HIGH TECHNOLOGY, EMPLOYMENT AND THE CHALLENGES TO EDUCATION*

Richard Gordon and Linda M. Kimball

The contribution of employment in high technology industry to future employment growth in the US economy is estimated to be small. Much high technology employment is not professional work at all, but routine labour, and much of that performed by minority groups with few career opportunities. Most new jobs will occur in occupations requiring no more than secondary education. High technology may generate employment in other areas, but often low grade work performed in the "homework economy". Appropriate education for employment in high technology industry and in computer-related fields is not necessarily specialised and technical; high-quality general education is probably more important. Instrumental education, ignorant of the demands of high technology, and of the demands a modern economy makes upon high technology, is likely to be counter-productive. Commercial and technical success requires a combination of cultural learning and technical skill.

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INTRODUCTION

Job creation can take a number of forms. Changes in processes, products or markets may generate entirely new forms of enterprise and new occupations or jobs. Economic and organisational expansion, or changes in occupational structure, can multiply (or contract) the number of positions within existing sectors of employment. Work requirements and skills might be transformed to such an extent that traditional jobs effectively become accessible to new types of worker. Since microelectronics and computer-based technologies have such profound and simultaneous impacts upon factors affecting employment (price/performance characteristics, product design, production methods, organisational structure, locational flexibility, firm size, productivity, labour demand), job

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creation and the nature of work in the contemporary era appear particularly dependent upon the social advance of high technology.

Because high technology's impact upon employment opportunities, occupational structure and skill requirements is mediated by its knowledge-intensive character, the information economy ostensibly presupposes new strategies of labour formation. New forms of scientific and engineering professionalism will be required to sustain high technology development. Large segments of the labour force will require extensive training, or retraining, in computer-related skills. Computer-based technologies will impose more sophisticated skill requirements on individual jobs and will shift the distribution of employment in favor of more advanced worker capabilities. Preparation for labour market entry will assume a background of familiarity with computer equipment and technological culture.

It is a common presumption that rapidly changing labour force requirements resulting from the application of new technologies have outflanked and undermined both the structure and content of existing education at all levels, a disjuncture that is all the more serious as information is converted into a commodity and knowledge becomes a strategic resource. Impelled by this sense of crisis, far-reaching educational reforms have been proposed in the United States and elsewhere. These programs simultaneously enhance the social importance of education while advancing its subordination to technological imperatives.

The present analysis examines the relationship between high technology and employment creation with specific emphasis upon aggregate employment levels, occupational structure and skill requirements, and the challenges confronting educational policy in advanced industrial societies. The first two sections present new evidence regarding employment generation and occupational structure within high technology industry itself and critically assess the industry's reputation as a model of knowledge-intensive job growth. Similar ambiguities concerning the general economic significance of computer-related occupations are delineated in the third section of the paper. The near universal tendency to extrapolate high technology's impact upon social employment from technical attributes alone is examined in the following section, where it is suggested that a prior determination of changes in the fundamental nature of work must precede any assessment of aggregate employment effects. In the fifth section it is argued that, while computerisation is **technically** compatible with a wide variety of skills, **social** constraints imbedded in the logic of deployment of computer-based technologies render certain skill configurations more efficient and productive than others. Finally, several contradictions inherent in prevailing assumptions about educational strategy for high technology employment are examined and proposals are made for transcending the limitations inherent in the equally vulnerable claims of technical and general education.

EMPLOYMENT CREATION IN HIGH TECHNOLOGY INDUSTRIES

Substantial labour displacement has occurred within traditional manufacturing and service industries subject to international competition, declining profitability, disinvestment and rationalisation. High technology industries are invariably represented as counter instances of employment generation in the information age. Job creation in high technology and related sectors is expected to compensate for job loss in other areas. Analysis of high technology employment in the US, the global center of expansion in electronics, provides a critical insight into the effectiveness of these compensatory mechanisms.

Definitions of high technology industry vary considerably. Some conceptions are too narrow, allowing one segment of electronics (usually semiconductor manufacturing) to represent the entire industry. Others are too broad, including standard manufacturing industries that are neither 'emerging' nor 'knowledge-based'. High technology refers here to enterprises engaged in research, development, design or manufacture of electronic products or computer-related services. This sector tends to have high ratios of research and development (R&D) investment to sales, and high percentages of scientific and technical personnel. It also involves considerable proportions of standardised manufacturing and routine labour. In terms of the US Standard Industrial Classification (SIC) System the high technology sector incorporates electronic computing and peripheral equipment (SIC 3573); telephone and telegraph apparatus, radio and television broadcasting, communication and signaling equipment (SIC 366); semiconductors, electronic devices and components (SIC 367); guided missiles and space vehicles (SIC 376); engineering and scientific instruments, measuring and controlling devices, optical instruments (SIC 381-383); and computer software and data processing services (SIC 737).

The most recent data reveal that each sector of the electronics industry has exhibited steady, sometimes spectacular long-term employment gains over the last two decades, though employment levels have been subject to sharp fluctuations and gains have been more substantial in semiconductors, computers and software than in other high technology sectors. By 1984, the domestic US high technology industry as a whole employed 2.73 million workers, an aggregate increase since 1965 of 182 per cent (compared with an increase in total US employment over the same period of 53 per cent).

This impressive growth record is mitigated in three different ways. First, electronics employment represents only 12 per cent of all jobs in US manufacturing and less than 3 per cent of total US non-agricultural employment. High technology is dwarfed by other economic sectors (employing one-sixth of the number of workers on government payrolls for example). Second, the future of global electronics competition, and thus of future employment impacts, is uncertain. While underlying trends, contrary to superficial appearance, appear to favor the US electronics industry against its Japanese and European rivals, it is more doubtful that recovery will produce the same level of sustained employment increase as in the past. Annual rates of labour force growth in 1975-1979 were more than twice the rates of increase over the 1980-1984 period. Third, though high technology industries will continue to expand more rapidly than total employment, they are expected to contribute less than 9 per cent of all new jobs in the period of 1982-1995.

Thus, all but a small proportion of the new jobs created in the foreseeable future will originate outside high technology industry. High technology industry's contribution to overall job creation in the economy is relatively small and the future expansion of the industry is likely to have little impact on reducing current levels of unemployment.

OCCUPATIONAL STRUCTURE IN HIGH TECHNOLOGY INDUSTRY

If high technology industry is an example of the positive relationship between technological innovation and job creation, it is also extolled for its embodiment of new forms of 'knowledge-intensive' labour. The industry's development ostensibly offers strong support for the view that an economy based upon new technology will generate net employment growth and produce jobs with higher average levels of skill and responsibility.

Comparative analysis of different US regional high technology complexes reveals that the production workforce typically comprises between one-third and one-half of total employment (compared with two-thirds or more of all workers in traditional manufacturing). Moreover, the industry has evinced a consistent increase in the proportion of scientific and professional employment over the past two decades (though this varies by sector). The decline in the relative share of the production labour force has been especially severe between 1980 and 1984. Projections for the growth of 'knowledge-intensive' occupations, therefore, find support in the increasing percentage of non-production workers within the expanding employment base of the electronics industry.

This model fails to register, however, either the existence of the remaining production labour force or the typical segmentation of occupations within electronics. Somewhat paradoxically, high technology industry generates a high proportion of traditional routine jobs, even restoring Taylorist forms of work organisation at the same time as they are receding in many other industries. Contrary to common belief, a major portion of jobs within information industries are not knowledge-intensive.

The high technology labour force is divided between a stratum of highly paid professional, scientific and technical employees and unskilled/semi-skilled production workers, usually non-unionised, performing routine tasks (sometimes in hazardous conditions) at comparatively low wages. The basic dividing line separating the two groups is educational: one set of jobs requiring advanced levels of educational achievement and specialised qualifications, the other requiring primarily basic aptitudes and positive work attitudes. Little mobility exists between the two segments.

Compounding the educational divide within the US electronics labour force is an equally fundamental stratification based upon gender and ethnicity. As the hierarchy of skill, status and income ascends within high technology, positions are increasingly occupied by white Anglo males. In Silicon Valley, for example, white males comprise a relatively small percentage of production workers (23 per cent), but predominate in technical positions (55 per cent) and professional (scientific, engineering and managerial) occupations (72 per cent). Conversely, female and ethnic minority workers cluster in less skilled jobs at the lowest level of the occupational ladder. Together they comprise 28 per cent of professional employees, 45 per cent of technical workers (these figures weighted by a large number of immigrant male Asian employees), and 77 per cent of production workers. Recent detailed research indicates, in addition, that women and minorities tend to cluster within specific job categories, within specific types of firms and within specific sectors of the industry, and that this clustering imposes severe obstacles to career mobility. Thus, in spheres where women and minorities tend to be employed, possibilities for entering more highly qualified positions are restricted; where career opportunities are more plentiful, few women and minorities tend to be employed.

COMPUTER-RELATED OCCUPATIONS

At one remove from employment in high technology industry itself, and overlapping with it, are occupations directly related to the application and use of computer technology (installation, programming, processing, operation, and servicing). Recent projections confirm the explosive rate of job creation in this area:

computer-related occupations comprise four of the top five (and five of the top ten) fastest-growing employment fields in the US between 1982-1995.

High rates of job growth, however, do not translate into high levels of aggregate employment. The five principal computer-related occupations will provide only 2.6 per cent of total projected employment growth in 1982-1995. Some computer-related occupations show negligible growth and others are declining. Not a single high technology or computer-related occupation appears among the twenty occupations projected to experience the greatest employment growth in the next decade and a half. The five largest growing employment sectors, providing more than five times as many new jobs as the top five computer-related occupations, are all characterised by relatively low skill requirements. Only two of the ten largest growing occupations (collectively providing 25 per cent of all new jobs in 1982-1985) require post-secondary education.

In sum, rapidly expanding high technology and computer-related jobs will make a small contribution to overall job creation. Numerically, the most significant new employment gains will occur in occupations requiring secondary education or less.

HIGH TECHNOLOGY AND AGGREGATE SOCIAL EMPLOYMENT

Analysis of the impact of high technology innovation upon general levels of social employment has become a field of vast over-simplification in which both optimistic and dire projections tend to employ flimsy economic evidence, narrow and misleading projections, and a lack of concern for qualitative, in addition to quantitative, change. Many aggregate studies forecast adverse employment impacts while assuming constant levels of productivity or omitting consideration of factors potentially offsetting job loss. Other studies base their optimistic calculations concerning employment increase on unrealistic or purely speculative estimates of price movements, sales volume or economic growth. Strictly speaking, the kind of data necessary for an assessment of the aggregate employment impacts of high technology is lacking; existing projections remain quite conjectural. This problem is compounded by the fact that, far from being mutually exclusive alternatives, quite divergent outcomes — employment increase and labour displacement — occur simultaneously.

Technological change is not necessarily correlated with declining labour demand. Historically, the cumulative impact of previous industrial revolutions has expanded available jobs roughly in parallel with the increase in active population. After World War II, technological innovation, productivity increase and employment expansion were compatible. With high technology, new industries are created, new products and services are generated, costs are lowered and demand stimulated. Traditional sectors may continue to grow despite computerisation. Application of computer-based technologies may require additional employment, even when introduced for 'labour-saving' purposes. Job loss resulting from delayed innovation or loss of international competitiveness may outweigh labour displacement issuing from automation.

On the other hand, abundant evidence suggests that the information revolution engenders job loss. Opposition to increasing state employment and prospective automation indicates that the tertiary sector may replicate the 'jobless growth' pattern of the primary and secondary sectors, thus removing the final barrier to pervasive structural unemployment. Examples of widespread job destruction are abundant in factories and offices. The disjuncture between traditional skills and those associated with computer-mediated work creates permanent unemployment for those made redundant in older industries.

Contemporary experience, therefore, suggests a wide range of possible simultaneous outcomes varying according to sector and to circumstances with regard to high technology's employment impacts: job displacement, declining employment per unit of output counter-balanced by output growth, jobless growth, direct employment increase. Overall economic trends, too uncertain to predict, will prove more influential in future employment outcomes. More importantly, preoccupation with the question of aggregate employment levels has tended to obscure even more significant transformations in the very nature of employment and the organisation of labour: changes in the concept of work, in the identity and character of those performing it, and in its location.

Four forms of labour are particularly important in considering the changing structure, content and location of work in an information society: outwork, part-time employment (permanent temporary work), labour in foreign production sites (temporary permanent employment) and self-service/informal work. These labour markets have quite independent histories and their dynamics remain quite specific in many respects. But they also have a number of features in common: (1) they comprise the most rapidly growing sectors of employment in advanced industrial economies, (2) high technology has reinvigorated each, and will continue to do so, (3) through high technology, these labour markets are connected on a global scale to form a single integrated system, (4) they provide a diverse range of skills, but most labour in these sectors is low-skilled, poorly paid, unorganised, and lacking employment benefits and job security, and

(5) the 'homework economy', formed by the intersection of these labour markets, has become a significant mechanism for articulating growing female labour supply with the production process.

Significant employment growth, directly influenced by high technology but lying outside official statistics or national territorial boundaries, is concealed within the homework economy. High technology, therefore, is likely to generate considerable employment in the future, but, like previous industrial revolutions, it will completely transform the way in which work is done, the kind of people who do it and its location. Unlike the benevolent image presented by the 'electronic cottage', the homework economy does not embody work that is more autonomous, highly skilled and well paid, but, in the majority of instances, just the reverse.

HIGH TECHNOLOGY AND SKILLS

Most studies of high technology and the qualitative nature of work tend to deduce changes in skills, tasks and worker activity from the technical attributes and operational routines of computer-based technology. Two standard perspectives can be derived from such a logic: (1) the embodiment of human functions in computer-based technology marginalises the worker, reducing decision-making and control functions, fragmenting tasks and decreasing the knowledge and skill required of the worker; (2) new technology frees workers from machine rhythms, replaces muscular strength by symbol manipulation, increases decision-making abilities and necessitates higher levels of skill and responsibility. Both orientations capture a portion of reality, but each is unable to provide a coherent explanation of the impact of automation on skill requirements.

Computerisation can be implemented in ways that directly decrease the skill content of jobs. Indeed, the deskilling ramifications of programmable automation are not limited to production or clerical workers, but include highly qualified managerial and professional workers as well. Similarly, workers' skills can be augmented with the introduction of programmable automation. More subtle changes are also possible. For example, when robots eliminate workers at the lowest grades of skill, they correspondingly raise the average skill level of the remaining labour force. When less-experienced workers are trained up to a deskilled job, requalification occurs for the worker, if not for the task itself. Demand for different types and levels of skill may develop simultaneously and in complex combinations. In fact, the precise mix of skills produced is not a function of technological capabilities (which are compatible with either deskilling or requalification), but of prevailing social theories and practices of management, work and production.

Computer-based technologies are not simply ensembles of technical attributes. The operating principles of the computer often are an incomplete guide to the way it is actually imbedded and utilised within differing organisational contexts. The system cannot be separated from the diverse skills required for its operation, the infrastructural resources required for its maintenance and development, and the values and goals of competing, often conflicting, groups regarding its appropriate design and use. In these and other ways it can be seen that computer-based technologies are equally dependent, in addition to their technical character, on the social arrangements in which they operate. The 'web of computing' (Kling & Scacchi) — the specific network of people, resources, services and organisational structure which mediates computer use — is an inherent component of the system. Computerisation is a form of social organisation.

The constraints imbedded in the social character of new technology are particularly manifest in mature forms of integrated automation (CAD/CAM, FMS, DDS) which permit a reconciliation of organisational goals of flexibility and efficiency. Regardless of their impact on the skill content of particular tasks, the gap between the logic imbedded in the design and managerial logic of such systems and the logic of actual systems operation renders them inherently contradictory: (1) integrated systems are governed in fact not by cybernetic feedback and regulation but by contingency; (2) work with computer-based technologies involves a change in the meaning of skill from the concrete mastery of specific tasks to a combination of formal and informal knowledge about the technical and social organisation of production; (3) such systems tend to reintegrate the production processes as a whole for the workers operating them.

The social character of technologically-integrated labour exhibits a fundamental contrast between the level of worker involvement anticipated by systems designers or managers and the extent of worker intervention actually required to maintain and to operate sophisticated automated systems. Paradoxically (and precisely as a function of the manifest inability to reduce social attributes to technical characteristics), systems designed to ensure predictability discover uncertainty as their basic principle of activity, and systems implemented to reduce or to eliminate labour depend for their efficient operation upon the high quality of extensive human intervention.

HIGH TECHNOLOGY, EMPLOYMENT AND EDUCATION

The rapidity and breadth of employment changes associated with high technology generates new challenges for education. Current policy analysis indicates a number of specific problem areas in the education system's adjustment to high technology's impacts. High technology industry and manufacturing or service organisations utilising computer systems are confronted with shortages of electrical/electronics engineers, computer professionals and technical workers. Large segments of the labour force have (or will) become 'information workers' involved in the production, manipulation or distribution of information goods and services, and will require new forms of technical and work-related education to equip them with the requisite levels of skill. Training programs must be retooled to provide new skills on a sufficient scale and substantial retraining efforts will have to be mounted for workers in older sectors whose skills have become obsolete. Finally, as computer-based technology becomes the essential medium for the transactions of everyday life, computer literacy, as well as basic scientific and mathematical skills, will be regarded as essential to informed active citizenship.

Technological change has outdistanced the traditional structure and forms of education: reform is necessary in both general and vocational education and at all levels of the system from institutions of higher learning to primary schools. Collectively these reforms demand a substantial reorganisation of the educational system to meet the immediate and long-term needs of the information economy. Both the need and the prospects for educational reform are exacerbated by the contemporary crisis of US science-based education which threatens the future development of high technology industry and potentially undermines US global industrial competitiveness and defence.

Educational reforms are undoubtedly required to service the needs of the information economy at all levels from the provision of greater numbers of trained engineers and scientists to the inculcation of elementary computer literacy. But these reforms must be carefully situated within broader perspectives which tend to be absent from the existing policy debate. Current proposals, especially those postulating that the education system attune itself more directly and more completely to changes in work practices and employment structure resulting from technological innovation, constitute potentially destructive over-reactions. They both underestimate the importance of other types of educational reform and, even more significantly, seriously miscalculate the educational implications of high technology itself.

First, temporary imbalances have been mistaken for structural misalignments. Specialist skill shortages in electronics and computer-related fields, for example, owe more to the unanticipated pace of industrial development in electronics than to any long-term inability of the education system to respond. Recent evidence indicates that the supply of electrical engineering graduates now meets demand and that increasing enrolments already threaten to create an oversupply. Though naturally lagging further behind, similar responses are occurring in computer engineering and computer science. Moreover, since the electronics industry operates on a global scale, labour demand can be satisfied in part in national and international labour markets.

Second, some structural imbalances have been treated misleadingly as temporary misalignments. Vocational programs focusing on narrow skills training frequently have been inadequate in matching traditional industrial needs, and promise to be still more unresponsive in the future as skill requirements change more rapidly. Vocational programs, therefore, cannot be applied to employment and training needs without substantial internal reformulation of their structure and goals. The same strictures apply to most retraining programs that ignore the social context and purposes of skill displacement and acquisition.

Third, policies for instrumental change, which erode the traditional distance between educational institutions and private enterprise, tend to be self-defeating. Thus, as professional science and engineering departments increasingly adopt purely industrial perspectives and abandon traditional educational values and purposes, they are weakened significantly by competition from industry itself. Academics desert universities for higher salaries in private industry or government research. Workloads increase intolerably for the remaining staff. The quality of equipment and research declines. Industrial absorption of new graduates leads to shortages of students with advanced degrees and threatens the further renewal of departments, perpetuating the pattern of crisis and withdrawal. Similar shortages arise, for the same reasons and with the same results, in secondary education. (Ironically, though not surprisingly, this crisis is especially severe in California and Massachusetts, the national centres of high technology development.) Far more than the temporary shortages which prompted the change, it is precisely the realignment of education in the pursuit of meeting instrumental economic objectives which in fact threatens the long-term quality of scientific and engineering research and development in the US.

Fourth, the assumed links among technology, employment and education, which underlie the proposals for educational reform, have been broken precisely by high technology innovation. It is widely assumed that technological change increases skill requirements within occupations and expands the proportion of higher skilled positions relative to low-skill jobs across occupations, thereby elevating the educational requirements for employment throughout the economy. The connection between technological development, educational attainment and upward occupational/social mobility, does continue to pertain for some occupations (including certain high technology professions), though usually reinforced considerably by labour market shortages resulting from unexpected industrial change or from entry barriers imposed by professional associations.

In many other fields, however, the post-war influx into secondary and post-secondary education has generated an oversupply of educated workers for the economy. Consequently, there has been a general inflation of educational requirements for formal employment: educational qualifications for jobs have risen not as a function of expanding skills intrinsic to the work itself, but as a result of relative abundance of over-educated applicants seeking positions.

High technology compounds the increasing discontinuities between education and work. In addition to its employment of higher proportions of scientific and technical labour, the electronics industry has encouraged the formation of substantial numbers of unskilled and semi-skilled manufacturing and clerical jobs. The social organisation of high technology in other sectors is as compatible with downgrading skill (and educational) requirements as it is with the enhancement of educational qualifications. The synthetic capabilities of high technology — its capacity for integrating formerly disparate functions and fields — as well as the increased pace of industrial transformation, creates uncertainty about the long-term viability of all forms of narrow expertise. Scientific and technical skills themselves are no longer immune to dequalification or rapid obsolescence. In all of these respects (and others) high technology demonstrates the fragility of the interrelations between employment and education and the need for a more complex understanding of the educational implications of technological change.

Fifth, the economic impact of high technology should not be exaggerated. Employment within high technology and computer-related fields will not substantially reduce prevailing levels of unemployment. More jobs will continue to be created outside the sphere of high technology and large numbers of jobs will require relatively low skills and educational qualifications. The diffusion of high technology, contrary to oversimplified assumptions, will contribute heavily to the growth of such jobs, particularly in the homework economy and in firms unwilling to alter traditional forms of hierarchical organisation to take advantage of the full range of new possibilities for administrative and work structures opened up by new technology. (Recent studies indicate, for example, that in the US 75 per cent of office automation installations are employed to reinforce disciplinary control over workers and reduce qualifications.) These trends demonstrate a continuing, perhaps even more urgent, need for the reinforcement of high-quality general education and the extension of traditional educational opportunities to still broader segments of the population.

Sixth, high technology should not be the more or less exclusive focus of educational and training policy. The future global competitiveness of the American economy will depend less on the singular success of high technology itself than on the economy's ability to meet international standards in traditional manufacturing (process and product) technology and organisational innovation; that is, on its potential to integrate rationally high technology with existing economic sectors. As much, if not more, attention should therefore be given (a) to reconstructing traditional skills and practices, and (b) to the interface of high technology skills and traditional skills, as to high technology skills themselves.

Seventh, a significant barrier to the reformist educational impact of technological innovation is the prior conformity of high technology to the existing structure of educational inequality based upon class, gender, ethnic background and geographic location. Educational inequality is a principal axis of differentiation within the occupational structure of electronics and the polarisation of the labour force tends to eliminate internal career ladders and preclude the kind of upward mobility associated with traditional manufacturing industry. To the extent that work organisation is recomposed and this polarisation reduced, workers on the bottom of the occupational ladder are either unable to compete for the new positions or are transferred into equally segmented intermediate job categories. Inequalities based upon gender and ethnicity prevail throughout high technology industry: in the industry's occupational structure, in its international division of labour, in the different modes of teaching computer literacy to boys and girls in school, or in the different forms of computer training delivered in inner city and suburban schools.

Although the number of women and minority men awarded degrees in scientific and technical fields is increasing, these strata remain vastly under-represented in the educational channels leading to highly skilled and well-remunerated high technology jobs. The distribution of scientific and technical credentials is also stratified hierarchically in such a way that those who are already under-represented in these fields are increasingly under-represented at advanced levels of academic training. Technical shortages, high labour costs and concomitant advances in computer-aided design have provided the basis for the reorganisation of work responsibilities in the engineering profession: lower status visual and manual skills are being simplified and consigned to those previously excluded; while more abstract engineering skills and highly valued managerial functions continue to be the almost exclusive domain of white Anglo (or Asian) men. Teaching methods and shifting criteria of excellence within engineering education ensure the reproduction of technical inequalities embedding these labour market conditions. Even the much expected democratising effects of using computers in schools have not materialised for the younger generation. Both access to computers and different approaches to using computers in elementary and secondary schools reconstruct traditional inequalities in such a way that power relationships between managers, workers and machines are differentially established in early childhood. In offshore assembly plants and in the homework economy, certain levels of education have been required of workers as a means of ensuring self-discipline, application and low error rates in low wage routine jobs.

Eighth, a final dimension of the relationship between high technology and education concerns an incipient cultural transformation in the very concept of knowledge itself. In its fifth generation form particularly, high technology (artificial intelligence, expert systems) has assumed the ground of knowledge itself; computers have come increasingly to specify culturally the form, possibility and limits of thought. In fact, this claim legitimates the extension of a particular, limited form of rationalistic knowledge throughout all areas of social life. Computers can produce 'knowledge' only within the narrow structure of a precisely articulated framework which imposes upon its users a specific conception of information, organisation and action. Unbreachable structural barriers preclude the simulation of genuine human thought and action in systems utilising artifical intelligence and natural language capabilities. Expert systems should be considered as 'novice systems' precisely incapable of delivering expertise. The design of computer systems must include an understanding of the limits of computerisation and of the necessary linkages between computer systems, their social contexts and the continuing necessity for extensive high quality human intervention in computer-mediated environments.

CONCLUSION

Emphasis upon instrumental adaptation to, and utilisation of, high technology undermines rather than liberates the potential for social and technical change. There is no doubt that the information economy presupposes the expansion of skills concerned with manipulation of the physical world. Scientific and engineering capabilities will become more widespread and receive more cultural prominence. Technical skills for the deployment of computer-based technology have become essential to the completion of a broad range of tasks in modern society. The need for some level of technical qualification as part of normal employment requirements will magnify as capital-intensive flexible production builds upon capacities for process and product specification, rigorous quality control standards and servicing varied end-user requirements. Service workers require knowledge of the functional integration of work tasks, firm operations and computer systems. Minimal standards of computer literacy are becoming a near-universal requirement for individual interaction with major social institutions.

Yet mere conformity to the 'imperatives' of new technology is quite insufficient to resolve the problems attending transformation to a computer-based society. Most importantly, workplace deployment of computer-based technologies increasingly will require abilities to participate in the social organisation of production and administration, which transcend the limits of particular skills resulting from individual technical training or specialised education. Only if workers are experienced with the range of tasks and operations necessary to complete production can they re-arrange the various components efficiently when confronted with the sudden or frequent demands for change inherent in the utilisation of computer-based technologies. Policies which impede this adaptability are inimical to the competitiveness of firms in an integrated world economy. Effective control and decision-making, practical learning and efficient utilisation of new technology reinforce each other: computerisation strategies designed to eliminate or confine such skills perform less productively than structures designed to enhance them. Computer-related jobs, in fact, are oriented to analytical, communication and control functions which require broad familiarity with learning skills, aptitudes for organisation and social interaction and an understanding of the social bases of technological culture. The foundation for individual expertise in this context is the organisational appropriation of the social character of high technology: education and training, therefore, must focus on the control and management of systems as well as the social prerequisites for the effective utilisation of new technologies.

Efficient (non-dysfunctional) deployment of computer-based technologies demands strategies of *social innovation* which will maximise the productive potential of high technology by providing the preconditions for decentralised, integrated work group control of the production process in its entirety and its permanent direction of evolving technological capabilities.

The flexibility of social organisation is central to the developmental possibilities of the technology itself. Paradoxically, the implicit social logic of mature automation is more democratic in its potential than either the forms of centralised work organisation or the instrumental education strategies typically justified in the name of adaptation to the technical requirements of computerisation. The conflict between the self-defeating 'technologisation' of society and the social organisation of technology will provide the framework for the future development of automation.

Instrumental education, ignorant of the social preconditions, character and consequences of new technologies, tends to be counter-productive, adapting people to imaginary or obsolete technical contraints, and invariably promoting second-best (or worse) uses of the technology itself. Yet, a reassertion of traditional educational values does not provide a complete answer to this dilemma. Continued support for classic democratic education remains imperative: cultural creativity across a wide spectrum of achievements (not scientific or technical expertise alone) is fundamental to any humane society and the need for an enlightened and active citizenry is hardly less significant in the information age than it was before. At the same time, traditional education shorn of familiarity with new technologies severs its recipients from vital material components of modern culture and aligns itself with instrumental education's propensity to compound existing inequalities. Ironically, in a context governed overwhelmingly by technological imperatives,the goals of commercial and technical success will best be served by combining cultural learning and technical skill within an education consciously oriented towards democratic social control of technological change.