Technological Impacts and Determinism in Technology Education: Alternate Metaphors from Social Constructivism

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In technology education, teaching about technology and society has usually been embedded in the notion of technological impacts on society. References to the impacts of technology on society are pervasive in the literature of technology education. The notion of technological impacts is simple to comprehend and has permitted the field to interpret technology in the context of society and culture, but it has also contributed to a simplistic and inflexible view of the relationship between technology and society.

The expression "technological impacts" is a metaphor that implies that technology is a discrete force with a discernible direction and influence. Metaphors are figures of speech widely used in all disciplines and essentially involve the transfer of descriptive terms from primary usage to different, but analogous, situations (e.g., Joerges, 1990; Ortony, 1979; Sacks, 1979; Simpson & Weiner, 1989, Vol. IX, p. 676; Winner, 1986). Technology is cast in a perspective of cause and effect relationships in which technology is the cause of impacts on society. In technology education, this perspective has become the dominant metaphor for conceptualizing the relationship between technology and society (e.g., Bame and Cummings, 1988; DeVore, 1980; Hacker & Barden, 1988; Hales & Snyder, 1981; "Resources in Technology," 1989, 1990; Savage & Sterry, 1990; Schwaller, 1989; *Standards*, 1985; Wiens, 1989, 1990; Wright & Smith, 1989). There are, however, other metaphors that emphasize the role of humans in directing technology. Some of these metaphors may be more appropriate for technology education than technological impacts.

The first part of this study examines the implications for technology education of a perspective committed to technological impacts. The metaphor of technological impacts only too easily can become the cornerstone for a philosophy of technological determinism as described in the second part. The third part introduces the work of social constructivists and several alternate perspectives for interpreting technology and society. Finally, implications for technology education are reviewed including suggestions for modifying current curricula, instructional patterns, and research.

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Technological Impacts

The term impact is at the heart of the issue because of its primary meaning and connotations. Impact suggests a striking together, collision, or shock. (See Simpson & Weiner, 1989, Vol. VII, pp. 694-695 for extensive illustrations of etymological foundation and usage, especially in dynamics and momentum.) Consequently, technology is viewed as a dynamic force causing collisions or impacts on society. Interpretations of social change are framed in a mechanistic perspective dominated by technology as primary cause. The impact of technology on society is likened to the impact of a hammer on a nail. This metaphor does not necessarily imply that technology is the only cause of impacts, but it does promote a conceptual framework that emphasizes: (a) cause and effect relationships with resulting collisions or impacts; (b) a mechanistic world; (c) technology as dominant force; and (d) importance of distinctions between society and technology. The metaphor of technological impacts is attractive because of its simplicity but it is inadequate as a means of teaching about the complexity of technology and society.

In contrast, one might focus primarily on the people or social groups who develop and direct technology. For example, instead of focusing on changes in automotive design and production techniques, one would emphasize the interaction of relevant social groups in directing such changes. This approach shifts the emphasis to social groups with less importance on technology. In the extreme form, this perspective would be characterized by a study of the impacts of society on technology. Such a metaphor risks, however, to lead to just the opposite mechanistic perspective in which technology is fully controlled by society.

These two perspectives have been contrasted to identify some of the key problems for technology education in teaching about technology and society. Alternative perspectives need to provide a more satisfying understanding of the technology/society relationship. What if, for example, society and technology were not viewed as distinct categories? Then the notion of technological impacts on society would dissolve. What if the term impact were eliminated? Then the notion of technology and society as opposing forces would need to be reexamined.

The mechanical view of technology and its impacts on society reinforces the idea that technical systems have an independent existence, ordered according to materials, processes, and laws that can be fully understood from an objective standpoint. It follows that technology appears to have a mass, velocity, and momentum of its own which can be objectively studied. Hence, the focus of study and interpretations are subordinate to these principles of technology rather than to individuals and groups who develop the artifacts and knowledge.

Technological Determinism

This particular view of technological impacts often leads to technological determinism of which there are various forms, all related to traditional notions of determinism. (See Trusted, 1984, for a systematic and historical introduction to the implications of determinism.) Determinism holds that everything is caused (determined) by a sequence of previous conditions and events, operating with regularity and, in principle, predictability. In its most extreme form, technological determinism maintains that materials and physical laws are such that technology is determined to develop in a particular way or pattern. There are variations of determinism and technological determinism, often distinguished by the extent of human intervention considered possible, the importance of technical constraints, the relative autonomy of technology, and questions of the historical development of technology (e.g., Constant 1989; Ellul, 1954/1964; Gille, 1978/1986b; Hickman, 1990a, 1990b; Ropohl, 1983; Wilkinson, 1964; Winner, 1977).

Determinism is inherently related to questions of free will and human responsibility. For example, if everything is determined by previous events and conditions, then humans could have little choice or responsibility for what happens. Such thinking is generally offensive to those who believe firmly in human freedom and liberty. Similarly, technological determinism implies diminished human choice and responsibility in controlling technology. When pressed, few people would claim unadulterated determinism and most would assert that humans have some degree of freedom to influence the direction of technology.

Nevertheless, the current curriculum and standards of technology education suggest that technology is a phenomenon with a particular form, content, and direction resulting in impacts that can be studied objectively. For example, the notion of "universal technical systems" such as communications, construction, manufacturing, and transportation implies a particular form and content. Similarly, the notion of a universal system such as "input, processes, output, and feedback" (Hales & Snyder, 1981) implies a unilinear direction. (See Schwaller, 1989 and Wiens, 1989 for a discussion of these standards in technology education.) Technology is thus viewed as a discrete system with its relationship to society expressed metaphorically and pedagogically in terms of impacts.

It may well be that the curricular model in technology education has surpassed its role as a content organizer and become an ideological model for technology. In this case, however, the model reinforces technological determinism because of its fixed form, content, sequential nature, and resulting impacts. The more established the model becomes, the more it is taken for granted as *the* form and content of technology. The addition of another category such as biotechnology only expands the breadth with little effect on the ideology unless it serves to reopen the issue of human interaction in technology and society.

The problematic nature of the relationship between social groups and technology has not received adequate attention. Technology education models establish a firm distinction between the knowers (people) and the known (technology) by emulating the natural sciences, where the knowers are the scientists and the known is the natural world. This traditional view of the natural sciences has also come under criticism, although science as taught in schools has not yet changed significantly (e.g., Engelhardt & Caplan, 1987; Suppe, 1977; Ziman, 1978). Note that emphasizing the objective knower is especially strong in industrial technology programs, and its influence on technology education is excessive.

It can be argued that a comprehensive study of technology must emphasize that the knower or student of technology is simultaneously the author of technology. In fact, both scientists and technologists study *and* construct science and technology, thus forming a complex relationship between knowers and the known. There is not necessarily a unilinear cause and effect sequence of technology followed by impacts as in the case of two colliding inanimate entities. (See Pinch & Bijker, 1987, p. 22, Ellul, 1977/1980, p. 4, and Pacey, 1983 for critiques of linearity.) There are, of course, specific phenomena such as the destruction of the ozone layer or traffic accidents, but their traumatic nature and sensationalist media converge to emphasize the ideology of impacts. Even more pervasive, however, are the humdrum, daily interactions of people with other people, artifacts, processes, and knowledge that gradually orient technological change.

What then are the alternatives? How can the notion of technological impacts be eliminated while retaining the importance of the social and cultural context? What approaches, models, or systems avoid the philosophical problems of determinism? How can philosophical metaphors be more fully integrated with mission and curriculum? Lest these questions be shrugged off as minor concerns, virtually half of the 11 most commonly noted weaknesses in NCATE technology education program evaluations as noted by Wiens (1989, pp. 3-4) are related to the issues raised in this study. These items include: (a) the four curriculum organizers, (b) technological systems, (c) socio/cultural/environmental impacts, (d) multicultural and global perspectives, (e) ethics and values, and (f) excessive influence of technical programs.

Technology and Society

Abandoning the emphasis on impacts implies a shift away from traumatic events and the rigidity of cause and effect sequences typical of technological determinism. Similarly, abandoning universal systems implies greater flexibility in conceptualizing technology and change.

Instead of focusing on the trauma of impacts, one can focus on the day-to-day decision-making of human beings in any technological environment. In addition to presenting linear cause-and-effect sequences such as input-process-output-feedback, one can emphasize the multi-directional interaction of all groups affecting technological decisions. Instead of emphasizing mechanistic metaphors of change, one can examine the social conflicts, compromises, successes, and failures of the technological enterprise. Rather than assuming universal systems, one acknowledges alternate systems and models.

Thus far, the issues raised in this study have been organized and described in relation to dominant trends in technology education. The most concise yet comprehensive recent source on alternate concepts and models is a volume of international scope and authorship edited by Bijker, Hughes, and Pinch (1987) called *The Social Construction of Technological Systems*. This work includes topics ranging from domestic technology to biotechnology, and from maritime navigation systems to expert systems. It is a synthesis of recent research and is readily accessible. For these reasons, it is used here as a major source of examples, although the reader is encouraged to consult the extensive bibliography included in the book. Despite the variety of topics and interpretive models in this volume, the approaches converge in three important ways: (a) emphasis on groups rather than individual inventors; (b) opposition to technological determinism; and (c) deemphasis on technical, social, economic, and political distinctions (Bijker et al., 1987, p. 3).

The latter issue seems to be the major point of contention between social constructivism and its critics. Many historians, for example, do not necessarily emphasize individual inventors or adopt deterministic approaches but do maintain clear distinctions among technical, social, political, and economic factors. In so doing, they avoid one of the major weaknesses of some social constructivists who neglect the material and structural constraints of technology (e.g., Cutcliffe & Post, 1989; Hounshell, 1984). Other perspectives also question technological determinism and need to be considered along with social constructivism in developing research in technology education (e.g., Bernard & Pelto, 1987; Chubin, 1990; Durbin & Rapp, 1983; Rothschild, 1988).

Bijker et al. (1987, p. 4) have attempted to achieve a degree of simplicity by delineating three methodological categories: (a) social constructivism, (b) systems metaphors, and (c) actor networks, all of which are critical to the continuing development of technology education. In the interests of simplicity, these three expressions are used as headings in the following analysis, although all three categories are part of the broad social constructivist research emphasis. In addition, critiques and supplementary references are included to promote integration in technology education programs.

Social Constructivism

In general, social constructivists emphasize the centrality of “relevant social groups” and “interpretive flexibility” in technological artifacts and change. They maintain that there is really more flexibility in the design of artifacts than technical and linear analyses would suggest. In particular, diverse social groups all contribute their own values and concerns to the design process. For example, Pinch and Bijker (1987) focus on the social groups most relevant to the design and evolution of the bicycle from the high-wheeler to the safety bicycle. They show how, in the late 19th century, diverse groups interacted through conflict, compromise, and agreement. The concerns of women cyclists (dress, social disapproval), young men (macho image), the elderly (safety), sports cyclists (speed), manufacturers (economics), and technologists (materials, processes, traditions) finally resulted in the stabilization of the safety bicycle design. Bicycle design could have gone in different directions depending upon varying degrees of influence or power of the relevant social groups. Pinch and Bijker provide a simple yet effective multi-directional graphic model as an alternative to linear process models. Their model integrates technological artifacts, social groups, problems, and solutions.

In contrast to this approach, technology education usually emphasizes the technical processes of change *followed* by an examination of their impacts on society. Attention is focused on the effects or impacts of the successful artifact, often after it has been established. Such models are based on a discontinuous, sequential, and success-oriented view of production and social assessment. How then can one integrate the social constructivist approach with technology education as an educational process?

To demonstrate a social constructivist approach, students could be divided into groups representing relevant social groups associated with a given technology or its environment. They would then develop competing designs based on the groups' dominant values or concerns (as found through interviews with relevant social groups). The competing designs would then be debated in large group sessions. Naturally, such a process would not replicate social behavior and its complexity but would emphasize how widely different variables, conflict, resolution, success, and failure interact in the design and the development of technology.

Perhaps the best-known example in technology education of a form of social constructivism is found in manufacturing classes organized around a student corporation. The importance of relevant social groups, the multidirectional nature of design, and social conflict with varying degrees of power and influence would need to be emphasized, however, to achieve an understanding of the social constructivist approach. Nevertheless, such a shift in emphasis should meet technology education standards and, at the same time, eliminate the limitations of the metaphor of technological impacts.

Systems Metaphors

Systems metaphors, as presented by Bijker et al. (1987), stem largely from the work of Hughes (1983), a historian of technology best known for his systemic approach to analyzing the development of electrification networks in Western society. In brief, Hughes examines technological change as a system of interrelated factors in the context of artifacts, institutions, and their environment. Two key concepts called “reverse salients” and “critical problems” are used to identify and analyze the dynamics of innovative energy in technological systems. Hughes' analysis could find wide applications in technology education, though most likely at the graduate level. His systems approach does not have the graphic and conceptual simplicity of Pinch and Bijker (1987), but his work is essential for any researcher on systems approaches for technology education. Hughes' interests in innovation and development coincide with the emphasis often given to these aspects of technology education programs.

The notion of systems metaphors is, however, much broader than Hughes' approach, for example, as illustrated by Gille (1978/1986a) and Ropohl (1983). Gille began his work on the history of technology and systems prior to Hughes. His most comprehensive work on technology (1978/1986a) contains detailed graphic descriptions of technical systems for different historical periods. The scope of his topics is much broader than Hughes'. In brief, Gille seeks to understand the interrelationships among elements in entire technical systems of a particular country or Western civilization and how they changed over the centuries. To do so, he shows how mutations of subsystems occurred (e.g., iron production or transportation), thus stimulating changes, imbalance, and eventually, a new technical system. Although Gille focuses more on the internal dynamics of technological systems, he is sensitive to the highly complex interaction of society and technology. While Hughes presents a very detailed analysis of the growth of electrification systems, including contrasting styles in the United States, England, and Germany, Gille tries to integrate major subsystems and shifts in the systems as they changed. (For a brief review by Hughes of Gille's systems approach, see Hughes, 1988.)

A third approach to technological systems is illustrated by Ropohl (1983), which has the additional advantage of being presented as part of a critique of technological determinism. Ropohl's “action system” consists of three subsystems: (a) goal-setting; (b) information processing; and (c) execution. In order to include social concerns, Ropohl assumes several levels of action systems: (a) micro-level of individuals; (b) meso-level of organizations; and (c) macro-level of national society (and eventually a fourth level of world society). The meso-level includes the production of technological knowledge and technical goods and the application of technical goods. Because of its sequential and matrix graphic form, Ropohl's system has some conceptual similarities with matrices used in technology education, although the subsystem categories are very different. For Ropohl, technological determinism does apply to the systemic quality of technical development as perceived by the individual but not to the controllability of technical development.

Most systems metaphors reflect an emphasis on technical process and development with variable degrees of integration of social factors. Such systems tend to promote a mitigated form of determinism in which technical systems have an inherent systemic quality, though allowing for a certain degree of human choice (e.g., Ellul, 1977/1980). Differences in systems approaches suggest differences in intent, philosophy, scope, and disciplinary background of their authors.

Actor Networks

Actor networks are characterized by the elimination of distinctions between technical, social, political, and economic factors, even to the point of “breaking down the distinctions between human actors and natural phenomena” (Bijker et al., 1987, p. 4). Technologists build networks but these networks are not viewed as systems of discrete, well-defined elements connected in ways that are always predictable. Uncontrollable factors, chance, and accidents are too pervasive in the concept of networks to justify the term "system."

For example, Callon (1987) casts engineers in the role of sociologists as they built networks to introduce the electric car in France during the 1970s. Elements are heterogeneous, ranging from electrons, electrodes, and lead batteries to auto manufacturers, governmental offices, and noise pollution, all combined in the actor network. Law (1987) also uses the concept of actor networks, but to show how the Portuguese were able to integrate people, ocean currents, winds, ships, money, knowledge, and a multitude of other elements to round Cape Bojador and thus sail around Africa to India by the 15th century. Cowan (1987) examines the development of domestic heating and cooling systems from an actor network perspective; however, she emphasizes the importance of consumers in influencing technological change. The simplicity of her graphic illustrations are comparable to those of Pinch and Bijker (1987) and can be easily adapted in technology education to teach about the actor networks approach.

A major advantage of the actor networks approach is the elimination of arbitrary distinctions and categories that often oversimplify technological complexity and reinforce disciplinary boundaries. Actor networks can be used to critique systems approaches which are based on the assumption that the system can be distinguished from its larger environment. On the other hand, actor networks may tend to reflect more explicitly the preoccupations of the researcher. Actor networks are very effective in analyzing the role of controversy and conflict in the development of technology, thus shifting the emphasis away from a preoccupation with technology as success.

Implications for Technology Education

The expression technological impacts needs to be abandoned as the primary metaphor for conceptualizing relationships between technology and society. These relationships are too complex to be understood solely as a set of causes and effects in which technology is the source of the causes and society the context of impacts. The immediate task is not, however, to find a single alternate metaphor but to recognize that there are different ways of approaching the study of technology and society. This diversity should be reflected in technology education programs, standards, and in the evaluation of programs. The current state of research and knowledge of the issues demand flexibility in the interpretation of the current technology education standards that address technology and society.

Nevertheless, flexibility of interpretation should not be construed to mean lack of rigor or "anything goes." Technology education has a mission with which its instructional and conceptual metaphors need to be integrated. For example, the emphasis on technology education for all students implies that women as well as men, non-experts and experts, and persons from all disciplines take an active part in decision-making. This inclusivity suggests the need for curricular research and critiques of technology assessment models, gender bias in technology, and the distribution of power (e.g., Carpenter, 1983; Noble, 1984; Rothschild, 1988).

Furthermore, technology education emphasizes the importance of *doing* technology as a continuous and necessary part of the learning process. And it is in doing technology that students socially construct technology. Students direct, order, and influence technology and in so doing, belie the most extreme forms of technological determinism. Even a brief observation of this learning process demonstrates the existence of the indeterminant and aleatoric, laziness and concentration, social distribution and acquisition of power, failures and marginal successes typical of all social processes.

Studying impacts places the emphasis on a restricted and traumatic point in a sequence, in a sense, after the fact. Studying the social construction of technology places greater emphasis on the learning process of doing technology. Social constructivism, including systems metaphors and actor networks, as well as other models (e.g., historical and philosophical analyses) provide frameworks for conscious reflection and extend our understanding of technological complexity.

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