problems and Promises*. Organization for Economic Cooperation and Development, Paris.
Jéquier, N. (1979). "Appropriate Technology: Some Criteria." In A.S. Bhalla (Ed.), *Towards Global Action for Appropriate Technology*. Pergamon, Oxford: 1-22.
Jéquier, N. and Blanc, G. (1983). *The World of Appropriate Technology*. Paris, Organization for Economic Cooperation and Development.
Johnston, R. and Gummett, P. (Eds.). (1979). *Directing Technology*. London, Croom Helm.
Jünger, G.F. (1956). *The Failure of Technology*. Chicago, Regnery.
Knorr-Cetina, K.D. (1981). *The Manufacture of Knowledge*. Oxford, Pergamon.
Koenker, E.B. (1980). "The Being of the Material and the Immaterial in Heidegger's Thought." *Philosophy Today* (Spring), 54-61.
Kuhlman, A. (1987). "Problems Associated with the Acceptance of New Technologies in Industrialized Societies." *International Journal of Technology Management*, 2(2), 209-217.
Landes, D. (1969). *The Unbound Prometheus*. Cambridge. Cambridge University Press.
Levidow, L. (1983). "We Won't Be Fooled Again? Economic Planning and Left Strategies." *Radical Science Journal*, 13, 28-38.
Lodwick, D.G. and Morrison, D.E. (1982). "Research Issues in Appropriate Technology." Paper presented to the Rural Sociological Society, Cornell University, Ithaca, New York, 20-23 August 1980 (Michigan Agricultural Experiment Station Journal #9649). In D.A. Dillman & D.J. Hobbs (Eds.), *Rural Society: Issues for the Nineteen Eighties.* Boulder, CO. Westview Press.
Long, C.D. (1977). *Congressional Record*, 8 February. Washington, D.C.: U.S. Congress.
Lovins, A. (1978). "Soft Energy Technologies." *Annual Review of Energy*, (3), 477-517.
Lovins, A. and Price, J.H. (1975). *Non-Nuclear Futures: The Case for an Ethical Energy Strategy*. Friends of the Earth International and Ballinger, San Francisco, CA and Cambridge, MA.
Lutheran World Service. (1977). *Village Technology Handbook*. Lutheran World Service, Geneva.
MacDonald, S. (1983). "Technology beyond Machines." In S. MacDonald et al. (Eds.), *The Trouble with Technology*. Frances Pinter, London.
Maderthaner, R. et al. (1976). *Perception of Technological Risks: The Effect of Confrontation*. International Institute for Applied Systems Analysis, Laxenburg, Austria.
Magee, J. (1978). *Down to Business: An Analysis of Small Scale Enterprise and Appropriate Technology*. Butte, MT, National Center for Appropriate Technology.
Marcuse, H. (1964). *One Dimensional Man*. Beacon Press, Boston.
Marsden, K. (1970). "Progressive Technologies for Developing Countries." *International Labour Review*, 101(5), 475-502.
Marx, K. (1954). *Capital* (first published in English in 1887). Lawrence and Wishart, London.
Mazur, A. (1975). "Opposition to Technical Innovations." *Minerva*, 13, 58-81.
Mazur, A. (1981). *The Dynamics of Technical Controversy*. Communications Press, Washington, D.C.
McLellan, J. E. and Dorn, H. (1999). *Science and Technology in World History: An Introduction*. The Johns Hopkins University Press, Baltimore and London.
Merrill, R. and Gage, T. (1977). *Energy Primer* (updated and revised from 1974 ed.). Sydney, Second Back Row Press.
Miles, D.W.J. (1982). *Appropriate Technology for Rural Development: The I.TD.G. Experience*. London, Intermediate Technology Publications Ltd.
Miller, C.C., Glick, W.H., Wang, Y., and Huber, G.P. (1991). "Understanding Technology-Structure Relationships: Theory Development and Meta-Analytic Theory Testing. *Academy of Management Journal*, 34(2), 370-399.
Miller, J.D. (1983). *The American People and Science Policy: The Role of Public Attitudes in the Policy Process*. New York, Pergamon Press.
Morrison, D.E. (1978). "Energy, Appropriate Technology and International Interdependence." Paper presented to the annual conference of the Society for the Study of Social Problems. San Francisco, September 1978.
Mumford, L. (1963). *Technics and Civilization* (first published in 1934). New York: Harcourt Brace Jovanovich.

Murray, J.A.H. et al. (Ed.). (1933). *The Oxford English Dictionary*. Oxford: Oxford University Press.
National Center for Appropriate Technology. (1981). *Information Brochure*. Butte, MT: National Center for Appropriate Technology.
Nelkin, D. (Ed.). (1984). *Controversy: Politics of Technical Decisions*, 2nd ed. Beverly Hills, Sage.
Norman, C. (1978). *Soft Technologies, Hard Choices*. Washington, D.C., Worldwatch Institute.
Office of Technology Assessment. (1981). *An Assessment of Technology for Local Development*. Washington, D.C., U.S. Government Printing Office.
Pacey, A. (1975). *The Maze of Ingenuity*. New York, Holmes and Meier.
Pacey, A. (1983). *The Culture of Technology*. Oxford, Basil Blackwell.
Papanek, V. and Hennessey, J. (1977). *How Things Don't Work*. New York, Pantheon.
Pecotich, A. and Willoughby, K.W. (1989). *The Ambiguous Status of Science and Technology: A Study of Management Attitudes and Public Policy in Australia*. Berkeley, Institute of Governmental Studies, University of California at Berkeley. IGS Working Paper 89-9.
Pion, G. and Lipsey, M. (1981). Public Attitudes towards Science and Technology. *Public Opinion Quarterly*, 45, 303-316.
Postman, N. (1988). *Conscientious Objections: Stirring Up Trouble about Language, Technology, and Education*. New York, Knopf.
Rapp, F. (1981). *Analytical Philosophy of Technology*. Dordrecht: D. Reidel.
Reddy, A.K.N. (1979). *Technology, Development and the Environment: A Re-appraisal*. Nairobi, United Nations Environment Programme.
Reinecke, I. (1982). *Micro Invaders: How the New World of Technology Works*. Ringwood, Australia, Penguin.
Robertson, J.A.L. (1978). "The CANDU Reactor System: An Appropriate Technology." *Science*, 199(4329), 657-664.
Robinson, A. (Ed.). (1979). *Appropriate Technologies for Third World Development*. London: MacMillan.
Roby, K. R. (1979). "The Appropriate Levels of Technology for Western Australia." In ANZAAS, *Prospect 2000*. Perth, Australia: Australian and New Zealand Association for the Advancement of Science.
Roszak, T. (1969). *The Making of a Counter Culture: Reflections on the Technocratic Society and its Youthful Opposition*. London: Faber and Faber.
Runes, D. D. et al. (1962). *Dictionary of Philosophy*. Totowa, N.J., Littlefield Adams.
Rybczynski, W. (1980). *Paper Heroes: A Review of Appropriate Technology*. Dorchester, Prism.
Schnaiberg, A. (1980). Responses to Devall. *Humboldt Journal of Social Relations*, 7(2), 278.
Schooler, D. (1971). *Science, Scientists and Public Policy*. New York: Free Press.
Schumacher, E.F. (1962a). "Help to Those Who Need it Most." Paper presented to the International Seminar, Paths to Economic Growth, 21-28 January 1961, Poona, India. In *Roots of Economic Growth*, pp. 29-42. Varanasi: Gandhian Institute of Studies.
Schumacher, E.F. (1962b). *Roots of Economic Growth*. Varanasi: Gandhian Institute of Studies.
Schumacher, E.F. (1965). "How to Help Them Help Themselves." *Observer*, Weekend Review (London), 29 August 1965.
Schumacher, E.F. (1973). *Small is Beautiful: A Study of Economics as if People Mattered*. London, Blond and Briggs.
Schuurman, E. (1977). *Technology and the Future: A Philosophical Challenge* (H.D. Morton, Trans.). Toronto, Wedge.
Scriven, M. et al. (1985). *Education and Technology in Western Australia*. Report of the Working Party on Education and Technology. Perth, Australia: Western Australian Science, Industry, and Technology Council.
Shapley, D. (1978). "Pen Registers: The 'Appropriate Technology' Approach to Bugging." *Science*, 199, 749-751.
Singer, C. et al. (Eds.). (1954-1958). *History of Technology*. Oxford, Oxford University Press.
Skeat, W.W. (Ed.). (1910). *An Etymological Dictionary of the English Language* (4th ed. [originally published in 1879-1882]). Oxford: Oxford University Press.
Skolimowski, H. (1966). "The Structure of Thinking in Technology." *Technology and Culture*, 7(3), 371-383.

Stewart, F. (1983). “Macro-Policies for Appropriate Technology: An Introductory Classification.” *International Labour Review*, 122(3), 279-293.

Stonier, T. (1983). *The Wealth of Information: A Profile of the Post-Industrial Economy*. London: Thames Methuen.

Stroker, E. (1983). “Philosophy of Technology: Problems of a Philosophical Discipline.” In P.T. Durbin and F. Rapp (Eds.), *Philosophy and Technology*, pp. 323-336. Dordrecht: D. Reidel.

Swinkels, D. (1979). “The Appropriate Levels of Technology for Western Australia.” In ANZAAS, *Prospect 2000*. Perth, Australia: Australian and New Zealand Association for the Advancement of Science.

Sykes, J.B. (Ed.). (1976). *The Concise Oxford Dictionary of Current English* (6th ed.). Oxford: Oxford University Press.

Thomas, A. and Lockett, M. (1979). *Choosing Appropriate Technology*. Milton Keynes: Open University Press.

Thompson, H. (1980). “The Social Significance of Technological Change.” *The Journal of Australian Political Economy*, 8(July), 57-58.

Tondl, L. (1974). “On the Concept of ‘Technology’ and ‘Technological Sciences.’ In F. Rapp (Ed.), *Contributions to a Philosophy of Technology*. Dordrecht: D. Reidel.

Undercurrents. (1972-1985).

United Nations Industrial Development Organization. (1979). *Conceptual and Policy Framework for Appropriate Industrial Technology*. New York: United Nations.

Vacca, R. (1980). *Modest Technologies for a Complicated World*. Oxford: Pergamon.

Wade, N. (1975). “Karl Hess: Technology with a Human Face.” *Science*, 187, 332-334.

Wade, N. (1980). “Appropriate Technology and the Too High Outhouse.” *Science*, 207, 40.

Waldrop, M.M. (1983). “Compact Fusion: Small is Beautiful.” *Science*, 219, 154.

Walt, B.D. (1978). “Appropriate Technology in Rural Mexico: Antecedents and Consequences of an Indigenous Peasant Innovation.” *Technology and Culture*, 19, 32-52.

White, L.J. (1962). *Medieval Technology and Social Change*. Oxford, Oxford University Press.

Williams, R. and Mills, S. (Eds.). (1986). *Public Acceptance of New Technologies: An International Review*. London, Croom Helm.

Willoughby, K.W. (1990). *Technology Choice: A Critique of the Appropriate Technology Movement*. Boulder and San Francisco, Westview Press.

Winner, L. (1977). *Autonomous Technology: Technics-out-of-Control as a Theme in Political Thought*. Cambridge, MA, Massachusetts Institute of Technology Press.

Winner, L. (1979). “The Political Philosophy of Alternative Technology: Historical Roots and Present Prospects.” *Technology in Society*, 1(1), 75-86.

Winner, L. (1986). “Technologies as Forms of Life.” In *The Whale and the Reactor: A Search for Limits in an Age of High Technology*. Chicago and London: The University of Chicago Press, 3-18.

Yankelovitch, D. (1982). “Changing Public Attitudes to Science and the Quality of Life.” *Science, Technology, and Human Values*, 7(39), 123-129.

Yearly, S. (1988). *Science, Technology and Social Change*. London, Unwin Hyman.