New Technologies, New Skills

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It is not an easy task for managers to ascertain the skill requirements of new technologies. But mistaken assessments can be costly. Reflect for a moment on the following three cases:

- *The numerically-controlled machine-tool case:*

  NC machine-tools were originally developed with the dual purpose of diminishing reliance on skilled machinists and augmenting technical capabilities. Early vendors' advertisements were very clear: with the new machines, after establishing the appropriate software to select and guide the cutting tools, "anyone can do the second piece."

  But in reality, in the three decades since the development of the NC machine-tool, its adoption has not led to any general trend to the elimination of the skilled machinist. Surveys show repeatedly that not only are most NC machines operated by skilled operators, but new training requirements and higher levels of responsibility are the general rule.

  Companies that took the vendors' suggestions literally, setting up their shops with expensive machines and inexpensive labor, found that the unscheduled downtime, the cost of errors, and the limited flexibility of this configuration severely limited the payoff to their investment.[1]
- *The Three Mile Island accident:*

  Decades of research into the control of nuclear facilities had produced a highly sophisticated system of monitors and fail-safe devices. The premise and the promise of this engineering work were that a better design will call for less, and less complex, human intervention. If the human element was the weakest link in the control chain, the least reliable component, it seemed logical to aim to "design the operator out of the control loop."

The Nuclear Regulatory Commission's investigation of the Three Mile Island near-catastrophe revealed, however, a crucial flaw in this reasoning. The dominant design philosophy has been blind to the link between more complex control mechanisms and more complex and unpredictable failure patterns. The control functions that are successfully automated are the simpler ones. The number of operators required can thus thereby be reduced, but the functions of the remaining personnel will be more, not less, demanding. Conclusion: there is a pressing need for significantly more sophisticated training than the industry or its regulators ever envisaged.[2]

- ***Or consider the case of large banks as they move from overnight batch processing systems to fully on-line "one-terminal per teller/one data-entry per transaction" systems:***

In a case I have examined in some depth, that of a major French bank with over 30,000 employees and a world-class computer system, management hopes for the pay off to this major advance in their level of automation were clear. Low-level clerical jobs like the teller's should be "de-skilled": they would not need any knowledge of banking procedures, because the sequence of processing steps they had to follow would be indicated on the terminal screen.

Not quite halfway through a five-year switch-over program to the on-line system, the bank found itself confronted by two major revisions to its "de-skilling" scenario.

First, operations managment had become very concerned by the considerable fragility of a fully on-line system that integrated some 2,000 bank branches. The people at the extremities of this vast system would have to be absolutely reliable, since any data they entered, as long as it passed some simple tests for internal coherence, would be fed instantaneously into all the bank's accounts and the corresponding funds transferred instantaneously. This concern for data integrity was slowly filtering up to general management.

Second, having begun with the assumption that skill requirements would be significantly reduced by the latest phase of automation, management had only slowly come to recognize a pressing need for training of lower-level personnel, not only in basic computer literacy, but also in the nature of the overall computer processing system and even in the logic of the accounting procedure.

These two considerations were imposing themselves on the bank with some force. Without costly remedial actions and revisions to their automation plan, the bank risked grinding to a halt under the accumulated weight of polluted databases, erroneous transactions, and angry customers. For a company where all the clericals had been trained exclusively on the job by fellow clericals, the discovery was a shock.

The Myth of a De-Skilling Trend

These three examples are not isolated instances. Such costly discrepancies between expectations and realizations for technology's impact on skill requirements are only too common. This article suggests some ways for avoiding these unhappy surprises for management. But before discussing them, it is important to measure the obstacles faced by managers in making their judgements.

The assessment of a new technology's impact on skills is inherently difficult. Management's information base for the task is almost invariably insufficient. The vendor is an interested party when it comes to performance estimates and is rarely available for advice on implementation.

Managers are therefore often forced to rely on a guiding assumption. Sometimes this assumption turns out to have been too high: due to plant tradition or exaggerated fears of the difficulty of mastering the new equipment, some plants assign skilled craftsmen to the new jobs, only to find that after the debug period, a lower level of personnel is more appropriate. But more frequent, and often in the end more costly, is the inverse error—underestimating the skills required for effective operation of new systems. Managers are often attracted by what could be called the "myth of de-skilling": the idea that as a general rule new generations of equipment have permitted and will permit reductions in skill requirements. This myth is a major obstacle to effective planning for the implementation of new technologies.

The de-skilling view is not altogether implausible. There are certainly cases in which automation has led to a reduction in skill requirements. Take the example of the professional-level insurance claims analysts responsible for the more complex cases. Computerization in this case meant that all the complicated procedures and decision parameters that were their expertise are programmed into the system, so that most of these cases can now be processed by a lower-level clerical worker.

The de-skilling view is, of course, in competition with what we can call the "upgrading hypothesis." Take the lower-level insurance claims processing clerks. For these employees—far more numerous than the professional-level analysts—the computerization process has simultaneously facilitated and upgraded their work. Such routine jobs now call for at least a minimum level of computer-literacy and often encompass a broader span of tasks.

In the struggle between these two views for preeminence as management's guiding assumption of what to expect from automation in the general case, the de-skilling case has, however, considerable support. First, there is the weight of traditional engineering doctrines. Machine systems design progresses under the momentum of a philosophy which focuses on perfecting machine performance. The problems confronted in the messy world of real implementation are relegated to a residual status, especially the critical problem of coping with errors and contingencies. "Idiot-proof" is still very often the engineer's implicit norm. This philosophy is reinforced by the traditional industrial engineering job-design doctrine which reflects the "Scientific Management" equation of efficiency with specialized simplicity.

NC machining is perhaps an excellent example. If everything were to work as perfectly as the textbooks indicated, a lower-level machinist might indeed suffice to monitor the machine-tool as it is taken through its steps by the NC tape. But surveys show an average of 45 errors in each hundred new NC programs.[3] The machinist's skills are critical to the accurate and timely identification of those errors. With engineers overly confident that programming could be perfected, it took until the recent development of "computer numerical control" for machine design to permit the machinist to correct programs at the machine. And the Methods and Personnel departments are still debating whether they want to encourage such a blurring of job definitions.

Engineering doctrines are frequently compounded by the "good news" syndrome in organizational dynamics. People tend to select the least troublesome alternative to transmit up the organizational hierarchy. Thus, if we trace discussions of operations problems as they progress from first-level management upward, the hypothesis of operator carelessness comes to appear progressively more plausible, while the alternative hypotheses of poor systems design and inadequate operator training are progressively less frequently mentioned.

Another common thread running through the three cases cited at the beginning of this article is wishful thinking. Given the real uncertainty surrounding a new technology's impact, it is easy for management to fall prey to the sirens' song: "Skilled labor is more expensive; perhaps with new equipment we can do without." It is easy to extrapolate from needing proportionately *less* labor to needing *less-skilled* labor.

Indeed, the dominant pattern of U.S. industrial relations promotes such wishful thinking, by encouraging a myopia of the zero-sum game kind: "If it's good for management, it can't be good for the workers—and vice versa."

Complementing these influences is the continued presence of a venerable tradition of social analysis dating back to Adam Smith. A considerable body of opinion supports the intuition that machines "embody" workers' skills. And if the machine "takes over" progressively greater proportions of the worker's task set, the remaining job must surely be de-skilled.

The fallacy here, however, is easy to identify: for every task transferred from worker to machine, there is a new task created—that of deploying the enhanced machine capabilities. We still need, therefore, a guiding assumption as to the net effect of these additions and subtractions to the worker's task set.

Major research efforts of recent decades have focused on automation's skill requirements, but have often left the requirements of the highest levels of automation intriguingly indeterminate.[4] To some extent, this result is justified by the fact that there is indeed a broad range of skill configurations that can more or less effectively be associated with highly automated systems. The higher the level of automation, the greater the room for managerial discretion in work design. But for another part, this "indeterminate" diagnosis reflects a failure to adequately grasp the qualitative shift in *types* of training, responsibility, and so forth required at the higher levels.

It is all too easy to ignore, underestimate, or misinterpret the new tasks like system monitoring and control. That is why, in the hope of permitting a clearer assessment of automation's skill requirements, this article identifies three qualitative changes in types of skill that often accompany automation: new types of task responsibility, a new degree of abstractness of tasks, and new levels of task interdependence.

The more systematic surveys of automation's skill requirements (see Appendix 1) show that while the net effect of subtractions from, additions to, and qualitative mutations of, the worker's task set is most definitely not *always* positive, the *general* trend has been an upgrading, not a de-skilling. This is the most plausible interpretation of the data that shows both a secular shift in the occupational structure, which has given more weight to the more-skilled occupations, and an increase in the skill requirements for most individual jobs.

There are, of course, numerous examples of real de-skilling. In particular, when product and process technologies are very stable over time, there may be considerable gains to specializing jobs and thereby reducing average skill requirements. This explains why traditional design engineering's idiot-proofing approach is sometimes efficient and why management's de-skilling expectations are sometimes realized. The traditional auto assembly-line is perhaps the best example of how effective this approach can be.

But it is important that managers not extrapolate the assembly-line model into activities that do not fit the special conditions which, for a certain period at least, made that model effective. Very few activities—indeed fewer and fewer of them—exhibit the degree of stability that justifies the de-skilling model.[5] The notion that de-skilling is the most likely outcome of automation is therefore a myth. Indeed the de-skilling view is a myth that is dangerous to effective management and competitiveness, since operations design premised on a guiding assumption that is incorrect will be outperformed, and costly realignments of personnel profiles will be necessary.

The choice of staffing pattern for a given technology always depends, of course, on a variety of factors other than purely technical ones. In particular, the stability or flexibility of operations, the characteristics of the labor force, and the prevailing industrial relations all play a role. This article, however, addresses the generalizations that rise above those contingencies.[6]

An examination of the case of banking computerization can help us identify useful generalizations about the new types of skill that managers responsible for effective automation need to plan for. Banking is not often the place that one looks for general lessons in these matters; its particularities are distinctive. But we will see that the emerging technological configurations of large, on-line computer systems in banking provide an example which dramatically highlights the problems faced by a broad spectrum of industries.

The Evolution of Banking

The basic organization of bank processing has evolved through four key stages.[7]

If we look at this evolution from the point of view of the most labor-consuming of banking operations—demand deposit accounting (DDA)—we can see what this aggregate development of bank automation means for employees responsible for particular tasks.[8]

I have used a presentation developed by James Bright, the "mechanization profile."[9] The sequence of steps in DDA runs down the left-hand side, and for each step the table indicates the technical level of the process: the lowest level is the manual system dominant until the 1930s; it is followed by mechanical accounting machines introduced in the period 1930–1950; then off-line computers that were introduced in the 1960s and 1970s; and finally the on-line computer systems that have become prevalent in the 1980s. (See Figure 1.)

Two facts stand out:

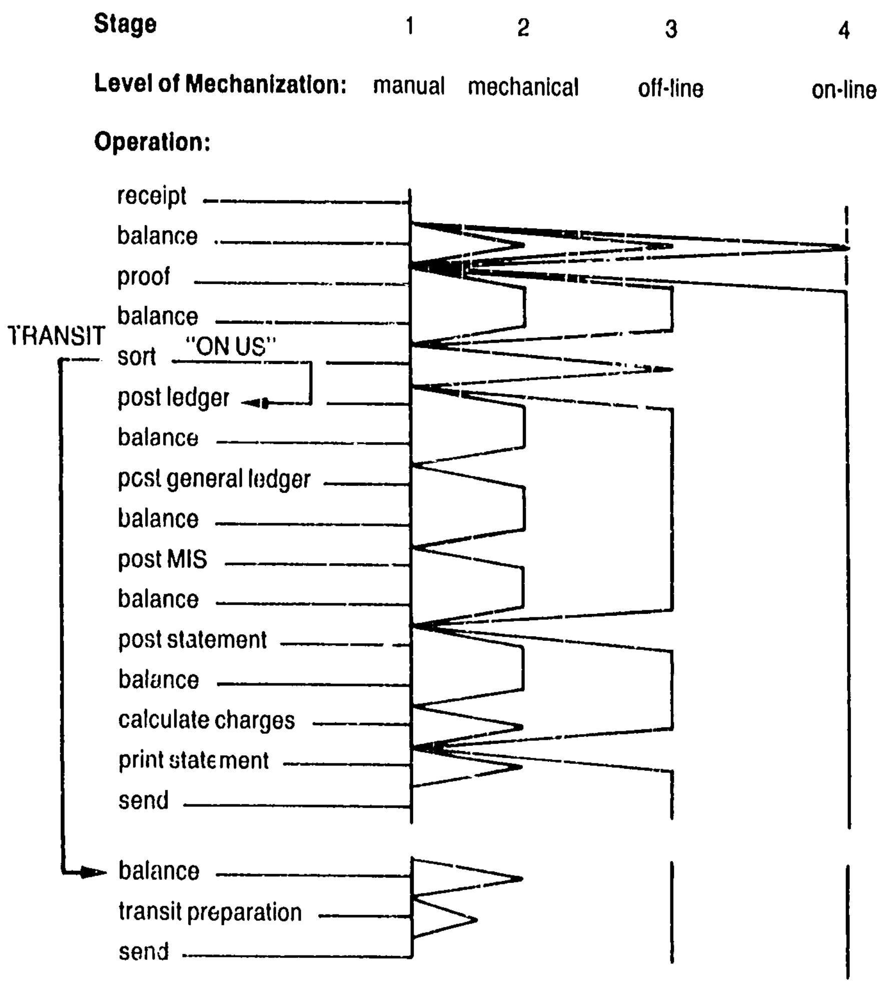
- At the second, mechanical level, we have much the same sequence of discrete operations as in the manual case, the only difference being the automation of account-balancing steps.
- But at the third level, and even more at the fourth, whole sequences of operations are programmed and are internal to the computer system. The number of times the check's key data are entered into the system is dramatically reduced.

How then should we characterize the effect of moving up the automation scale?

To say that labor has been "eliminated" is to say too much or too little. Too much because some employees are still needed to guide data-entry and to control for the system's correct functioning. Too little because, even leaving aside our curiosity for the new employees who are responsible for developing and maintaining the computer system, we want to know where employees have really been eliminated and above all we want to know what the remaining jobs look like.

A more precise term to characterize automation's impact might be *peripherization*: employees have been pushed from the center of the "account fabrication process" to the periphery of a powerful automatic system, into tasks of data-entry, system control, and system maintenance. Whereas previously some two-thirds of bank personnel were employed at fabrication

Figure 1. Stages of Demand Deposit Accounts Processing



tasks like bookkeeping, an increasing proportion is now in direct contact with the customer or working on higher-level professional-technical tasks. The parallel peripherization process in manufacturing automation is evident in the often dramatic reductions in "touch" labor.

What then are the skill requirements of such a system? If we imagine the organization of production in the bank as an old-fashioned pyramid, with a summit of managers, middle layers of professionals and supervisors, and a base of employees, large-scale computerization of the fabrication process seems above all to take a bite out of its base.

To the extent that such a simple image captures the process, it is easy to see why average skill levels tend to rise with automation. If, as is often the case, it is mainly (but of course, not exclusively) the lower-skilled layers of the pyramid whose tasks are automated, then the average level of the remaining positions will be higher. Furthermore, some of the remaining jobs will be upgraded, and some new, higher-skilled jobs will usually be created. On the other hand, another subset of the remaining jobs may suffer de-skilling; but unless this de-skilling effect is of truly massive proportions, the total effect will be an upgrading.

Indeed, between 1969 and 1977, the period of most intense computerization, the proportion of lower-tier employees in major French banks fell from 58% to 45%, with the complementary gains spread across the professional/supervisory category (32% to 42%) and the management category (9% to 13%).

Management of these transformations calls for an awareness of the fact that the higher-level jobs may not go to current job-holders; [10] but it is of the utmost importance to have a correct sense of the aggregate trend, too. If the model derived from bank automation has any general applicability, this aggregate trend should be an upgrading one. The data on U.S. labor force trends cited in Appendix 1, weak as they are, do at least support our model.

Note, furthermore, that this image of automation generates a prediction totally at odds with the much-discussed "disappearing middle" thesis. If the computerized pyramid is redrawn to show the final shape of the new organization, we see a shift not towards an hour-glass but, on the contrary, towards something closer to a sphere.

But this is only the most rudimentary of characterizations of the skills required in the automated context. What, then, can be said of the quality of the remaining lower-level clerical jobs?

The new on-line computer configuration gives rise to some new features of work, or at least singularly reinforces certain existent features of the operating tasks. A closer examination will cast light on qualitative dimensions that need to be addressed in any serious skills assessment.

The New Features of Work

The features of work that have emerged as critical, as the bank moves into the highest levels of bank automation, cluster around *responsibility, abstractness,* and *interdependence.* The qualitative shifts in types of skill that have brought these three features to the fore are, I believe, central to the diagnosis of automation's skill requirements. An accurate sense of the changing requirements of banking clerical tasks in these three regards is essential to defining appropriate Human Resource Management and Operations policies. In this, the banking case may hold lessons for other industries.

Responsibility—The importance of employees' sense of responsibility at the higher levels of automation is hard to overstate. Quite independently of any humanistic job-enrichment values, it is advanced systems' vulnerability to errors that calls for a major shift in our thinking regarding responsibility requirements. The traditional importance of "responsibility for effort" is displaced by a responsibility for results, for the integrity of the process.

Notice, first, that the bank is dealing with a level of automation that is in many ways qualitatively higher than even that of chemical refineries' "continuous flow" operations. In the bank, we have a veritable "instantaneous flow" system: once the data-entry is made, at the front desk or elsewhere on the system's periphery, the corresponding transaction is instantaneously effected, and, equally instantaneously, adjustments are made to all the relevant accounts.

Massive efforts are deployed to automatically check operators' authorization levels and data's internal coherence. And these efforts result in very ingenious cross-checking and personal identification code systems. In this way, the simpler errors are eliminated, and the *frequency* of errors is thereby reduced, as is indeed the *total cost* of errors. But the remaining errors are on average the more complex ones, and new sorts of errors are created that are often more difficult to trace. Computerization can thus reduce the total cost of errors even though the *unit cost* of the remaining errors—their potential impact, their discovery and rectification costs—may be augmented.

This generalization is supported by research in an altogether different environment, aircraft cockpits.[11] Earl Wiener, in analyzing cockpit automation, offers an everyday example which captures this new automation-error model—the digital alarm clock: "Unlike the analog alarm clock, it can be set very precisely, but it operates on a 24-hour cycle; thus one can inadvertently (by default) set a wake-up time at P.M. instead of A.M. With the introduction of digital clocks a new blunder was born: the precise 12-hour error."

The prevalence of this new type of error gives the teller's job, like that of other lower-level clericals, a new and augmented importance, because in the new systems there is usually no one further down the processing chain to catch errors.

If errors are not picked up by the automatic filters, they can become nightmares. Putting databases on-line for both data entry and access, for example, means that whole sectors of the bank may find themselves using inaccurate data as the basis of subsequent operations or calculations. Another example is the local check processing operations that must stop entirely to resolve a discrepancy—and not just for half an hour; these problems can paralyze a whole unit for one or two days at a time. Why? Partly because the error detection system eliminates all but these, the most complex cases. But for another part, the sophistication of the system itself creates new problems. Audit trails, for example, may simply disappear.

These operators are now on the "front line" in the effective deployment of the system's much-enhanced capability. If the system goes down—which it does on average once a day, if only for a second—it is the tellers and operators who must assure themselves that the transaction they had half-completed will be effected without starting over, or alternatively, that the transaction can be restarted without inputting it twice.

The problem has its parallel in manufacturing. The active role of operators in avoiding accidents—whether it be "minor" accidents that can make or break a firm's quality reputation, or major ones like Three Mile Island—is an increasingly critical efficiency and competitive variable. This trend reflects not only new competitive conditions, but also an underlying technological tendency.

Effective analysis of the impact of computerization on work involves, therefore, an accurate assessment of the job's responsibility requirements. Workers have always had the responsibility of fulfilling their part of the "wage/effort bargain." But in banking, and perhaps in many other situations, these higher levels of automation call for a qualitatively different type of responsibility: responsibility for overall process results, not merely for the supply of a reasonable degree of effort. The responsibility-for-results solicited in the banks is not of a very high "level," but is so pervasive as to have become a critical competitive variable.

It is, of course, hardly new that managers want motivated, responsible workers. What seems to be profoundly new is the fact that this is no longer a wish but an operational imperative imposed on management by the nature of the automatic system.

Abstractness—As automation pushes workers out of fabrication and into peripheral, interface functions, there is a certain abstraction of tasks and of goals. Intellectual mastery therefore becomes a key performance factor.

Manual tasks become mental. Being computer-mediated, their mastery entails an extensive familiarity not just with a handful of codes, but with a whole new, more or less artificial, language. Operations tend to assume the algorithmic form of sequential decision trees. Handling a cash withdrawal at a front desk on-line terminal, for example, involves a minimum of nineteen distinct steps, where each step may lead off into supplementary steps of data-checking or file-updating. Thinking becomes "procedural": the key task of the employee is to size up the situation so as to select the right one from a set of procedures and to then follow that procedure through and be able to reconcile the procedure with any anomalies the situation might present. Learning to deal with anomalies and contingencies involves higher-order conceptual processes, such as when the document lacks some data, when the system signals some irregularity, or when the system malfunctions.[12]

Moreover the "technological culture" required of clericals is not restricted to a general computer literacy—which itself is not so meager an accomplishment. If a client comes in wanting to know why a transaction ordered a month ago still hasn't been effected, there is often no downstream office to which the teller can turn for information. With less back-up to their operations, clericals must have an understanding of bank accounting flows and of the computer system operations.

Abstraction also affects back-office tasks. The remaining processing jobs' accuracy requirements call for a similar extension of intellectual mastery. It has always been a good idea to give workers some idea of the next processing step; now, that step is itself an entire chain of automatic operations. The correction of anomalies in the accounting departments undergoes drastic change. The complexity of this task is multiplied many times over; training requirements increase as accountants confront the difficulties of computerized processing.

The importance of understanding the firm's system, in both the operating procedures and the processing steps these procedures trigger, calls for a new and broader type of training. Previously, it was by the successive apprenticeship of several departments that upwardly mobile personnel learned most of their banking. Now, experience cannot suffice, as the critical operating procedures have been internalized in the computer system.

Interdependence—The third feature to emerge as critical at higher levels of automation is the synergy created by the interdependence of tasks.

Recall the problems entailed by the elimination of the processing chain. There is usually no longer anyone "down the line" to pick up errors or to respond to queries. The sequential form of dependence has been all but eliminated; it has been superseded by a new and higher form of interdependence we might call "systemic."[13]

The sequential dependence exemplified in the processing chain posed its own managerial challenge—coordination of discrete tasks, much like the problem of assembly-line balancing. The new more systemic, network interdependence takes this challenge to a higher plane. It allows for no easy decomposition of tasks, but on the contrary, demands ongoing and flexible integration of the hitherto distinct functions of operations, systems design, and training.

The reciprocal nature of this interdependence in operations is exemplified in the reliance on common databases. Users thereby become dependent on other users' data input accuracy. On another level, "social skills" allowing for effective teamwork become more important.

Systemic interdependence also encompasses the ongoing cooperation of system users—operations—and system designers: this cooperation has become critical to operations efficiency. New application programs to deal with new products are constantly being generated. This increased subsystem flexibility can only realize its potential if there is active cooperation between operations and support staffs to assure that the new procedures cover all contingencies and that they are rapidly debugged. Many computer-intensive operations are thus finding it more efficient to relocate their applications programmers within the user departments.

This new level of system flexibility also calls for more, and more flexible, training programs. On-the-job training of new employees by their experienced colleagues is being supplemented by more theoretical programs, and these programs are designed to respond to the rapid introduction of new applications. Systemic interdependence thus also encompasses the closer cooperation of operations and training functions. The "life-long learning" idea is not just another passing fad; it reflects the changing nature of technology.[14]

The New Skills Challenges

The banking case points to three clusters of new or enhanced job requirements intimately associated with the more advanced technology: responsibility-for-results, abstract mastery, and systemic interdependence. Depending on their circumstances, other occupations or industries may, may not, or may not yet, reflect these changes. But in any context the effectiveness of Operations and Human Resource management policies depends on the "fit" between these policies and the technology trends in these three "dimensions."

Ignoring these qualitative dimensions can lead to the adoption, consciously or unconsciously, of inappropriate "benchmarks" in the evaluation of skill requirements."[15]

- If the responsibility benchmark is responsibility-for-effort, resonsibility-for-results will be ignored. The steel industry had to confront this issue as it automated; it became obvious that production operators' responsibility for assuring operations' continuity was a greater productive contribution than the craftsmen's traditional responsibility for careful parts machining.
- If the benchmarks are all jobs calling primarily for "concrete" manual skills, the system will undervalue more abstract tasks. Some office jobs, usually staffed by women, seem to have been undervalued in this way, when menial physical exertion has been valued above routine mental effort.
- And if the system interdependence is such that a sustained integration of learning and doing seems necessary, the assumption that skill requirements can be deduced from job assignments may have to be jettisoned or profoundly modified in favor of a system in which wages reflect skills acquired rather than the skills required for the particular job currently occupied.

It is important, moreover, to understand the profound, but perhaps inescapable, managerial challenges that the new skills pose. If automation does call for these new qualities of work, the future will demand some important rethinking of current managerial approaches.

- Old as management's wish for more responsible operators may be, the recognition of responsibility-for-results is not without posing considerable problems.

How, for example, are we to incorporate responsibility into job evaluation systems? The example of the steel industry's collective bargaining agreement is enlightening: its measure of job responsibility is simply in dollars of potential damage to materials or number of lives. But given how difficult it is to identify individual responsibility in modern, complex process, implementing such a criterion requires a reasonable degree of consensus. And that may only be possible in a context of sustained labor/management cooperation.

To the extent that automation calls for recognition of the heightened importance of worker responsibility, it seems therefore to also call for changes in labor/management relations. But recent articles by R. Walton ("From Control to Commitment in the Workplace," *Harvard Business Review*, March-April 1985), E. E. Lawler and S. A. Mohrman ("Quality Circles after the Fad," *HBR*, January-February 1985), and B. Reisman and L. Compa ("The Case for Adversarial Unions," *HBR*, May-June 1985) all show how difficult it is to trace a route from here to there. The key sticking point is perhaps the ambivalence of any labor/management interaction, an ambivalence that is due to the inevitable precariousness of the convergence in these stakeholders' interests. The challenge is then in learning how to sustain cooperative efforts when there is a continual risk of divergence of interests.

- The challenge to management posed by the more abstract tasks is double, reflecting distinct problems relative to the abstraction of the "means" and of the "ends" of people's work.

First, when the "means" are computer-based, learning becomes less rote and more intellectual, and training has to become more general and scientific. We are thus witnessing the generalization of new mental disciplines involved in procedural thinking and broader spans of cognitive, problem-solving skill. Workers' attitudes will have to evolve; so too must management's tendency to define training needs overly narrowly.

These new means of work will also require some adaptation of software, equipment, and environment to satisfy basic ergonomic criteria. It takes some time—and debate—for those new criteria to become clear.

But, and this is the second and complementary challenge of abstraction, the effective use of these "abstract" skills is conditional upon successful adaptation to the likelihood that abstraction of the "ends," or goals, of work will encourage job boredom.

Responsible now not for a discrete, tangible operation, but for much less obvious objectives like process continuity, database integrity, and customer satisfaction, the tellers, clericals, and operators in automated settings can find it difficult, from their vantage point, to identify these task goals as their own, to make them sufficiently concrete to sustain interest and motivation.

A partial solution may be to instill a sense of professionalism and "ownership." But some activities are so mundane that such approaches may be

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impossible, in which case work-time reduction might be an important part of the solution.

- The management of systemic interdependence poses a triple challenge to traditional policies.

First, the perennial tendency of functional departments to become fiefdoms will become more costly, as interdepartmental cooperation becomes increasingly central to competitively successful implementation of new technologies.

Second, nurturing the identity of the work-group will assume a progressively greater importance. This means that as automation progresses, turnover in low-level clerical positions will become more, not less, expensive in lost operations efficiency and lower quality of service.

Third, as the form of interdependence shifts toward the systemic, we should expect the basis of financial incentives for results to shift from the individual (piece-rate) to the group (team bonuses) and to the business unit (profit-sharing). But group bonuses can run counter to our individual-oriented sense of justice. The challenge here is to balance the individual's needs for self-expression and the group's functional role.[16]

Conclusion

It is clear that the real diversity of automation's skill effects, the difficulty of predicting them, and the costs of not correctly anticipating them, all militate in favor of very careful assessment efforts.

The first lesson of the banking case is thus that a careful assessment of the qualitative dimensions of what we call "skill"—type of responsibility, degree of abstractness, nature of interdependence--will prove valuable. And examples abound to indicate that these dimensions should be examined in any industry.

But if, as is usually the case, the assessment of some automation project's impact on skill requirements is clouded by uncertainty, then management needs a guiding assumption.

The banking example would suggest that the most useful guiding assumption to bring to the difficult task of skill requirements assessment is that optimal performance generally demands of even low-level jobs:

- more responsibility for results,
- more intellectual mastery and abstract skills, and
- more carefully nurtured interdependence.

The second lesson of the banking example is therefore that we are better off assuming that, more often than not, skill requirements increase with automation.

Indeed, even if, in some situations, technology and market conditions justify the efficiency of low-skill configurations with very short cycle-times, management should recognize the hidden costs of this solution. Management should be alert to the sacrifices such designs impose in terms of labor motivation as well as in long-run operations flexibility. Careful consideration should be given to the advantages of job-rotation and of programs that give employees real "think-time"—which preserves and encourages their mastery of the process, as well as their involvement in its improvement.

But, if the banking example is any guide and the broader statistical data on the long-run trends in the economy mean what they appear to say, then as a general rule, sustained competitiveness will call for workers capable of mastering new, and in general more demanding, technologies. The myth of de-skilling is dangerous to our long-term economic health.

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3. N. L. Flaver and Earl Kincaid, " 'Oops', said the NC Programmer," *American Machinist* (June 1983).
4. See James Bright, "Does Automation Raise Skill Requirements?" *Harvard Business Review* (July/August 1958), where "responsibility" and "education" requirements are described as "increasing or decreasing [or nil]" as one moves to the highest level of automation. See too, a standard text like Roger Schmenner's *Production/Operations Management* (Chicago, IL: SRA, 1981), "Progressing from job shop to continuous flow process, it is more likely that . . . job contents diminish, although 'art' is more likely to be found at either end of the process spectrum," p. 115.
5. See W. Abernathy, K. Clark, and A. Kantrow, *Industrial Renaissance* (New York, NY: Basic Books, 1983).
6. I shall leave aside entirely the problem of automation and employment: the issues of skill distribution and employment levels are largely separable.
7. Field work for this research was conducted in France in 1981 (see Appendix 2). The technological evolution of French banks is quite similar to the U.S. experience, and the current technical levels are, if anything, more advanced in France: for a population of one-fourth the U.S., the French banking system currently conducts a higher number of electronic transactions.
8. See Richard Matteis, "The New Back Office Focuses on Customer Service," *Harvard*

Business Review (March/April 1979), for the description of the Citibank letter of credit department's parallel evolution.

9. See J. Bright, *Automation and Management* (Boston, MA: Harvard Business School, 1958).
10. There are some important degress of freedom here for astute managers to recruit programmers in-house so as to create a computer services department with the intimate acquaintance of processes that only former operators can have.
11. Earl Wiener, "Beyond the Sterile Cockpit," *Human Factors* (February 1985), p. 83.
12. See Shoshanah Zuboff, "New Worlds of Computer Mediated Work," *Harvard Business Review* (September/October 1982); and B. A. Sheil, "Coping with Complexity," Palo Alto Research Center, Xerox, 1981.
13. Or, following Thompson, "reciprocal," *Organizations in Action* (New York, NY: McGraw-Hill, 1967).
14. See Larry Hirschhorn, op. cit.
15. These benchmarks may be implicit or, for organizations with job evaluation plans, explicit; in either case inappropriate points or reference will lead to suboptimal results.
16. It would therefore seem that technical change itself encourages the shift documented by George Lodge in *The New American Ideology* (New York, NY: Knopf, 1975), or, in a comparable endeavor, by Roberto Unger in *Knowledge and Politics* (New York, NY: Free Press, 1975), from "Lockean individualism" to "communitarianism."

Appendix 1

There is a striking parallel between, on the one hand, the discrepancies between management expectations and realizations of the kind mentioned at the beginning of this article, and, on the other, the discordance between:

- a venerable, multi-stranded tradition in social and economic theory which posits a long-run, average tendency of technical change to reduce skill requirements; and
- the more "common-sensical" view that real-world technical change is usually accompanied by skill increases.

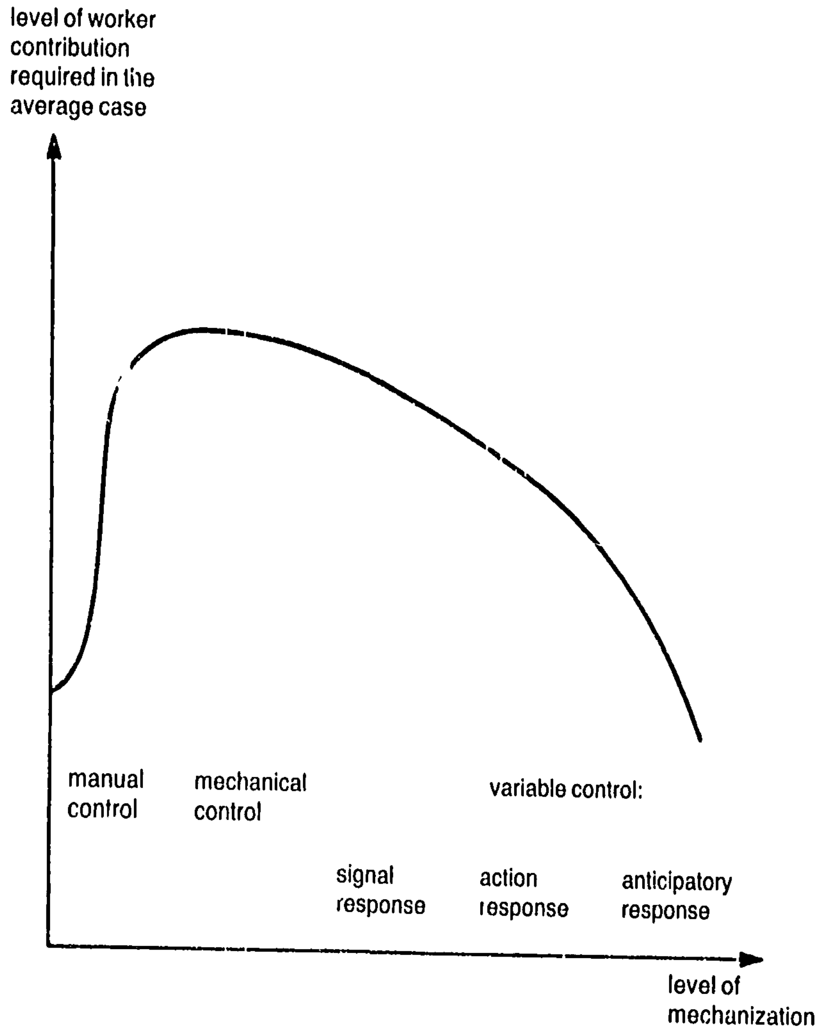
The lineage of the "de-skilling" tradition is long:

- Adam Smith, in *The Wealth of Nations*, on pin manufacturing divided into 18 distinct operations;
- Karl Marx, in *Capital*, takes up Ure's critique (*Philosophy of Manufacturers*) of machinism that reduces the worker to "a mere fragment of a man";
- major studies on the 1920s and 1930s, on destruction of crafts in U.S., like the *National Research Project on Reemployment Opportunities and Recent Changes in Industrial Techniques* (Works Progress Administration, 1940);
- James Bright, *Automation and Management* (Boston, MA: Harvard Business School, 1958), and a summary of some key parts in "Does Automation Raise Skill Requirements?" *Harvard Business Review* (July/August 1958);
- Harry Braverman, *Labor and Monopoly Capitalism: the Degradation of Work in the Twentieth Century* (New York, NY: Monthly Review Press, 1974), who relies on Bright;
- Stanford's Henry Levin and Russell Rumberger "The Low-Skill Future High-Tech," *Technology Review* (August/September 1983).

The basic thesis is well summarized by Bright's self-explanatory diagram.

If, as the de-skilling tradition would have it, powerful forces assure the reduction of skill requirements, then surely some aggregate tendency should be manifest in the occupational data.

James Bright's assessment of how total contribution required of operators may vary with levels of automation



Source: James Bright, "Automation and Skill," *Harvard Business Review*, (July/August 1958). Reproduced by permission.

What, then, do the U.S. data tell us? Bluntly put: very little. Which explains why the optimistic, up-grading thesis has received, for all its plausibility, so little scholarly support.

It is possible, however, to isolate the conditions that would be required for the de-skilling hypothesis to be true—and to show them to be completely implausible.

Consider the following table that reproduces the Census estimates of occupational structures in 1900 and 1970 for the total employed population (over 14 years old).

Employment Structure of the Total U.S. Labor Force (%)

	1900	1970
White-collar workers		
Professional, technical	4.3	11.5
Managers, officials, propriotors	5.8	8.1
Clerical	3.0	17.8
Sales	4.5	7.1
Manual and Service workers		
Craftsmen, foreman	10.6	13.9
Operatives	12.8	18.0
Laborers (excl. farms, mines)	12.5	4.7
Private household workers	5.4	1.5
Other service workers	3.6	11.3
Farm workers		
Farmers, farm managers	19.9	1.8
Farm laborers, foremen	17.7	1.3
Total	100.0	100.0

Source: Historical Statistics, Series D182-232

We can now use some index of the relative skill of each category to calculate an average skill level of the whole labor force in each year. Unfortunately, a reliable index is hard to find. The best available index is perhaps that generated by the U.S. Employment Service's *Dictionary of Occupational Titles.* In it we can find an estimate of the general skills required to perform at an average level of proficiency. Unfortunately again, the survey on which it is based does not go back to 1900, and readers have been cautioned against comparing the scores in different years. We can, however, take the scores in one intermediate year, say 1950, and use them to rank the average skills of each occupational category in both 1900 and 1970. This assumes that the relative skills of each occupational category have not changed over the period. Accepting this assumption only provisionally, we can calculate a comparable index of average skill level for 1900 and 1970: it increases from the equivalent of 10.3 years schooling required in 1900 to 11.2 in 1970.*

Thus, the effect of the changing occupational structure—as distinct from the effect of changes in the component individual jobs—is clearly an upgrading one. And significantly so. Under these conditions the plausibility of the de-skilling hypothesis can only be sustained if we believe that skill requirements for individual jobs within each occupation have undergone a systematic downgrading sufficient to more than compensate for this compositional upgrading effect.

*I have calculated these results from the data in R. Rumberger, "The Changing Skill Requirements of Jobs in the U.S. Economy," *Industrial and Labor Relations Review,* 34/4 (July 1981).

The implausibility of that idea is manifest when we think not of this or that particular example of de-skilling—they clearly abound, and may call for policy remedies—but of the whole gamut of occupations. Indeed, Kenneth Spenner ["Deciphering Prometheus: Temporal Change in the Skill Level of Work" *American Sociological Review* Vol. 48 (1983)] has recently reviewed all the major studies on post-World-War-II skill trends. He found *not one* to show a long run de-skilling trend of individual occupations; most show a small but clear net upgrading of both the average occupation and the labor force as a whole.

Of course, the autonomous role of technology in these changes is difficult to measure. To some extent, technological choices may reflect the availability of a more educated work force. But the data show at least that automation has generally been accompanied by increases in skill requirements.

So why does this divergence between "common sense" and serious theoretical reflection persist?

Part of the difficulty lies in the tendency of such debates to polemical excess. Protesting the misfortunes of a relative minority, advocates of policy intervention are naturally wont to exaggerate in their depiction of the extent of the problem.

Furthermore, the tradition of thought most eloquent in its critique of de-skiling from a managerial point of view—the sociotechnical systems approach [see, for example, W. A. Passmore and J. J. Sherwood, eds., *Sociotechnical Systems: A Source Book* (San Diego, CA: University Associates, 1978); L. E. Davis and J. C. Taylor, *Design of Jobs* (Santa Monica, CA: Goodyear, 1979)]—has emphasized the wide range of managerial discretion in work design at *any* level of automation. They have, therefore, had little impact on the debate concerning the direction of changes in the optimal work design as the level of automation rises.

But for another part, the optimists and the pessimists seem to mean different things by the term "skill": the pessimists seem to have in mind the dignity of the craftsman, while the optimists seem to focus principally on educational and technical requirements.

These ambiguities cannot but influence managers when they grasp for a general sense of where automation is leading their Operations and Human Resource policies over the longer run. To what framework can they turn? What notion of skill requirements can help them identify the new challenges posed by automation?

Economists are of little help. For many decades, orthodox economists considered the issue outside their domain. Since the Chicago-led "human capital revolution," they have come to think of skill as the amount of human capital accumulated in training. In this perspecitve, wage-rates are determined primarily by the scarce resources invested in acquiring human capital.

This framework has the attraction of a certain rigor. There are obviously other factors, social and institutional, that play their part in setting wages (and heterodox economists, by highlighting these factors, have contributed to a more realistic appreciation of wage determination). But the "dull compulsion" of economic, market forces is difficult to deny.

The economic framework is necessarily inadequate, however, when we want to identify the qualities that the training activity (or any other element of Human Resource policies: selection, promotion, and so fourth) is designed to elicit.

The search for a framework for thinking about these qualititive issues reveals several alternatives. Some are excessively narrow, like those that reduce skill to the "autonomy" of the ideal craftsman, or to a generic "information processing complexity," for example.

Others, like job evaluation systems or the psycho-sociological research literature, permit great nuance but are too flexible to provide any general sense of direction since they require extensive adaptation each time focus shifts to a new set of jobs.

One of the major difficulties in formulating a useful characterization of automation's impact on skills seems therefore to lie in the very notion of skill. The persistence of the two currents of thought, optimists and pessimists, seems to indicate that the reality is more complex than either admits.

Adler, Paul, *New Technologies, New Skills* , California Management Review, 29:1 (1986:Fall)
p.9

Appendix 2

The analysis reported here is based on my 1981 dissertation on automation and work in French banks.

Apart from analysis of the available literature, especially French but also U.S. and British, its principal database comes from four months full-time field work in one of the four French banks classed in the top ten worldwide by balance-sheet.

Hundreds of interviews with managers at all levels were complemented by one month's participant-observation as a teller in two branches at different stages of automation.

There are a number of differences between French and U.S. banks. Apart from the relative concentration of the industry and the weight of the three banks nationalized in 1945, French banking has a very strong collective bargaining agreement, making banking jobs relatively attractive and assuring low turnover in all but a handful of clerical positions.

Far from limiting the generality of the lessons drawn, the particularities of French banking serve to highlight the issues that are the focus of this article.