The Canadian Journal of Higher Education, Vol. XIII-3, 1983
La revue canadienne d'enseignement supérieur, Vol. XIII-3, 1983

SPECIAL FEATURES / CONTRIBUTIONS SPECIALES

Technology and the Human Adventure*

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At a time when we sense ourselves to be moving towards a knowledge-based society in which new technologies of communication and computation are perceived to be central intermediaries of transformation, the dichotomy of C.P. Snow's two cultures, which ignored technology and its deep associations with art and culture, seems peculiarly limited. Humanists for the most part simply ignore technology and historians until recently have largely disregarded technology, although this peculiarly human endeavour has been associated with every important historical change of significance. And of those who profess to some knowledge of technology, very many believe, wrongly, that it is simply applied science.

In the twentieth century, science has come to be an expression of man's will to know the material and behavioural world, a searching out of what can be represented as being general in the multitude of particular circumstances. Technology is an expression of man's will to do, to contrive, to create something particular and useful out of the general possibilities and limitations that our experience, skills, knowledge and imagination offer us. The science of semiconductor physics is about general properties of certain classes of materials. Large-scale integrated circuits are contrivances put together for particular operational purposes through the shaping and treating of specially prepared materials.

It is in the nature of man as mythically defined in the Book of Genesis to seek to know, and to contrive, to contrive tools, machines, processes, systems, networks, organizations, institutions, cities, and in so doing to transform himself and his world. There is no halcyon age, there is only the adventure of exploration and encounter with knowing and doing. Leonardo da Vinci expressed the technological freedom of Genesis in these words:

> Where nature finishes producing its shapes, there man begins, with natural things and with the help of nature, to create infinite varieties of shapes.[1]

* Revision for Publication of an Address to Canadian Society for the Study of Higher Education Learned Societies Meetings, Vancouver, B.C., June 5, 1983

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Before exploring some of the characteristics of technological change, let me emphasize a characteristic that sets technology clearly apart from, although dependent upon, science. Michael Polanyi, in his book *Personal Knowledge,* has lucidly explained that technological artefacts embody operational principles which are based on rules of right or effective behaviour as judged by human intent.[2] These operational principles are distinct from the laws of the physical and mathematical sciences. Operational principles which are "software" account only for the intended working of systems. Defects in operation may, as with a "bug" in a computer program, originate from faults in operational design, or be rooted in physical failure, which was the case when the word "bug" was first coined. The canon of operational knowledge that is used in embodying operational principles into technological artefacts is a distinctive part of the expertise, in particular of engineers. All true professions, including that of education, are characterized by evolving canons of operational knowledge. The processes of discovery in creative professional achievement whereby such canons are evolved can be usefully distinguished but not separated from the processes of discovery in research which are at the roots of science. Professional faculties in our universities, while embracing all of the understanding of potentialities that the sciences can offer, should not be ashamed to proclaim the significance of their own operational essence which is rooted so deeply in the expression of human intent and purpose.

With this background, let me present some views about the character and structure of technological change. Most of us, I think, believe that the rapidly emerging technologies of digital communications, coupled with powerful computational capabilities of microcomputers, are symbolic of the so-called knowledge-based society that is destined to bring many transformations in the patterns of interaction that characterize the acts of living, working, playing and celebrating.

The first point I wish to make is that technologies are not morally neutral. They are illumined or stained with the purposes of those who contrive and propagate them. As Jürgen Habermas has said:

> Technology is always an historical-social project: in it is projected what a society and its ruling interests intend to do with men and things.[3]

Let me illustrate this point with three examples, the last drawn from world-class Canadian technology that is current.

The first example takes us back two hundred years to March, 1776. James Boswell, the alter ego of Samuel Johnson, is standing beside Matthew Boulton, the entrepreneur associate of James Watt. They are in the great Soho works near Birmingham where a steam engine of Watt's design is being constructed. In the course of conversation Boulton turns to Boswell and says:

> I sell here, Sir, what all the world desires to have – Power.[4]

In this simple declaration emerged the concept of inanimate packaged power that could be designed to desired size and be located wherever the need, of people who could afford it, arose. With the development of electrical power systems a century later, the concept of packages of power was extended to the idea of energy as a distributable commodity that would fuel the growth of economies.

It is the year 1878 and Hippolyte Fontaine, the entrepreneur associate of Zenobe Gramme, the Belgian cabinet maker who designed many of the first European dynamos, is addressing in Paris one of the first joint meetings of French and British engineers. In his address, as he discusses the prospects for networks of electric lights, he utters these words:

> By naked light, unaided, spacious halls, or extensive yards may be lighted up so that by night, as by day, the movements of merchandise, or manufacturing operations on a large scale or work in open air, may be followed up.[5]

In short, Fontaine would turn night into day, and since that time, natural rhythms of work and sleep have been changed for those who work on the graveyard shift.

A century on into our own decade, we in Canada are world leaders in digital communications through the aspirations, engineering capabilities and corporate leadership of companies such as Northern Telecom. In a recent annual report[6] of this company there is projected a vision of "the intelligent universe" in which the global village is laced with a world-wide net of digital communications characterized by a complex grid of links interconnecting intelligent nodes that direct packets of digitized symbols from node to node and to and from terminals through which persons generate, organize, manipulate, exchange, share and store symbols that are intended to be meaningful to them. What is radical about this "intelligent universe" is the speed and complexity with which symbols can be manipulated and transmitted. In human consequences it is at least as radical for our society as the packaged power of the steam engine was to the society of two centuries ago and the distributed electrical network of power and light was to the society of a century ago.

My first major point, therefore, is that technologies are driven by human aspirations of individuals and corporations, by creators and users. They will be promoted, if not for our purposes, then for the purposes of any who are able to acquire and use them. They have a dynamic in human historical terms that does not wait upon dispassionate judgements of what development may be conceived to be morally sound or just. The idea of the technological imperative has its roots here. The lesson is that, if we are to participate in the transformation, we must engage in the fray. Man cannot deny his will to contrive.

Next I would like to reflect on distinctive features of the structural changes that accompany the emergence of major new technologies. I believe a conception of these features is essential to understanding the roles it is feasible to play in shaping technological impacts. I will draw heavily on the elegant insights provided by C.S. Smith, an eminent metallurgist, in his splendid book *The Search for Structures* which relates structural change in crystalline and non-crystalline materials to technology, science and art.[7]

First I introduce his idea of *qualities.*[8] With materials we speak of the quality of elasticity, plasticity, texture. Such sensual qualities of materials on a human scale have their roots in substructures such as crystals, grains and dislocations on a smaller physical scale than that of the mass of material that possesses the quality. It is the interactions of the substructures that lead to the expression of a quality such as plasticity. The value of or interest in the quality of plasticity, however, arises from the uses to which the quality is put in the application of materials and therefore on external interactions on a scale larger than that on which the quality itself is perceived. If one thinks of "the intelligent universe" as a megastructure with a hierarchy of substructures and subunits ranging from digitized regional networks to intelligent nodes to interactive terminals to microcomputers to large-scale integrated circuits to optical fibres to symbols projected on screens, to human interrogators and observers, one can ask what qualities of these structures are humanly pertinent. Part of the milieu of any new technological structures is, of course, their embedding among older technologies and patterns of use. Heredity plays a strong role in technological change.

What are some of the qualities that are important to technological systems? Northern Telecom has declared that they seek to market systems that are congenial, controllable, and compatible, that allow continuity and achieve cost-effectiveness. A current technological synonym for 'congenial' is 'user-friendly'. I would observe here that the extension to technologies of such intimately human words as 'friendly' and 'congenial' deserves careful reflection. Controllability, in the sense of Northern Telecom, implies that the local user has the capacity to determine how the system is to serve him. Compatibility implies that one user can communicate effectively with many other users near and remote, that packets of symbols can pass freely from node to node. One is reminded of the days when differences in gauges between railways impeded the flow of goods. Continuity implies the capacity to interlink and interact with older existing technological structures. Continuity refers to a form of hereditary compatibility and more deeply acceptability. Users also like the quality of reliability or robustness. Let me emphasize the conceptual point that qualities in technological systems are identifiable at interface levels betwen inner, more detailed structure and outer, more macro structure. The quality of cost-effectiveness can be coupled to that of frugality and efficiency. The time-span over which technological change can be propagated to the point of causing transformation depends strongly on the achievement and recognition of those qualities that lead us to accept it and even to embrace it.

What are some of the characteristics of technological change? There are three basic stages of nucleation, growth and saturation, of beginning, development and maturity. If we plot a curve of relative development versus time, the characteristic shape of the growth curve is that of the "S" curve or logistics curve. At any given time, such processes of development are at different stages in different fields of technology. Cyril Smith has described this universal process in these human terms:

> The transition from individual discovery and rare use of techniques to the point where they affect the environment of Everyman and the content and means of communication between people and peoples underlies virtually every great social or political change and every fundamental change in man's view of the world.[9]

How are we to understand the distinctive character of the stages of technological change and of their dependence upon key internal qualities and environmental energies of corporate entrepreneurship, social interest and governmental regulation? I draw freely upon analogies between the structure of materials and the structures of technological systems such as those of "the intelligent universe".

Among solid materials we can distinguish those that are elastic from those that are plastic. Elastic materials are those that, when deformed by an external force, return to their original shape when the force is removed. Universities as structures are more elastic than plastic! Elasticity represents the characteristic of inertia to structural change. Plastic structures when stressed take up new configurations which reflect the history of forces of change exerted upon them. Every work of sculpture is an embodiment of the quality of plasticity. Now plasticity, in metals for example, derives from the presence, in the generally ordered environment of crystals, of local imperfections called dislocations. Dislocations are places of local disorder in relationships between atomic neighbours. Dislocations can move and propagate through the structure. Imperfections in a previously ordered state are at the root of change of shape. In technological change, the analogy to such imperfections is the process of nucleation through invention, entrepreneurship, marketing and individual use.

Technological change first takes place in small parts of systems which can adjust, and change propagates gradually through more complex aggregates. Change at any level involves catastrophic change in relationships with near neighbour elements of the structure although at both higher and lower levels of structure relations may be topologically unchanged. Let me use the exact words of Cyril Smith as he explains the rising slope of the "S" curve:

> In a large system local changes may be nucleated in many locations, and patches of the new, more stable, structure will continue to spread until eventually they impinge on and interfere with one another. Once the difficult stage of nucleation has passed, patches of the new form will grow by accretion at a rate depending only on how quickly the parts at the interface can rearrange themselves . . . Change, then, begins slowly, uncertainly, and in places that are highly dependent upon local circumstances because nuclei necessarily are misfits in the existing structure or orthodoxy.[10]

In the period of maturation, new structure has largely replaced the old and there is a period of adjustment as the stability of the larger structure comes to dominate the smaller detail. The quality of overall elasticity emerges to characterize overall inertia. Only in this phase, as Cyril Smith observes, does necessity become the mother of invention. In the nucleating phase, change is driven by imagination and aspiration and the forms that emerge cannot be known until they can be observed. Technological change inherently involves the creation of new structures and forms that are misfits with the old and not a priori knowable.

What inferences may one make from the preceeding analysis with respect to the impact of technological change on our systems of education? The proponents of particular technological means and artefacts tend to become overly enamoured of the apparent wonders of new devices perceived in isolation from the structural milieu into which they must be planted. The complex structures of our mature educational systems have immense elastic structural inertia and the spread of new form through the nucleation of novel 'imperfections' is readily impeded by preexisting structures. But with more sensitivity to the expression of key qualities much more can be done. Even good administration has a role! What is highly probable is that new structural forms or networks that have education as a goal will emerge, become institutionalized, and change the balance of significance of conventional forms. The "intelligent universe" will be characterized by forms that are more molecular and interactive than monolithic. Not so much the small will be beautiful as the local with diverse interconnections. What about the role of the universities in this evolution?

Universities are unique in that not only do they teach but they are deeply engaged in determining what there is to be known. Karl Jaspers wrote that:

> The University is the corporate realization of man's basic determination to know. Its most immediate aim is to discover what there is to be known and what becomes of us through knowledge.[11]

Our universities, as institutions concerned with the ground of knowing, have a responsibility to contribute imaginatively to the potentialities for technological change and the economic benefits of such change both through the knowledge base of the sciences and the canons of design and operational principles that distinguish professional schools. In these economically and socially troubled times that is particularly clear. But in a singular way, universities have a responsibility to contribute to our comprehension of the nature and consequences of technology as an expression of man's will to contrive and to transform the very ground of living, working and playing together. It is a singular failure of our fragmented universities not to do so more effectively.

In the images of these remarks the fragmented university is a disordered array of imperfections whose power to nucleate change and to attract support is inhibited by its inability to display qualities of coherence. This lack of operational power may of course very properly be in the nature of the university as an institution engaged in understanding the ground of knowing and of doing.

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