SMR FORUM

Organizational Learning— The Key to Management Innovation

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RAY STATA, CHAIRMAN OF ANALOG DEVICES, makes a strong argument that U.S. industry's most serious competitive problem lies in a declining rate of innovation—and that this decline can be traced more to a lack of *management* innovation than to weak *product* or *technology* innovation. As a member of MIT's New Management Style Project, Mr. Stata has been applying innovative ideas and systems thinking to improve the performance and competitiveness of his company. His description of that process is unusually interesting in the way that it blends theoretical thinking with real-time problem solving. *Ed.*

Sloan Management Review

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Spring 1989

FOR MORE THAN fifteen years, Analog Devices grew consistently at a rate of about 25 percent per year. Then for the first time, between 1982 and 1987, we missed our five-year goals—and by a country mile. True enough, like other semiconductor companies we were affected by the malaise in the U.S. electronics industry and by the strong dollar. But the external environment was only part of the problem: something was also wrong internally, and it had to be fixed.

But what was the problem? We had the largest share of our niche market in high-performance linear integrated circuits. We had the best designers and technologists in our business. We had excellent relations with a highly motivated workforce. We were not guilty of underinvestment, nor of managing for short-term profits. The only conclusion was that there was something *about* the way we were managing the company that was not good enough. So I set about to understand what was wrong and how to make it better.

In the 1980s, our plight was not uncommon in corporate America. Companies that for decades enjoyed world leadership in their markets were being brought to their knees. Of course, there are many purported reasons for the loss of U.S. competitiveness. The high cost of capital, an overvalued dollar, a deteriorating education system, overconsumption at the expense of investment, government regulations, misplaced emphasis on military as opposed to economic security, and undisciplined government spending certainly all contributed to this decline. However, many who have studied the situation believe that the root of the problem is our declining rate of innovation. If this is true, then the challenge lies in better understanding innovation and in determining how to do more of it.

Usually we think of innovation in terms of technologies that give rise to a new class of products or to improvements in the design and manufacture of existing products. But at Analog Devices, and many other U.S. companies, product and process innovation are not the primary bottleneck to progress. The bottleneck is management innovation.

Peter Drucker points out that the rise to industrial dominance of Great Britain, Germany, and the United States was based on technological innovation in engines, electricity, chemistry, aviation, agriculture, optics, and so forth.[1] Japan is the first nation whose rise to industrial power was clearly based on management innovation, not technological innovation in the traditional sense.

Michael Cusumano reinforces this point in analyzing Japan's conquest of the automobile industry.[2] In the early years of the Japanese industry, small Japanese automakers, especially Toyota, beat out their giant U.S. competitors not with product innovation, superior manufacturing technology, or greater capital investment per employee. They did it with management innovations that turned their presumed disadvantage of lower production volume and smaller lot sizes into an ad-

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vantage: shorter manufacturing cycles, lower inventories, and (eventually) higher quality and lower cost.

Certainly management innovation alone is not enough. As Abernathy and Utterback point out, the optimum blend of product, process, and (I would add) management innovation depends on the circumstances in a particular industry.[3] But I would argue that where many U.S. firms lag most today is in the *management innovation* required to take fullest advantage of their *technology leadership*.

Until very recently management innovation received little serious consideration either from corporations or academic researchers, especially in comparison with the resources invested in product and process innovation. The results of this neglect are evident in the competitive crises facing U.S. industries.

Management innovation, like product and process innovation, depends on new technology. New technology for management, as for engineering, comes in the form of new knowledge, tools, and methods. In my quest to improve the performance of Analog Devices, I began to search for new technologies and ideas that would change, if not revolutionize, the way we were managing our company.

Around that time I had the good fortune to meet MIT's Jay Forrester and Peter Senge and learn of their work in applying system dynamics to the analysis and design of complex social systems.[4] For thirty years Professor Forrester has pioneered the use of feedback theory and systems analysis to examine the behavior of systems not only in management, but also in politics, economics, medicine, and the environment. He has created a whole new field of knowledge that is only now finding its way into management practice.

Peter Senge invited me to join eight other organizational leaders in what was called the "New Management Style Project."[5] We have met on a semiannual basis over the past four years, and this collaboration has proven to be fruitful for all of us, practitioners and academics alike. As I shall point out later, this project can serve as a prototype for industry/university partnerships, which are needed to accelerate management innovation.

Organizational Learning

The initial focus of the New Management Style group was on using system dynamics to improve our thinking about complex organizations. But as time progressed, we began to explore systems thinking in a broader context. About this time Arie deGeus, director of group planning for Shell International, joined the group because of his interest in system dynamics as a tool to accelerate organizational learning. As we listened to deGeus's ideas and his experiences at Shell, organizational learning emerged as a fundamental concept; it not only helped us to better appreciate the power of system dynamics, but also to integrate a broader range of management tools and methods to facilitate organizational change and improvement.

In an even broader context, as I come to understand this concept more fully, I see organizational learning as the principal process by which management innovation occurs. *In fact, I would argue that the rate at which individuals and organizations learn may become the only sustainable competitive advantage, especially in knowledge-intensive industries.*

What is organizational learning, and how does it differ from individual learning? We tend to think of learning as a process by which individuals gain new knowledge and insights and thereby modify their behavior and actions. Similarly, organizational learning entails new insights and modified behavior. But it differs from individual learning in several respects. First, organizational learning occurs through shared insights, knowledge, and mental models. Thus organizations can learn only as fast as the slowest link learns. Change is blocked unless all of the major decision makers learn together, come to share beliefs and goals, and are committed to take the actions necessary for change. Second, learning builds on past knowledge and experience—that is, on memory. Organizational memory depends on institutional mechanisms (e.g., policies, strategies, and explicit models) used to retain knowledge. Of course, organizations also depend on the memory of individuals. But relying exclusively on individuals risks losing hard-won lessons and experiences as people migrate from one job to another.

The challenge, then, is to discover new management tools and methods to accelerate organizational learning, build consensus for change, and facilitate the change process. Let me share some of the specifics of how organizational learning is serving as an umbrella to unify my approach to systems thinking, planning, quality improvement, organizational behavior, and information systems.

As we worked our way through the planning process, it became clear that our almost fanatical commitment to decentralization was impeding progress.

Systems Thinking

Systems thinking, and in particular system dynamics, is a powerful tool to facilitate both individual and organizational learning. One of the early lessons learned from system dynamics is that organizations are like giant networks of interconnected nodes. Changes intended to improve performance in one part of the organization can affect other parts of the organization with surprising, often negative consequences. That is, decisions based solely on information at the local level, which is often the only information available, can be counterproductive to the system as a whole. The undesirable buildup of inventory in distribution channels is a well-known example of what happens when local managers do not understand the conditions of the total environment in which they are operating.

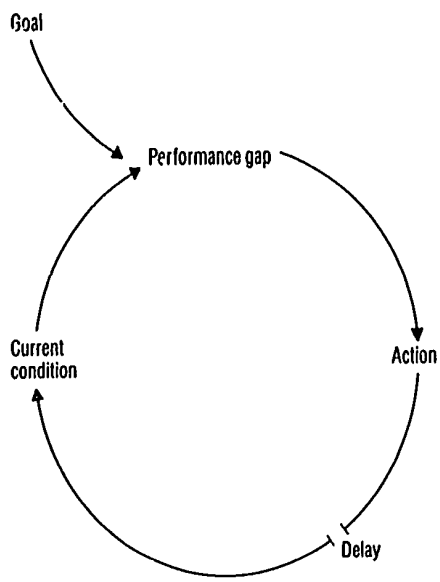
Human cognitive capabilities limit our ability to understand what is actually going on in complex organizations. In fact, recent experimental studies by John Sterman at MIT show that decision makers consistently misjudge complex systems with multiple feedback processes and delays.[6] Fortunately, owing to the work of Forrester and others in system dynamics, tools to analyze and design complex electronic and mechanical systems have been adapted to perform the same functions in complex organization systems. Using these tools and desktop computers, we can simulate organizational behavior and show how the structure and policies of companies may generate undesirable performance that is often blamed on the external environment. We can also demonstrate how decisions that improve performance in the short term sometimes only make it worse in the long term.

Forrester and Senge make the point that the role of organizational leaders is undergoing dramatic change. Historically leaders were referred to as "captains of the ship" to denote their role in operating the vessel entrusted to their care. But future leaders must be both designers and operators. Their principal contribution will be to shape the design of the organization structure and policies so as to best fulfill the corporate mission. Expertise in organization design will be a critical skill—a skill that will require considerable technical knowledge about how to analyze, modify, and simulate the behavior of complex human systems.

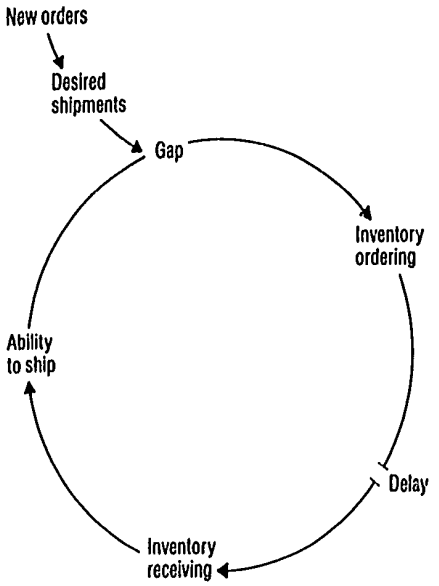
Let us take one of the most elementary concepts of feedback theory as applied to organizational design. That is, when you model organizational behavior, one basic characterization of a system is the delay time between cause and effect—for example, between when an order is received and when it is shipped, when you start manufacturing a product and when you finish, when you start to design a new product and when you introduce it to the market, or when you receive a request for information and when you respond. Using system dynamics to simulate organizational behavior, you find that often one of the highest leverage points for improving performance is the minimization of these system delays. In designing the organization, the leader should focus on optimizing the response time to changes in the external environment, with minimum overshoot and undershoot of output from the desired goals (see Figure 1).

You might argue that this is an obvious conclusion and that you don't need system dynamics to prove it. What is *not* obvious is the magnitude of loss from excessive inventories, excessive lead time, and poor customer service that result from these system delays. Only when the loss is quantified does its critical importance strike home. To put it another way, if these conclusions are so obvious, then why did it take U.S. manufacturers so long to grasp the critical importance of manufacturing cycle time and to focus on reducing time to market? It certainly was not obvious to me five years ago that excessive manufacturing cycle time was the principal cause for our poor delivery performance. And even now that it is obvious, there is considerable debate at Analog Devices about when you reach the point of diminishing returns in driving down cycle time as a means of improving on-time delivery, product quality, and cost.

Figure 1 **Systems Principles: Delays and Instabilities**



1. Basic Balancing Process with Delay



2. Balancing Process with Delay in Production Distribution System

Balancing or adjustment processes are a universal feature of complex human and social systems. The human body dilates and expands capillaries, opens and closes skin pores, sweats and shivers to maintain body temperature in the face of changing environmental temperatures. Corporations likewise respond to gaps between desired and actual levels of performance.

The purpose of internal adjustment processes is to maintain desired balances in the face of environmental changes. However, adjustment mechanisms can also become the source of unintended and unwanted instabilities, especially when there are long delays between action and consequence (see "1" above). In the presence of delays, an action that persists until a performance gap is eliminated will result in overshoot and oscillation; thus a bather gets scalded by overadjusting a shower that responds slowly to the faucet setting.

The principle of delays and instabilities has many applications in corporate systems. For years, executives and master's students in MIT's Introductory System Dynamics courses have done a product-distribution simulation, affectionately known as the "Beer Game." In the simulation, retailers and wholesalers, distributors, and factories interact through ordering and shipping cases of beer to meet changing patterns of customer demand. In the process, the players unintentionally generate uncontrolled cycles in production, inventories, and orders because they fail to take into account the delays that intervene between inventory ordering and inventory receiving (see "2" above).

There are two basic design improvements to reduce instabilities created by delays in adjustment processes: modulate the decision makers' actions or shorten the delays. In the beer game, about 10 percent of the teams achieve stable outputs because they don't overreact in ordering inventory. However, the resulting product-distribution system is still sluggish in response to large changes in customer demands. In real industrial systems, where information systems and means of production and distribution can be redesigned, the leverage often lies in shortening delay times so that the system can be both stable and highly responsive.

Another important use of system dynamics is as a training tool. Once we have decided the correct policy on cycle time for example, how do we help the organization learn how that policy works best and why? By explicitly revealing our mental model of how we believe the organization works or should work (that is, how the "nodes" in the organization are connected and what factors govern their interaction), we create a precise language with which to share our understanding. By comparing our model with others, we provide a mechanism not only to converge on a shared model, but also to communicate to younger, less experienced managers the organization's stored experience and knowledge. System dynamics has the same teaching potential in management schools as it does in industry. In fact, MIT recently introduced system dynamics as a teaching tool to augment the case study method. Students use a model developed by John Sterman to learn how flawed business policies led to the dramatic rise and fall of People Express Airlines.

Planning as Learning

My approach to strategic planning for our most recent five-year plan, 1988 to 1992, was strongly influenced by discussions with Arie deGeus in the New Management Style Project. In a recent article, deGeus suggested that the benefits accruing from planning are not just the objectives and strategies that emerge, but the learning that occurs during the planning process.[7] He contends that one form of organizational learning results from understanding the changes occurring in the external environment and then adapting beliefs and behavior to be compatible with those changes. If learning is a goal, then the way you structure the planning process and who you involve in it can make an important difference.

Analog Devices is a highly decentralized company; in the past top management set the broad corporate objectives and assumptions, but most of the detailed strategic planning was carried out in the divisions. But this time, in order to encourage organizational learning, we formed fifteen corporatewide product, market, and technology task forces that drew together 150 professionals from throughout the company. We wanted to better understand the opportunities we faced as a corporation and how we needed to change to fully exploit those opportunities. The result of twelve months of deliberations was a delineation of nine imperatives for change, as well as specific recommendations for how to bring about those changes. An even more important result was that a broad cross-section of our top professionals understood why some basic beliefs and assumptions that had served us well in the past needed modification.

For example, one of our strongest beliefs was that the best way to organize our resources was to use relatively small, autonomous divisions. However, as we worked our way through the planning process, it became clear to all of us that our almost fanatical commitment to decentralization was impeding progress. We concluded that we needed to coordinate technology development across divisions and to centralize certain aspects of manufacturing, especially wafer fabrication. We also had to better coordinate product planning to capitalize on the combined strength of our diverse product and technology base in penetrating new markets. We had to learn to present ourselves as a single vendor to our key accounts instead of as a collection of autonomous divisions, often competing with each other. We all realized that in accepting these conclusions we had unleashed powerful forces that would change the culture, structure, and behavior of the company in ways not yet foreseen.

Another strong belief that melted under scrutiny was that we had to choose between a proprietary, differentiated product strategy and a low-cost producer strategy. This either/or choice has proven to be a false and misleading alternative not only for Analog Devices, but for many other U.S. companies, as well. We had always taken pride in technology leadership and focused on opportunities where customers would pay high margins for performance, usually in applications with modest volume requirements. Now some of these applications were developing high-volume potential. Moreover, applications for our products and technology were emerging in computer peripherals, communications networks, and even consumer products like digital audio, and customers were demanding low prices in return for high volume.

We decided that our long-term strategy should be to serve certain selected, high-volume applications where our technology provides unique benefits, lest competitors capture these markets, learn our technology, and eventually use a lower cost structure to penetrate our traditional lower-volume industrial and military markets. This strategy change was drastic. Only through a process of open

deliberation, during which the consequences of the alternatives became very clear, did the organization "buy into" this new direction.

Once a decision was made, the organization enthusiastically turned its attention to learning what it would take to win in certain selected high-volume applications that we were well aware of but had long ignored. In less than a year we were selling digital-to-analog converters to compact audio disc player manufacturers in Japan and Korea, and we had a research effort under way to develop a monolithic analog-to-digital converter for high-definition television.

We now have confidence that we can develop high-volume manufacturing capability to serve these new markets profitably, and we are busy putting these resources in place. We also believe we can and must be both product innovators and lower-cost producers. This change in beliefs has greatly expanded our vision of opportunity and of the types of customers and markets we shall serve in the future.

These examples illustrate just a few of the dramatic changes taking place at Analog Devices. I believe our approach to planning as a learning process has greatly facilitated our ability to forge a consensus for change among those who must make it happen. It has also helped reduce the obstacles and resistance to change, that is, outdated beliefs and assumptions created by past success.

Quality Improvement: A Methodology for Change

Even when there is a strong consensus for change, achieving it is easier said than done. For example, another imperative reinforced by the planning process at Analog Devices was the need to improve customer service, product quality, and yields. Of course this concern was not new. Since the early 1980s, as our customers have gotten a taste of what Japanese electronic companies could deliver, and as just-in-time (JIT) programs have become more prevalent, pressure has mounted to improve performance. What was new was the realization of just how much we had to improve to meet our customers' expectations, and how little time we had to do it. On-time delivery of products that work has become the major factor in vendor selection and performance evaluation. We can no longer win by the sheer force of being first to market with the latest products and technology.

Quality improvement, or total quality control as it is often called, is a management methodology for achieving improvement and change.[8] In 1983 we began to introduce quality improvement methods at Analog Devices. We decided to focus our attention on product quality, on-time delivery, lead time, yields, and new-product time to market. We went to seminars, read books, gave speeches, and introduced information systems to measure our performance. But three years into the mission we were not getting very far very fast. I had an uneasy feeling that I did not know what I was supposed to be doing to lead this effort and that there were a lot of other dedicated managers in the same boat.

We knew all about error detection and correction and about doing it right the first time. But we did not have any notion of what rate of improvement was satisfactory or what we could do to accelerate the improvement process. Considering that many Japanese companies had been working the quality improvement game for more than twenty years and that they are not standing still even now, we had a justifiable sense of discomfort.

Because of our "lean and mean" attitude toward staff functions, we had resisted the addition of a quality improvement staff. Line managers were expected to learn on their own. But learn from where, learn from whom? Reading books and going to seminars was not enough. So we finally broke down and recruited a quality improvement professional to teach us how to tap the mainstream of experience and knowledge that is rapidly accumulating in this field and to help our managers become more expert practitioners. Only then did the organization begin to see real progress. One of the early lessons I learned from our quality guru was that there is a rational basis on which to set standards for rates of improvement. From his consulting experience, our director of quality improvement had documented case histories where quality improvement methodology had worked. What these cases showed was that while the rate of improvement varies from case to case, the rate in each case is remarkably consistent over an extended time period. Figure 2 shows three actual businesses' learning rates. Note that in the first case, performance improved by 50 percent every 10.4 months, in the second case every 7.8 months, and in the third case every 3.6 months. He called this characteristic slope of improvement the *half life*.

An analysis of a larger number of case studies

indicated that the half life for improvement fell within a relatively narrow range, usually six to twelve months, across a wide range of applications.[9] The reason for this phenomenon is clear enough when you understand the method by which quality improvement is achieved.

The method is deceptively simple. For example, as I mentioned, one of our goals was to reduce the percentage of orders shipped late. To do this we assembled a team from various organizations involved with customer service to analyze the causes of lateness. For each late shipment we determined the cause, and then we plotted their distribution. We found that a relatively small number of causes was responsible for 50 percent of the problems.

Next we assembled problem-solving teams to attack these major causes of lateness. When the cycle was completed, we repeated the process by prioritizing the causes for 50 percent of the remaining problems and then eliminating those causes. This cycle was repeated again and again; each time the most important remaining problems were identified and resources were focused on solving them.

In this example, as in others using this method, the slope of the learning curve is determined by how long it takes to identify and prioritize the causes of the problem and to eliminate those causes. The skills of the people and the level of resources do have an impact, but surprisingly the time required for each cycle of improvement is largely a function of the complexity and bureaucracy of the organization. Or, to put quality improvement in the larger context of this paper, the slope of the characteristic half-life curve is determined by the rate of organizational learning.

Notice that this theory of learning differs from the Boston Consulting Group (BCG) "experience curve" theory that says learning occurs as a function of cumulative production volume, independent of lapsed time. The quality improvement theory says that learning, properly managed, occurs as a function of time, independent of cumulative volume. How else can we explain the success of the Japanese automobile industry, which learned faster than the U.S. industry with substantially less cumulative volume? If we combine the two ideas, we can say more accurately that the slope of the BCG experience curve is determined by the rate of organizational learning. A steeper experience curve occurring at lower production volume can soon overcome a more shallow experience curve occurring at higher volume.

Figure 2A Examples of Quality Improvement versus Time
Product Defect Rate

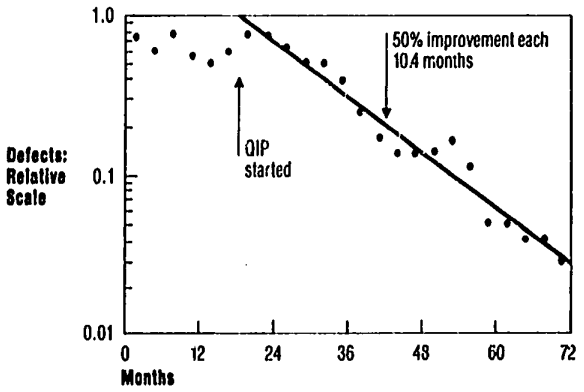


Figure 2B Average Defects per Unit

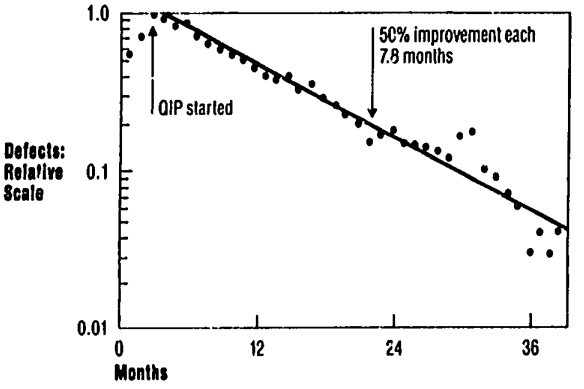
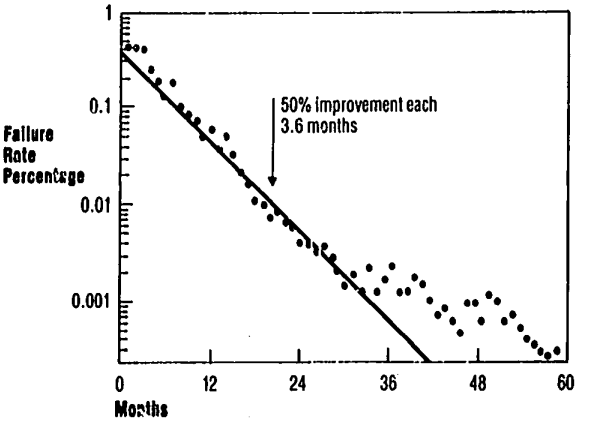


Figure 2C Failure Rate Improvement



We know that communication across organizational boundaries is less effective than within organizational boundaries and that many problems accumulate because of poor communication. Quality improvement is a way to create temporary organizational structures, or teams, that cut horizontally across organizational boundaries and enhance communication and cooperation. It is a way to get people to think about problems and issues objectively and quantitatively instead of subjectively and politically. It is a way to separate the vital few problems from the trivial many—and to focus organizational resources on resolving them. In short, quality improvement is a way to accelerate organizational learning.

Using the half-life concept, at Analog Devices we set very aggressive five-year goals for quality improvement (see Table 1). The results of continuous improvement with nine-to-twelve-month half lives over an extended period are awesome. The first reaction of our organization was to recoil from what looked like unrealistic objectives. But we reminded our managers that if a company really gets its quality improvement act together, there is no fundamental reason why these goals cannot be achieved. There are companies in Japan already operating at these levels on some of these measures.

Behavioral Influences on the Learning Process

The values and culture of an organization have a significant impact on the learning process and on how effectively a company can adapt and change. In particular, poor communication between people and between organizations can be a major block to learning and quality improvement.

Table 1 Analog Devices: Quality Improvement Program Goals

Measurement	1987	Half Life (in months)	1992
External			
On-Time Delivery	85%	9	>99.8%
Outgoing Defect Level	500 ppm	9	<10 ppm
Lead Time	10 weeks	9	<3 weeks
Internal			
Manufacturing Cycle Time	15 weeks	9	4-5 weeks
Process Defect Level	5000 ppm	6	<10 ppm
Yield	20%	9	>50%
Time to Market	36 months	24	6 months

We decided another imperative for change at Analog Devices was to elevate teamwork as a virtue in our culture. We hoped to better balance our historical bias toward divisional autonomy with the recognition that many high-priority changes require interdivisional cooperation. If teamwork was our goal, then other virtues had to be emphasized. We tried to capture the essence of these virtues in the concepts of *openness* and *objectivity*. By openness, we mean a willingness to put all the cards on the table, eliminate hidden agendas, make our motives, feelings, and biases known, and invite other opinions and points of view—thereby engendering trust in relations between people. By objectivity, we mean searching for the best answers based on reasoned positions and objective criteria, as opposed to political influence and parochial interests. We also mean making judgments based on facts, not opinions or rumors.

In order to encourage teamwork, openness, and objectivity, we have included these attributes in our performance appraisal process and our criteria for hiring and promotion. Moreover, during performance reviews we solicit feedback from peers and subordinates on these and other competencies. It is only when you tie pay and promotion to these intangible factors that the organization knows you are serious and begins to modify its behavior.

The concept of teamwork has many dimensions. We have found that the best way to introduce knowledge and modify behavior is by working with small teams that have the power and resources to enact change. For example, quality improvement training starts with the division manager and his or her direct reports. The group not only develops a common understanding of new concepts and language, but peer pressure can also help to bring along skeptics who might otherwise block progress. Moreover, the new knowledge can be immediately transformed into action as an integral part of training. This approach, in contrast with sending people individually to centralized training programs, highlights the distinction between individual and organizational learning.

Information Systems: A Help or Hindrance to Learning

Information, of course, is essential to the learning process. It is helpful to think about information *systems* in terms of whether they help or hinder organizational learning. Let me give a few exam-

ples to illustrate this point.

Many companies distribute their products through international sales affiliates. Product divisions "sell" their output to sales affiliates at some transfer price. The affiliates, in turn, resell at the highest price the local market will bear. Each group is measured separately on "sales" and "profits," but the company's *real* sales and profits are the combination of the two, with proper accounting eliminations. Analog Devices got started this way because we initially used a network of trading companies and representatives to distribute our products internationally. Over time we replaced these independent agencies with wholly owned sales affiliates, but the original organization and information system remained intact for over twenty years.

The system worked extremely well so long as there were enough profits to satisfy the goals of both organizations. But as competition intensified, more and more time was spent in haggling over the transfer prices between divisions, instead of in figuring out how to retain our market share in a competitive world. The system actually encouraged managers to hide the facts and play games to increase their share of the profit pie. So this year we threw out our old management information system, disbanded transfer prices (except for tax purposes), and went to worldwide product line reporting. Now both affiliates and product divisions operate from the same set of books.

Under the new system, division managers see results on a worldwide basis segmented by territory—with direct visibility, although not complete control, of end-customer sales revenues and distribution costs. By the same token, affiliate managers also see worldwide results with profit and cost visibility segmented by product division.

Under the old system, the only people who saw the worldwide results were the corporate accountants; even then the results were aggregated, rather than segmented by product line. No one in the corporation actually knew the real worldwide sales and profits for any product.

The worldwide product line management system focuses division and affiliate managers on common goals and performance measures that encourage cooperation rather than conflict. Separate information systems that hide interdependence and give a false sense of control are not realistic. As you might expect, though, our managers ask, "How can we be responsible for what we can't control?" The answer is that we can influence others with information and reason. Control is an illusion—compelling in the short term, but unachievable in the long term. Information systems that hide this dilemma do not get at the problems. Already I can tell you that, since we started using worldwide product line information, a lot of thoughtful discussions have taken place around the company, and some constructive behavior changes have occurred. The new information system is helping managers on both sides to understand their businesses better and to make better decisions.

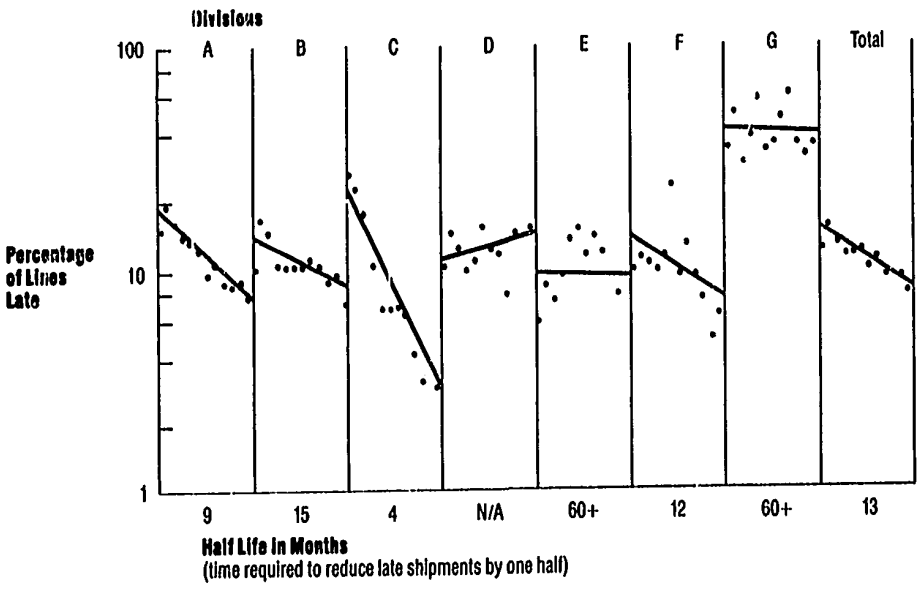
Another problem with management information systems is that they are strongly biased toward reporting financial information to stockholders and government agencies. Unless quality improvement and other more fundamental performance measures are elevated to the same level of importance as financial measures, when conflicts arise, financial considerations win out. To address this issue, we designed what we call a division scorecard that reports only the barest of financial information and places greater emphasis on quality improvement goals. This scorecard is used not only to evaluate division performance, but also to structure division bonus plans.

How information is displayed makes an incredible difference. Consider, for example, the format we use to display on-time delivery information (see Figure 3). This simple summary replaces pages of information that used to be circulated to managers. With all these pages, the most crucial information was missing—namely, the half-life trend. Because the information is plotted on a log-linear scale, the trend is readily discernible. For management purposes, displaying all divisions together on a single page has great motivational value. A high level of internal competition exists to generate the fastest learning curve; it is obvious and embarrassing when you are not performing.

Management information systems transform data into information and then help managers transform information into knowledge and knowledge into action. The challenge is deciding what information and knowledge—in what form—are needed. If we keep organizational learning in mind as a goal of information systems design, then we are more likely to generate the information and knowledge that managers need to take effective action.

We still have only a primitive knowledge of how organizations learn and of how to overcome ob-

Figure 3 **Analog Devices On-Time Customer Service Performance Monthly Data (August 1987–July 1988)**



stacles to organizational change. Industry and universities need to work together developing tools and concepts that facilitate the process of change.

The Need for Collaborative Research

Among engineers and scientists there is a consensus that collaborative university-industry research promotes innovation and competitiveness. The National Science Foundation's Engineering Research Center (ERC) program, patterned on MIT's interdisciplinary research centers, is an attractive prototype partnership. The criteria for winning ERC grants include cross-disciplinary research, industry participation, new knowledge generation, improvement of the United States' competitive position, and linkage to the education system. If we broaden the concepts of innovation and technology to embrace management, then the need for collaborative research in management is no less than it is in engineering. Perhaps it is even greater.

Japanese industry is concentrated in huge, vertically integrated corporations, whereas the United States has a fragmented industry structure, especially in knowledge-intensive industries. In fact, six of the world's ten largest corporations are Japanese; only three are American. Because of their size, these mega-corporations can be more self-sufficient in technical and managerial research, education, and training. America's superior research universities could potentially offset this advantage, but only if they work closely with industry.

The New Management Style Project closely follows the ERC model and offers an excellent prototype for the development of collaborative partnerships between business schools and industry. We have learned from this experience that an effective partnership should include the following characteristics.

- *Focus on Critical Management Problems.* Academics and industrialists should work together to identify critical issues of practical significance to practicing managers. They must be issues for which academic research can add to the store of knowledge and tools, codify industry practice into more widely usable and teachable form, or both. In order to do this, universities may need to rethink their research agenda, as well as how faculty contributions and performance are evaluated. It may also require a willingness on the part of universities to set aside their preference for tidy "academic research," and, instead, confront messy, real-life management issues.
- *Develop and Disseminate New Learning Tools and*

Methods. One important partnership goal is the broad dissemination of new tools and concepts in both management education and practice, either through academic research or through discovery and documentation of the best industry practices.

- *Test Tools and Methods in Practice.* Some of the companies in the New Management Style Project are testing new concepts by serving as experimental laboratories. The real value of *new* management ideas can be determined only when they are put into practice. Research partnerships provide a unique opportunity to perform controlled experiments in real-world settings.
- *Provide Cross-Organizational Learning.* An important benefit for the industrial partners is the opportunity to share experiences and learn from each other—not superficially, but with the benefit of thoughtful discussion. I certainly learned a great deal from my partners in the New Management Style Project, and so did the academics who heard firsthand about common issues and concerns.
- *Use a Cross-Disciplinary Approach.* Important problems are generally complex; they do not align themselves with a single technology or discipline. Thus a partnership focused on real-world problems should bring together specialists from several related disciplines. MIT has done this very successfully in science and engineering through interdisciplinary research centers. This approach is promising for management schools as well.
- *Provide Cooperative Education Opportunities for Students.* One objective of the partnership is to introduce the most current knowledge and methods into management education, but these partnerships could also provide a unique opportunity for cooperative education. That is, during the summer months, students could become involved with research projects already being undertaken by the university and the company. These work assignments could lead to a thesis or study project that is part of the academic program. Blending theory and practice in an internship program is perhaps the best approach to professional graduate education.

Conclusions

Five years ago Analog Devices had no conceptual framework for the kind of thinking outlined in this paper and no prayer of making the kind of improvements that are essential to our survival. Now I believe we are on the right track, and we are seeing real progress across a broad front. But the question remains, are we learning fast enough? Or will one of our competitors, either here or abroad, learn even faster in the future? That unsettling question concerns me most of all.

Management innovation is already an important aspect of industrial competitiveness, and it will surely become even more of a factor in the future. Like any innovation process, management innovation requires new technology and new ideas and then the rapid diffusion of the new knowledge into practice. These results do not come free; they require a major investment of time and resources. We have to ask ourselves, as a company and as a nation, are we investing enough in management innovation? Do we even know how much or how little we are investing? I suspect we are not investing nearly enough and, as a result, the huge sums we are pouring into product and process development will not produce anywhere nearly their full potential. Clearly, industry has a vested interest in working more closely with universities to advance the state of management technology and practice.

Our research universities must also play a major role in boosting management innovation and restoring competitiveness. One way, as proposed here, is to work with industry to develop better management tools and concepts and to help companies put these ideas into practice. Better understanding of how to accelerate organizational learning and adapt to a changing world environment would be a good place to start. ■

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