Toward Learning Organizations:
Integrating Total Quality Control and Systems Thinking

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Total Quality Control and systems thinking have complementary strengths that can greatly enhance an organization's ability to improve its performance through a more balanced learning process. As Daniel Kim explains below, the integration of the two approaches can provide the synergistic boost that will help U.S. firms reassert their competitiveness and build the foundations for a new type of organization—a learning organization, where front-line people work in self-managed groups, managers develop their research skills and take on the role of theory-builders, and leaders become more like philosophers who inspire the human spirit. At the core of these learning organizations will be learning systems and processes firmly rooted in the two disciplines of TQC and systems thinking.

Total Quality Control

Japan's success in wielding Total Quality Control[1] (TQC) as a competitive weapon jolted American managers out of their complacency and illustrated the need for drastic changes in management practice. We have had to discard old ideas that cost and quality are an either/or decision, recognize the need for closer worker involvement, and assume that management is responsible for defects arising from faulty systems.[2] The Japanese, however, began their TQC activities in the early 1950s and took nearly four decades to attain their current level of worldwide prominence. Companies in the U.S. often overlook this fact as they embark on TQC programs of their own. Many firms have discovered just how painfully slow the process of instituting TQC can be: Time frames of eight to 10 years are quite common. Joe Juran, an internationally recognized expert on Total Quality Management, underscored this point at a European conference on quality control addressing the subject of "When Can the West Catch up with Japan":

> Japan has done its QC education well. But it took ten years for this education to show results, for quality to improve, and for productivity to rise. No matter how hard Western nations try to engage in QC education, they may not catch up with Japan until the 1990s, since it requires ten years for the QC education to take effect.

Juran first spoke those words in 1981, and we see in retrospect that he was overly optimistic. The Japanese overtook the U.S. sometime in the 1980s by improving their manufacturing capabilities at a faster rate than the U.S.—and they show no sign of slowing down. Ray Stata, chairman and

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president of Analog Devices, presented a provocative argument that, unlike "the Boston Consulting Group's experience curve theory, which says that learning is a function of cumulative volume, independent of time . . . learning, properly managed, occurs as a function of time, independent of cumulative volume."

This statement carries a message far more startling than Juran's prediction: We will never catch up with the Japanese because they have a permanent head start on us. In other words, we can't catch up by simply imitating what they have done; we must innovate and improve upon TQC.

Peter Drucker wrote in 1990 about the "postmodern factory" whose essence will be defined by the synthesis of four principles and practices—Statistical Quality Control (SQC), new manufacturing accounting, "flotilla" or module organization of manufacturing processes, and a systems approach. According to Drucker, the integration of these four concepts will build a new theory of manufacturing in which every manager "will have to learn and practice a discipline that integrates engineering, management of people, and business economics into the manufacturing process." Implicit in Drucker's theory is the underlying goal of creating an environment conducive for continual learning.

Being TQC-driven means creating such an environment by advancing continuous improvement at every level of the organization. From factory workers to CEOs, the goal is to become better learners. But to endure, organizational learning must advance on both the operational and conceptual level.[3] Learning at the operational level entails changing behaviors or methods of doing things in order to improve the performance of a particular system. It can involve physical changes in a machine setting, procedural changes in a production step, or a psychological change in a worker's attitude about his or her job. Learning at the conceptual level means changing one's mental models about how the world works. It includes changing the way one thinks about a problem by reframing it in a new context and exploring the implications. Learning at one level without the other is like trying to run a marathon with one foot nailed to the starting line; you can be off to a quick start, but you won't get very far.

Organizational Learning[4]

All organizations learn, whether they consciously choose to or not—it is a fundamental requirement for their sustained existence. The extent to which companies consciously manage the learning process, however, varies greatly. Some organizations are quite deliberate, developing capabilities that are consistent with their objectives. Others make no focused effort, and inadvertently acquire habits counterproductive toward achieving stated goals. For example, superstitious learning can occur when an experience is particularly compelling but the connections between actions taken and outcomes produced are misunderstood or far apart in space and time. Organizations can also suffer from competency traps when they accumulate experience in an inferior procedure with which they have had initial favorable results. In the grip of this kind of trap, a company may either fail to notice a superior procedure or dismiss it as unattractive.

In the early stages of a company's existence, organizational learning is often synonymous with individual learning, for it usually involves a small group of people and has minimal structure. As an organization grows, however, a distinction between the two levels of learning emerges. Somewhere in that process, a system for capturing learnings from its individual members evolves. The way in which an organization learns through individuals is a topic of growing interest, but has not yet reached consensus. One of the main dilemmas shared by all who tackle this issue was posed by Chris Argyris and Donald Schön:

> There is something paradoxical here. Organizations are not merely collections of individuals, yet there is no organization without such collections. Similarly, organizational learning is not merely individual learning, yet organizations learn only through the experience and actions of individuals. What, then, are we to make of organizational learning? What is an organization that it may learn?

Clearly, organizations learn through their individual members and, therefore, are affected either directly or indirectly by individual learning. Argyris and Schön present a theory of action perspective in which organizational learning takes place through individual actors whose actions are based on a set of shared models. The authors argue that most organizations have shared assumptions that preclude challenging people's attributions and that provide self-sealing affirmation of those attributions. Engaging in such actions, which Argyris and Schön refer to as single-loop learning, ensures that very little learning occurs. The authors present an alternate model of learning, double-loop learning, in which people openly inquire about the company's prevailing assumptions and are, in turn, open to having them challenged, tested, disconfirmed, and replaced.

Operational and Conceptual Learning

The two levels of learning that take place in an organization—operational and conceptual—can be likened to Argyris and Schön's concept of single-loop and double-loop learning. In single-loop learning, people respond to changes in their organizational environment by detecting errors and correcting them to maintain the current level of operation. Single-loop learning occurs within the prevailing context and does not encourage any reflection and inquiry that may lead to a reframing of the situation. In plain terms then, *operational learning* has to do with the actual *doing* of things. It represents learning at the procedural level, where one learns the steps that one must follow to complete a particular task. Examples of such learning include filling out entry forms, operating a piece of machinery, handling a switchboard, retooling a machine, and so on.

Whereas operational learning emphasizes the *how* of doing things, *conceptual learning* emphasizes the *why* of doing things. That is, it has to do with the *thinking* behind the doing. Like Argyris and Schön's double-loop learning, conceptual learning involves bringing to the surface and challenging an organization's deep-rooted assumptions and norms that have previously been inaccessible, either because they were unknown, or known but undiscussable. Conceptual learning involves issues that challenge the very nature or existence of prevailing conditions, procedures, or conceptions. Through conceptual learning, opportunities arise for reframing a problem so as to generate radically different potential solutions.

Learning Cycle Time

Another important aspect of organizational learning involves the rate of learning. Analogous to manufacturing cycle time, learning cycle time can be defined as the time it takes to encounter, understand, and internalize a new concept or task so that the learner is capable of using that new task or concept when the need arises. As one shortens the learning cycle time, the number of learning cycles possible per unit time increases, thus increasing the rate of learning. For example, shorter manufacturing cycle times can help reduce learning cycle times by eliminating delays and inefficiencies. The speed with which one completes tasks, however, does not directly translate into organizational learning—increased speed is a result of organizational learning, not necessarily its *cause*.[5] In fact, faster and more frequent iterations can lead to random drift rather than improved performance, because they continually modify a situation before one can grasp what is happening.

As the pace of change continues to increase, the importance of learning cycles for sustaining competitive advantage grows as well. Learning cycle times do not have to be the same throughout an organization—differential rates of learning do and should exist. An organization's overall rate of learning is not necessarily gated by its slowest link, but is determined by the composition of its portfolio of learning rates and the relative importance of each rate. *It is essential that those parts of the organization with the fastest learning rates be precisely where the organization needs to be learning the fastest; that is, in the areas of critical importance to its strategic future.* This need for faster learning cycle times poses a dilemma, however, for most issues of strategic importance have inherently long time horizons (or cycle times). We'll return to this dilemma in the section on managerial microworlds.

TQC as a Vehicle for Organizational Learning

The TQC mission is not just about improving production steps and reducing cycle times; *TQC is a thought revolution in management.* Put another way, TQC is about changing the mental models of management in order to enhance an organization's capability to determine its own future. This change requires more than a one-time shift in thinking; it means continually reevaluating the way managers think. Sustaining this thought revolution requires not only continual improvement activities in which many firms are engaged but also changing the common knowledge and mental models shared within an organization; it requires *organizational learning.*

TQC embodies a total commitment to satisfying customers by developing, designing, and producing high-quality products. At the conceptual level, TQC has forced managers to abandon old mental models of viewing quality/cost and quality/productivity as either/or decisions. It is also changing managers' definition of quality from "conforming to specifications" to "satisfying customers' needs." The concept of building-in quality rather than inspecting-in quality constitutes a major shift in the way managers once viewed the production process. These changes in mental models have driven changes and learning at the operational level. Quality has improved through the use of statistical quality control (SQC), which helps lower production costs through smaller variances and reduced scrap rates. The practice of listening more closely to customers has increased customer satisfaction, and as workers learn to inspect their own work for defects, separate quality inspectors are becoming obsolete.

A BRIEF HISTORY OF TQC[6]

After the devastation of World War II, Japan had to rebuild its industrial base almost from scratch. With the help of U.S. occupation forces, the Japanese began applying the modern techniques of quality control in rebuilding their industries. A group of engineers and scholars formed the Union of Japanese Scientists and Engineers (JUSE) to engage in research and disseminate knowledge about quality control. The concept of quality control was introduced to Japan in 1950 when JUSE invited Dr. W. Edwards Deming, a recognized expert in the field of sampling, to give a seminar on statistical quality control for managers and engineers.

Although Deming's tools proved valuable for production problems, managing the process of getting workers to use them effectively was difficult. Dr. J. M. Juran's visit in 1954 shifted Japan's quality control emphasis from the factory floor to an overall concern for the entire management. The initial concept of Total Quality Control emerged from that shift in thinking.

In TQC, all quality efforts are carried out with the purpose of improving the product or service provided *as seen by the customer*. The definition of customer includes internal as well as external buyers. Quality control (QC), or quality assurance (QA), began with an emphasis on inspecting-out defects and evolved into the concept of controlling manufacturing processes in order to prevent defects in the first place. This idea was later extended to include the product development process—to design-in quality from the very beginning. The inclusion of the product development process produced the need to involve the entire company in quality control activities. QC was no longer the province of inspectors performing an isolated function, but a companywide activity that involved all divisions and all employees.

QC Circles grew out of the important role that workers played in the actual manufacture of products. The cornerstone of the QC Circle lay in education mixed with on-the-job application of tools. In addition, the idea of the QC Circle was based on a strong belief in voluntarism. This belief led to a slow start, but the movement later mushroomed rapidly as early success stories spurred other companies to follow suit.

The results of Japanese TQC activities require little elaboration. In the space of only a few years, Japanese car makers grabbed an ever-increasing share of the U.S. automobile market. Since the early 1970s, Japanese car makers have produced more and more fuel-efficient and higher quality cars. They have soundly bested many U.S. industries such as steel, semiconductors, motorcycles, televisions, and cameras, and they threaten the entire U.S. consumer electronics industry. They have penetrated every market they have entered with superior quality products in workmanship as well as design. As one striking example of their success, Japanese semiconductor manufacturers currently supply 85 percent of the worldwide memory chip market.

Although it has taken some strong convincing, many U.S. manufacturing firms have embraced the TQC way of conducting business and have made significant strides toward improving quality. AT&T, for example, cut the development time for their model 4200 cordless telephone from two years to one year while improving quality and lowering costs. All three U.S. auto makers have undertaken TQC activities that have helped reduce defects, cut cycle times, and increase customer satisfaction.

Computer and semiconductor manufacturers have also instituted TQC in their organizations. Analog Devices, a leading manufacturer of linear integrated circuits, included Quality Improvement objectives in their strategic planning and bonus incentives. At Hewlett-Packard's Lake Stevens, WA, facilities, workers cut failure rates for their 30 products by 84 percent, and manufacturing time by 80 percent. In recognition of their crusade for quality, Motorola received the first annual Malcolm Baldrige National Quality Award—the American equivalent of Japan's prestigious Deming Prize. Florida Power and Light became the first non-Japanese company ever to win the coveted Deming Prize in Japan.

The tools and methodology of TQC gained widespread acceptance because they fit in with the traditional model of problem solving, which is based on reductionism and analysis. It is indisputable that the application of traditional TQC tools[7] to manufacturing has proven highly successful. Steadily, and with remarkable efficiency, the TQC process has reduced defects, shortened cycle times, and increased throughput in the manufacturing process.

TQC embodies both a holistic philosophy about the enterprise of running a business and a set of statistical tools applied at the lowest levels of an organization. It is this blend of the macro and the micro that makes it such a potent discipline. Without its philosophy, TQC would be simply a bag of tools applied to mere firefighting, or solving problems only as they arise. Without its statistical tools, TQC provides a guiding light to a goal but no way to navigate the terrain. TQC's success lies in linking the lofty goals for top management with a set of tools for operators to achieve those goals.

TQC is particularly well equipped to advance learning at the operational level. The seven tools of TQC (Pareto chart, cause-and-effect diagram, stratification, check sheet, histogram, scatter diagram, and control charts) are relatively easy to understand and use. Through the use of control charts and Pareto analysis, for example, operators can understand and improve their production steps. Under the TQC umbrella, engineers can design experiments and collect data on the factory floor to better understand and improve manufacturing processes. Improvement through operational learning involves an incremental process whereby a particular problem is whittled down bit by bit. At the heart of this learning process is Deming's PDCA (Plan-Do-Check-Action) cycle, which promotes continual improvement by cycling through the PDCA problem-solving loop. Transfer of learning from individuals to organizations is managed through an organization-wide TQC effort designed to facilitate the sharing of learning in one setting with the rest of the organization.

As quality continues to improve at companies engaging in TQC activities, a great deal of learning doubtless continues to take place at the operational level. New methods of soldering a joint or assembling an engine, for example, are tried, tested, and absorbed into the organization's memory. Aside from the initial mental breakthrough required at the outset of instituting TQC, however, new learning opportunities at the *conceptual* level become less available. A manager can go on advocating improvements *within* the current framework of organization policies and traditions without gaining much insight about the whole system. TQC provides limited methods and tools for organizational learning at a deeper level, where managers can gain a better understanding of their organization and improve the way they manage. That is, TQC is valuable for enhancing learning at the operational level but is limited in its ability to advance management thinking at the conceptual level.

Systems Thinking and Organizational Learning

Compared to TQC's emphasis on operational learning, systems thinking's underpinnings are more conceptual in nature. Systems thinking[8] approaches problems from the basis of the whole, rather than breaking things up into individual pieces and trying to understand each part. Where TQC focuses on *analysis* of the separate parts that make up the whole, systems thinking strives for *synthesis* of the constituent parts.

According to systems thinking, if a system is decomposed into its components and each component is optimized, the system as a whole can be guaranteed not to be optimal. A common characteristic of many complex systems is that they are often designed with the intention of optimizing the parts rather than the whole. In a typical company, the manufacturing function is expected to operate as efficiently as it can. The same goal holds for marketing, accounting, engineering, and so forth. At a leading manufacturer of linear integrated circuits, initial attempts to use TQC to improve on-time delivery performance led to each function jockeying to improve its own performance measure. This outcome did not ultimately benefit customers. In the insurance industry, underwriter departments tend to see optimization of their function as independent from other functions such as marketing and claims. The above examples all lead to functional gridlock—each function striving to optimize its own performance while the organization as a whole is grossly suboptimized.

Systems thinking helps break through functional walls of isolation by providing a framework for understanding the importance of managing the interconnections among the various functions. It also provides a methodology for thinking about the ways in which prevailing mental models may restrict learning, gaining deeper insights into the nature of complex systems, finding high leverage points in the system, and testing one's assumptions about the efficacy of various policy choices.

System dynamics is a field within systems thinking that is particularly rich in the area of conceptualization and synthesis of complex systems. It also provides a methodology for synthesizing disparate kinds of variables that have traditionally been considered too "fuzzy" to measure. By focusing on making mental models explicit, exposing them to challenge, and building new models based on insights gained from this process, system dynamics helps managers gain a more systemic view of their organization.

In contrast to TQC, systems thinking offers no simple tools to date that can be used at the operational level to actually make the improvements indicated by a system dynamics study. Systems thinking is often weak in specifying operational procedures or methods to effect a desired change in procedure or structure. Managers may gain a terrific insight that easing time pressure is a high leverage point for reducing turnover and, in turn, increasing productivity, but systems thinking gives them little guidance for how to accurately measure each of the variables, implement changes, and monitor progress.

Beyond TQC: Systemic Quality Management

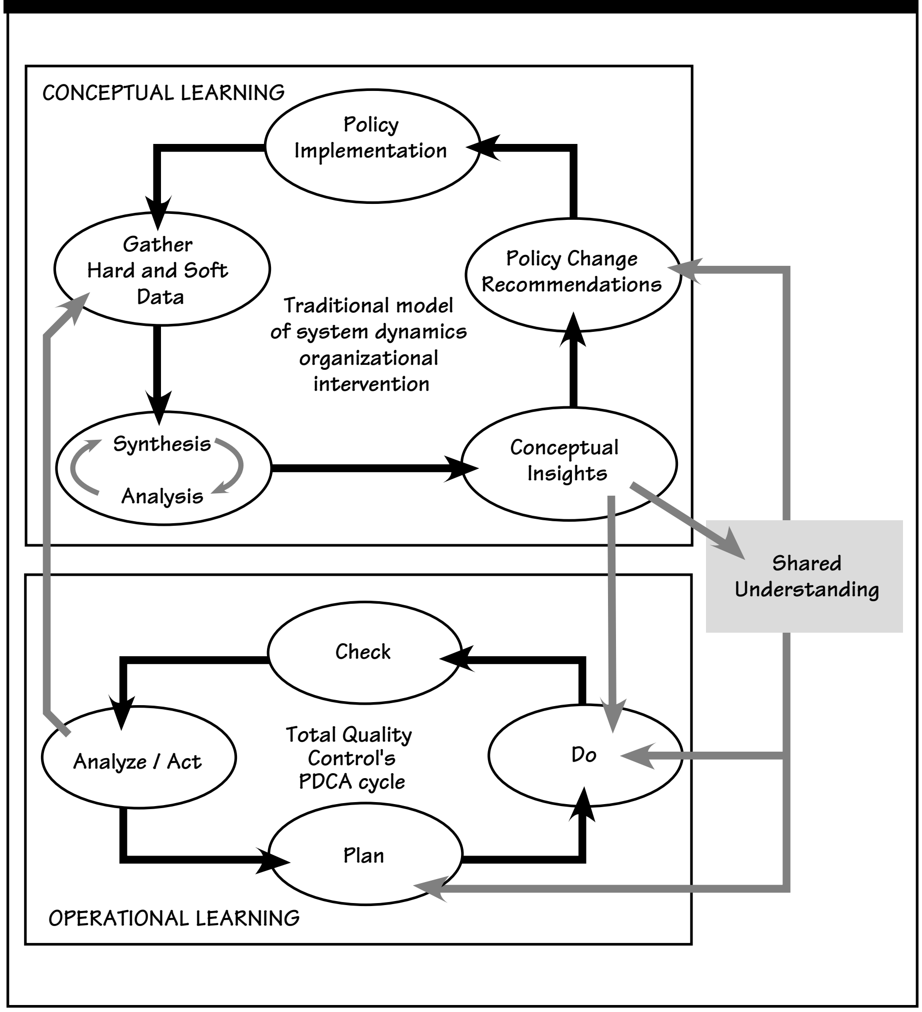
As I argued earlier, we must do more than play "follow the leader" if we hope to regain and sustain a competitive advantage in the global marketplace—we must innovate beyond TQC. Integrating TQC and systems thinking can accelerate organizational learning beyond the current capabilities of traditional TQC methods. The two approaches form a synergistic pair whose individual strengths complement each other and provide a balance of operational and conceptual learning (see "Systemic Quality Management Model"). Each process informs and enhances the other. Together, they advance organizational learning by helping to build a shared understanding of conceptual insights and operational processes, and create a powerful new model I call Systemic Quality Management (SQM).

In the SQM model diagram, the top box represents the traditional system dynamics approach of gathering data, conceptualizing, building a model, running simulation analyses, and proposing policy changes. An implicit assumption of this process is that the insights alone would be compelling enough to produce action. In reality, however, such policy change recommendations are seldom implemented, because building shared understanding traditionally has not been part of the process. Clearly, more could be done on implementation.

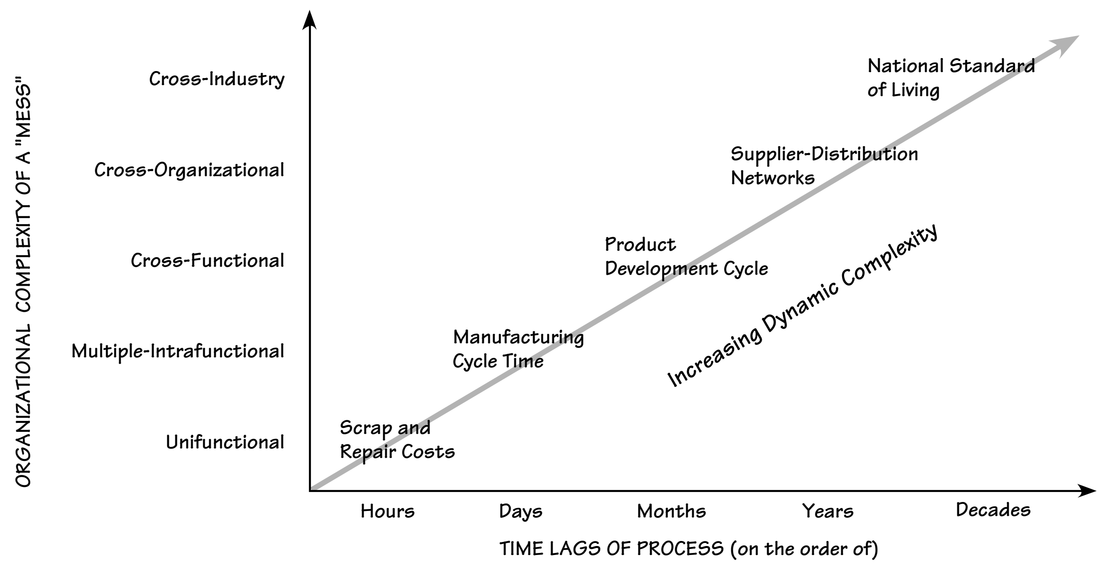
The bottom box represents a typical TQC process of quality improvements, the so-called PDCA (Plan-Do-Check-Act) cycle, which should be carried out at every level of an organization. Requests from a higher level are interpreted and translated into a plan of action with the appropriate check points identified for monitoring progress relative to the plan. The plans are incorporated into the budgetary cycle and implemented. The check points identified earlier are tracked, and deviations are observed. The data is then analyzed, and actions are taken to correct any discrepancies. Although the PDCA cycle can help in implementing new requests given from above and in maintaining control over current processes, it is relatively weak on identifying the high-leverage areas that can drive the whole process.

Combining these processes means integrating conceptual and operational learning by blending the two into a seamless process. For example, building shared understanding through the use of management flight simulators and learning labs[9] can enhance the PLANning and DOing steps by providing a common base of conceptual models. Having greater shared understanding can also facilitate buy-in of policy change recommendations. Conceptual

SYSTEMIC QUALITY MANAGEMENT MODEL



COMPLEXITY AND TIME LAGS OF ORGANIZATIONAL "MESSES"



insights such as "eroding goals" and "worse-before-better behavior" can help those involved in the DOing to see how their actions relate to the overall system. The analysis and action produced through the PDCA cycle should generate new data that would feed into the data gathering process as well as the next cycle of the PLAN.

Through SQM, organizations can identify high-leverage points *and* act upon them. Because there is an abundance of written materials available on TQC and limited systems thinking literature, I will concentrate on illuminating the ways in which systems thinking can contribute to the SQM model.

Tackling Organizational "Messes"

Although TQC seems to have been applied to everything from reducing defects to solving inventory control problems and designing customer-oriented products, there are cases for which current TQC tools and methods are inadequate. In particular, TQC is ill-equipped for tackling a class of problems that Russell Ackoff labels as a *mess*:

> What is a mess? That's the significant thing—a mess is a system of problems. Now, the significance of this is that the traditional way of managing is to take a mess and break it up into problems and solve each problem separately, with the assumption that the mess is solved if we solve each part of it.
>
> But remember . . . if you break a system into parts and make every part behave as effectively as possible, the whole will not behave as effectively as possible. Therefore, the solution to a mess does not consist of the sum of the solutions to the problems that make it up. And that is absolutely fundamental.

"Complexity and Time Lags of Organizational 'Messes'" is an attempt to classify "organizational messes" into a matrix based on Organizational Complexity (the number of units and level of complexity of their interconnections) and Time Lags of Process (current cycle time of projects). "Fuzzy" variables often accompany Ackoff's "messes" because such systems are rarely clear cut or well defined. Organizational efforts that grapple with problems involving a high degree of organizational complexity, long time delays, and fuzzy variables provide opportunities for improvement and enhanced learning through SQM.

Organizational Complexity. Many initial improvements gained in most companies come rapidly and with relative ease, either because the situation was so bad that almost any concerted effort would have yielded quick results, or because most early projects revolved around single functional units requiring minimal cross-functional cooperation. These initial projects are often part of a *bootstrapping* strategy, advocated by Juran, in which other functional units in the organization slowly buy into the TQC philosophy after its value has been proven. This buy-in process progresses slowly, taking longer and longer as it involves increasing levels of cross-functional cooperation.

One study shows that the rate of improvement in a wide range of TQC projects is primarily a function of the organizational complexity of the project, not the specifics of the project itself. This finding isn't too surprising if you listen to Edward Baker, Ford's Director of Quality Planning and Statistical Methods, explain the difficulties of communicating in top-down organizations:

> Consider an organization with six levels below the senior executive and a span of control of three. This makes 1,093 people. More importantly, there are 586,778 potential two-person interfaces that represent potential internal supplier-customer relationships. These 1,093 people depend on one another to get their job done, but their interdependencies are not explicit.

Managing even a few of those supplier-customer relationships can be a daunting task. Without a full understanding of the interdependencies, people can take actions that produce undesirable results. For example, managers at Xerox who bought into the concept of Just-in-Time (JIT) manufacturing "solved" their inventory problems by demanding that their suppliers hold inventory until they were ready to accept it. By "injecting" a good idea into one part of the system without a full appreciation of the whole, they severely strained the good supplier relations that had been painstakingly developed over many years. In the SQM model, building a shared understanding about the whole system lies at the core of organizational learning.

Time Delays. Another attribute of early TQC projects is that the time delays within those systems are relatively short. For example, reducing defects at a specific production step means getting real-time data and analyzing it to see what the data has to say. The process step usually takes minutes or hours, not days or months. Thus, it is feasible to collect data and be confident about causal conclusions drawn from the data. When the time delays of a project are extremely long, such as a product development process that takes several years, running real-time experiments becomes impractical, and current data is of limited usefulness. One can tweak individual steps within the process but cannot gain much insight about the implications of this tweaking on the process as a whole.

A research project studying the dynamics of software development, for example, revealed that an emphasis on accuracy in estimating project completion led to increased accuracy but at significantly higher costs and longer completion times. The research findings indicate that people's decisions are greatly influenced by the project schedule itself. Thus, owing to the pressures and perceptions that a given schedule produces, different estimates create different projects. Using a system dynamics model, researchers ran two different estimates of a 64,000-delivered-source-instruction software project. In the base simulation, Method A produced a 2,359 person-day estimate. The simulated project actually consumed 3,795 person-days, leading to an error of 38 percent. Method B's estimate of 5,900 person-days (150 percent higher than A's estimate) resulted in a project that consumed 5,412 person-days, which has a 9-percent error factor. Although Method B's estimate appears more accurate, it leads to a much more costly result—the project consumes 43 percent more person-days. With such simulation testing, one can gain insight into a project that spans several months from the very beginning rather than retrospectively.

Fuzzy Variables. According to Juran, the three laws of TQC are "look at the data," "look at the data," and "look at the data." Hard, measurable data is the fuel that drives the TQC engine. Getting good, reliable data is not always easy, even on mechanical processes that have universally accepted units of measure such as units per minute, or pounds per unit. The task of collecting data becomes much more difficult as the measured item becomes much less clear. Fuzzy variables include such notions as Effect of Time Pressure on Productivity, Effect of Delivery Delay on Demand, and other information that may be available only at the intuitive level. Issues stemming from fuzzy variables are likely to increase as the service industries begin looking for ways to apply TQC.

In the case of Hanover Insurance, a property and casualty insurance company, exploring the dynamics of managing a claim office highlighted the link between the amount paid in claim settlements and the quality of adjusting.[10] By interacting with a decision-making game (based on a system dynamics model), claim managers experienced how their decisions led to the erosion of quality and resulted in higher settlements. In the absence of hard, measurable data, the model framework allowed managers to *visualize* and *experience* the interconnectedness of such concepts as time pressure, work intensity, time effectiveness, and quality standard.

The "Laws" of Systems Thinking

Systems thinking can help make sense of messes by providing a framework for understanding the interconnected nature of systems and how they interact in the short and long term. Over the years, certain systems principles have been identified that provide a framework for understanding the dynamic implications of a whole system without requiring a detailed knowledge of its individual components. Peter Senge, author of *The Fifth Discipline: The Art & Practice of the Learning Organization,* states that complex systems are subject to the following laws:

- Today's problems come from yesterday's "solutions."
- The harder you push, the harder the system pushes back.
- Behavior grows better before it grows worse.
- The easy way out usually leads back in.
- Faster is slower.
- The cure can be worse than the disease.
- Cause and effect are not closely related in time and space.
- Small changes can produce big results—but the areas of highest leverage are often the least obvious.
- You *can* have your cake and eat it too—but not at once.
- Dividing an elephant in half does not produce two small elephants.
- There is no blame.

The above laws hold true because in complex systems cause and effect generally are not close together in space or time. Yet we often assume and act as if they were. We take action on what appears to be the obvious culprit, only to find that our solutions have exacerbated the very problems we intended to solve.[11] These unintended consequences are the result of complex systems' tendency to resist changing their behavior. The most common cause of such policy resistance is multiple "compensating feedback" relationships that attempt to maintain internal balances despite external interventions. It is this feedback that produces the pattern of better behavior before worse behavior. The principle of "shifting the burden to the intervenor," for example, results from the intended action of helping someone. However, it also produces the unintended consequence of undermining that individual's ability to help him- or herself.[12] The elephant analogy represents the notion of "indivisible wholes"; that is, dividing an elephant in half doesn't produce two elephants—it produces a *mess.*

A common characteristic of the "laws" listed above is that they appear counterintuitive at first glance. This is more than mere coincidence—counterintuitive behavior is fundamental to the nature of complex systems. Applying linear thinking and static tools to nonlinear and dynamic problems often leads to solutions that produce tomorrow's problems. Thanks to delays and multiple feedback loops within a system, our well-intentioned "cures" can often produce results that are much worse than the disease we sought to cure. In such situations where our intuition is a poor guide, we need a new set of tools.

The Ten Tools of Systems Thinking

One of the greatest strengths of TQC lies in its ability to educate people in using the tools. Each of the Seven Tools of Quality and the Seven Management Tools for quality is well developed and documented. Under the guidance of JUSE (Japanese Union of Scientists and Engineers), training in the use of the tools has been standardized so that large groups of people can learn them relatively easily. By translating sophisticated statistical methods into easily understood tools like control charts, histograms, check sheets, and scatter diagrams, JUSE has made Statistical Process Control accessible to the masses.

Similarly, a number of tools have been developed over the years for applying systems thinking to organizational "messes" (summarized in the table on pages 10–11). The tools fall under four broad categories: Brainstorming Tools, Dynamic Thinking Tools, Structural Thinking Tools, and Computer-Based Tools.[13] Although each of the tools can be used separately, they also build upon one another and can be used in combination to achieve deeper insights into complex systems.

Brainstorming Tools. The table shows the double-Q diagram, which is based on what is commonly known as a fishbone or cause-effect diagram. The Q's stand for *qualitative* and *quantitative,* and the technique is designed to help users begin to see the whole system. During a structured brainstorming session with the double-Q diagram, both the "hard" and "soft" sides of an issue remain equally visible. The diagram also provides a visual map of the key factors involved.

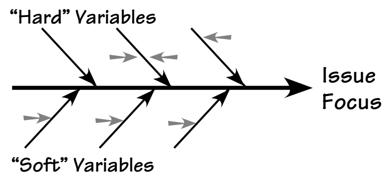
A double-Q diagram begins with a heavy horizontal arrow that points to the issue being addressed. Major quantitative factors branch off along the top and major qualitative factors run along the bottom. Arrows leading off of the major factors represent subfactors. These subfactors can, in turn, have sub subfactors leading off of them. Many layers of nesting, however, may signal that a subfactor should be turned into a major factor. Although double-Q diagramming may sound like a very rigid process, it can help give form and structure to "fuzzy" problems that have yet to be clearly defined.

Dynamic Thinking Tools. Behavior over time diagrams are more than simple line projections—they require an understanding of the dynamic relationships among the variables being drawn. For example, say we were trying to project the relationship between sales, inventory, and production. If sales jump 20 percent, production cannot instantaneously jump to the new sales number. In addition, inventory must drop below its previous level while production catches up with sales. By sketching out the behavior of different variables on the same graph, we can gain a more explicit understanding of how these variables interrelate.

Causal loop diagrams provide a useful way to represent dynamic interrelationships. Loop diagrams make explicit one's understanding of a system structure, provide a visual representation with which to communicate that understanding, and capture complex dynamics in a succinct form. The loop diagrams can be combined with behavior over time diagrams to form structure-behavior pairs that provide a rich framework for describing complex dynamic phenomena.

Systems archetypes refer to certain common dynamic structures that recur in many different situations. These archetypes, consisting of various combinations of balancing and reinforcing feedback loops, can be used as templates into which real-world examples can be fit. Specific archetypes include "Drifting Goals," "Shifting the Burden," "Limits to Success," "Fixes That Fail," "Tragedy of the Commons," and "Escalation," among others.

BRAINSTORMING TOOLS



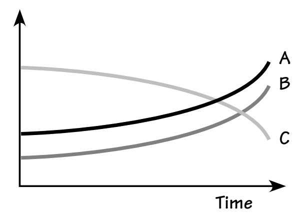
DOUBLE-Q DIAGRAM

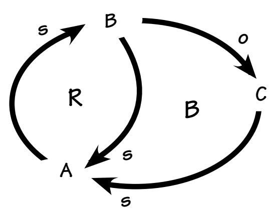
Captures free-flowing thoughts in a structured manner, and distinguishes between "hard" and "soft" variables that affect the issue of interest.

DYNAMIC THINKING TOOLS

BEHAVIOR OVER TIME DIAGRAM

Can be used in conjunction with the double-Q diagram to graph the behavior of each variable over time and to gain insights into any interrelationships between them. (Also known as reference mode diagrams.)



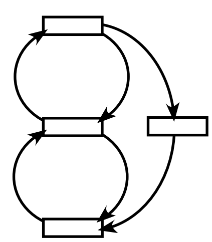


CAUSAL LOOP DIAGRAM

Used in conjunction with the double-Q and behavior over time diagrams, can help you identify reinforcing (R) and balancing (B) processes.

SYSTEMS ARCHETYPE

Helps you recognize common system behavior patterns such as "Drifting Goals," "Shifting the Burden," "Limits to Success," "Fixes That Fail," and so on—all the compelling, recurring "stories" of organizational dynamics.



Structural Thinking Tools. Graphical function diagrams, structure-behavior pairs, and policy structure diagrams can be viewed as building blocks for computer simulation models. Graphical functions are useful for clarifying nonlinear relationships between variables. Structure-behavior pairs link a specific structure with its corresponding behavior. Policy structure diagrams represent the decision-making processes that drive policies.

Computer-Based Tools. This group of tools—computer models, management flight simulators, and learning laboratories—play a particularly important role in helping managers tap the power of systems thinking.

The Manager's Dilemma: Reflection vs. Action

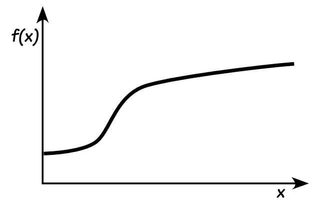
Until recently, on-the-job learning was adequate for managing in a world where change, though accelerating, still occurred across generations rather than within generations. Donald Schön pointed out that a major disruption arose when the pace of change crossed into the intragenerational state—lessons learned became obsolete within the same generation. As the world grows increasingly more complex, problems take longer to solve and proposed solutions have shorter lives. In fact, Ackoff posits that solutions are often stillborn because problems change so rapidly that solutions, when found, are often no longer relevant.

One consequence of such rapid change is that managers are forced to make decisions with equal rapidity. However, the complexity of today's problems makes it imperative that managers take time to reflect on their decisions. How, then, can a manager speed up and slow down at the same time? How can one manage in a world where experience is no longer the best—or even adequate—teacher, where change makes yesterday's lessons obsolete? How can organizations remain viable given this dilemma? At a more macro level, how can we learn about the tremendous messes we face today and implement solutions in time? In real life, we cannot fulfill this simultaneous need for both the compression and expansion of time. In *microworlds,* however, as we will see below, we have an opportunity to sidestep this dilemma.

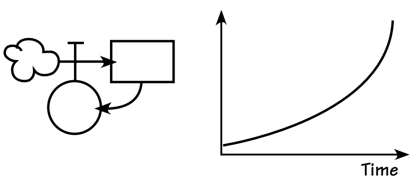
STRUCTURAL THINKING TOOLS

GRAPHICAL FUNCTION DIAGRAM

Captures the way in which one variable affects another, by plotting the relationship between the two over the full range of relevant values.



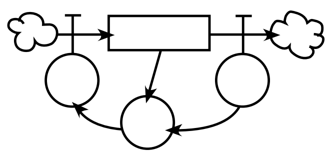
STRUCTURE-BEHAVIOR PAIR



Consists of the basic dynamic structures that can serve as building blocks for developing computer models (for example, exponential growth, delays, smooths, S-shaped growth, oscillations, and so on).

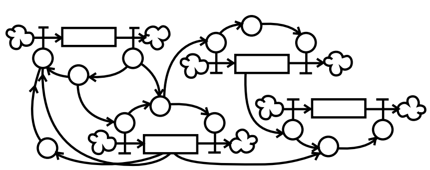
POLICY STRUCTURE DIAGRAM

A conceptual map of the decision-making process embedded in the organization. Focuses on the factors that are weighed for each decision, and can be used to build a library of generic structures.



COMPUTER-BASED TOOLS

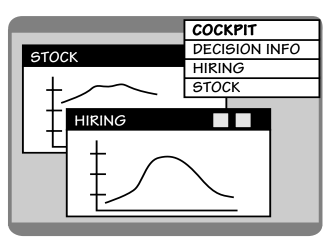
COMPUTER MODEL



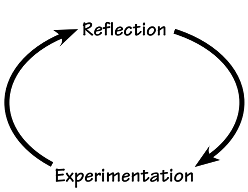
Lets you translate all relationships identified as relevant into mathematical equations. You can then run policy analyses through multiple simulations.

MANAGEMENT FLIGHT SIMULATOR

Provides "flight training" for managers through the use of interactive computer games based on a computer model. Users can recognize long-term consequences of decisions by formulating strategies and making decisions based on those strategies.



LEARNING LABORATORY



A manager's practice field. Is equivalent to a sports team's experience, which blends active experimentation with reflection and discussion. Uses all the systems thinking tools, from double-Q diagrams to MFSs.

From Learning Systems Toward Learning Organizations

Managerial Microworlds as Learning Systems

There are three important elements of learning: a set of tools appropriate for the task or concept to be learned, a framework that provides a context for the learning, and a playing field in which to practice and learn with those tools. Baseball teams have their equipment, rules of the game, and a field on which they can practice. Airline pilots have flight simulators, grids of the air space, and simulated flight conditions. No team would dream of playing a regular season game without having practice games. Airlines would never risk multimillion-dollar airplanes and the lives of hundreds of passengers for a pilot to learn by trial and error.

Managers, on the other hand, do not have comparable tools and environments in which to practice and learn—initiation by fire is the rule. Experimental data on decision-making performed within complex feedback environments underscores the need for a manager's equivalent of a pilot's flight simulator. Professor John Sterman of the MIT Sloan School of Management has demonstrated how subjects are insensitive to feedback from their own decisions in a production-distribution simulation game, leading to grossly suboptimal behavior. An analysis of managers' decisions in an insurance claims game revealed misperceptions of the time delays involved with their decisions. In experiments on human control of stock-adjustment tasks, research revealed that varying the strength of feedback (in either the positive or negative direction) had a detrimental effect on performance.

Managers, on the other hand, do not have comparable tools and environments in which to practice and learn—initiation by fire is the rule.

Management Flight Simulators. A management flight simulator is a manager's equivalent of a pilot's flight simulator—with its analogous gauges, lights, throttle, steering wheel, and so on. The first flight simulator developed at the MIT Sloan School of Management was the *People Express Simulator*.[14] *People Express* has been used with entering classes of masters students at the MIT Sloan School of Management, who spend a day engrossed in strategizing and operating the simulated airline.[15] The simulator requires each team of players to make up to five decisions on a quarterly basis as they try to manage the growth of a start-up airline (whose structure is modeled after the now-defunct People Express). Spreadsheets, graphs, and internal management reports containing competitor and market information are provided on a quarterly basis. Through repeated trials of launching a start-up using various strategies, the students gain simulated experience of the dynamics that People Express actually experienced.

Although the management flight simulator by itself can be valuable for bringing an experiential and dynamic aspect to an otherwise static case, its usefulness as a stand-alone tool has limits. For example, a player is strictly a consumer of the model on which the simulator is based, and does not participate in the creation process. This lack of involvement in conceptualizing the model may result in a shallow understanding of the model's dynamics, which are gained primarily through trial-and-error experimentation in multiple game plays. A deeper understanding of the underlying structure requires more than repeated plays of the game; participants need more explicit discussion of the theory underlying the MFS. Thus, the value of the flight simulator as a learning tool can be extended through the development of an environment within which one can replicate the conceptualization phase of the simulator development, design various scenarios to highlight specific dynamic lessons, and create an environment in which the simulator serves as an experimental tool for learning.[16]

Learning Laboratories. Extending the boundaries of the microworld beyond the computer simulator itself, the learning-lab concept can be viewed as a manager's equivalent to a sports team's practice session. The learning lab is a managerial "practice field" with an emphasis on team learning; in the lab, one can test new strategies and policies, reflect on the outcomes, and discuss pertinent issues with others in the group. In a learning lab, a management team can accelerate time by simulating a model (or virtual world) of a real-life system quickly *and* slow down the flow of time at each decision point to reflect on their actions.

The learning lab provides a unique forum in which participants can question operating norms and assumptions safely, via the game model. In an insurance company implementation of a learning lab, for example, although the company itself emphasized pursuing high quality standards, the behavior in

the games showed that controlling expenses dominated people's actions.[17] One manager remarked that while playing the game,
"I kept telling myself, 'Don't add to staff, don't add to staff,' even though there is no one telling me not to, *and* I know that I really need to!" In many cases where there was extra people capacity, managers chose to either cut staff or push for more production to reduce expenses rather than to work on improving quality.

The learning-lab environment helps develop an inquiry mode of learning that challenges managers to "think about their thinking."

Another set of operating assumptions that were brought to the surface and challenged were the notions of "proper" workload and productivity. In one scenario, managers concluded that work backlog per employee and productivity were such that they labeled it a "country club," or an office with too little to do. Many responded by reducing the number of personnel or pushing for more production from each person in order to cut expenses per claim. This practice inevitably led to increases in settlement dollars in excess of any savings in expenses. Most participants acknowledged that they had made their decisions in the game (and admittedly, in real life as well) on the basis of assumed acceptable numbers, without questioning the decisions' appropriateness for a specific situation.

In the learning lab, the process of making operating assumptions explicit and testing those assumptions encourages managers to reflect not only on the decisions they make, but on the *process* by which they make those decisions. The learning-lab environment helps develop an inquiry mode of learning that challenges managers to "think about their thinking" and break away from outmoded frames and perceptions.

Toward Learning Organizations

Organizational learning is the root from which all competitive advantage stems. The level of advantage depends on the speed and quality of learning, whether behavior change is accompanied by cognitive change, and whether continual education is emphasized over sporadic training. By emphasizing the importance of trying to *understand* a problem, not simply *solve* it, systems thinking attempts to transform problem-solving organizations into *learning organizations.* A learning organization is one that consciously manages its learning process to be consistent with its strategies and objectives through an inquiry-driven orientation of all its members. That is, learning organizations *actively and explicitly* encourage the learning process to ensure that areas of strategic importance are not neglected. This is accomplished, in part, by embedding *learning systems* that foster the continual enhancing of the organization's capabilities through its members. Management flight simulators and learning labs are two such learning systems.

Building a learning organization means continually developing the capacity to create one's vision of the future. Designing and implementing effective policies to create desired results requires an understanding of an organization and its environment as a unified system. Only with this understanding can we focus on a small set of high-leverage points to produce changes that self-reinforce and endure. To acquire such an understanding requires an ongoing management education process to develop a new style of thinking with the right blend of analysis and synthesis—to be able to see the analogy of the two small elephants in all complex systems. The unique organizational realities of the '90s and beyond will require managers to take on new roles and acquire new skills.

Managers' New Roles: Researcher and Theory-Builder

As the role of workers increasingly becomes one of self-managing work groups, the role of managers will undergo redefinition as well. Given today's pace of change and organizational complexity, managers need to know how to apply the research skills of a scientist to better understand their organizations. The old paradigm of experiments in organizations being fed into research institutions, receiving the output and feeding it back into the organizations, is no longer adequate. Intragenerational change means that the research cycle must happen faster than ever, otherwise solutions (in the form of research results) will be stillborn; the problems they were addressing will no longer be relevant. The dichotomy between manager and researcher must end, because the pace of change is such that one can no longer separate the two functions—managers must wear both hats simultaneously. Ed Baker's proposal that the CEO's new role should be that of Head of Research and Development for the Enterprise is the type of leadership needed for supporting such a shift.

Managers must also become theory-builders within their organizations. They must create new frameworks within which they continually test their strategies, policies, and decisions so as to inform themselves of improvements on the organization's design. It is no longer sufficient to apply generic theories and frameworks like Band-Aids to one's own specific issues. Managers must take the best of the new ideas around and then build a workable theory for their own organization. Those who are interested in building Peter Drucker's "postmodern" factory, for example, must translate his ideas into a framework that can be applied in their own organization. As theory-builders, managers must have an intimate knowledge of how their organization works together as a whole.

There is no "golden formula" that will hold for all time, or even for one's tenure in a present position. Companies who lived by the learning-curve theory almost died by the learning-curve theory. (The case of Texas Instruments and the personal-computer debacle is one example.) Others who followed the BCG business-portfolio theory also suffered their share of problems by either giving up entire markets or not taking full advantage of synergies among their different businesses. Theory building should not be done as an academic exercise but as a process, grounded in reality, that continually helps provide a framework for interpreting one's competitive environment.

TEN TOOLS OF SYSTEMS THINKING: ADDITIONAL RESOURCES

1. Double-Q Diagram
Based on the TQC tool "Cause-and-Effect Diagram." See Ishikawa, Kaoru (1982) *Guide to Quality Control.* Ann Arbor, MI: UNIPUB.

2. Behavior Over Time Diagram
Based on diagrams referred to as "reference modes" in system dynamics literature. See Richardson, George and Alexander Pugh (1981) *Introduction to System Dynamics Modelling with DYNAMO,* Portland, OR: Productivity Press; Anderson, Virginia and Lauren Johnson (1997) *Systems Thinking Basics: From Concepts to Causal Loops,* Cambridge, MA: Pegasus Communications, Inc.; and *The Systems Thinker,* published 10 times a year by Pegasus Communications.

3. Causal Loop Diagram
See Richardson, George and Alexander Pugh (1981) *Introduction to System Dynamics Modelling with DYNAMO,* Portland, OR: Productivity Press; Anderson, Virginia and Lauren Johnson (1997) *Systems Thinking Basics: From Concepts to Causal Loops,* Cambridge, MA: Pegasus Communications, Inc.; and *The Systems Thinker,* published 10 times a year by Pegasus Communications.

4. Systems Archetype
See Senge, Peter (1990) *The Fifth Discipline.* New York: Doubleday; Senge, Peter et al. (1994) *The Fifth Discipline Fieldbook,* New York: Currency Doubleday; *The Toolbox Reprint Series,* Cambridge, MA: Pegasus Communications; and *The Systems Thinker,* published 10 times a year by Pegasus Communications.

5. Graphical Function Diagram
Based on diagrams referred to as "table functions" in system dynamics literature. See Richardson, George and Alexander Pugh (1981) *Introduction to System Dynamics Modelling with DYNAMO,* Portland, OR: Productivity Press.

6. Structure-Behavior Pair
Referred to as "Atoms of Structure" in *Academic User's Guide to STELLA* by Barry Richmond, published (as part of software documentation) by High Performance Systems, Hanover, NH. Also see Goodman, Michael (1974) *Study Notes in System Dynamics,* Portland, OR: Productivity Press.

7. Policy Structure Diagram
Contact professor John Morecroft at the London Business School.

8. Computer Model
Software packages available for building system dynamics computer models include: ithink™ and STELLA™ by High Performance Systems, Hanover, NH; Professional DYNAMO by Pugh-Roberts, Cambridge, MA; Vensim by Ventana Systems, Inc., Belmont, MA; and Powersim by Powersim Corporation, Herndon, VA.

9. Management Flight Simulator
Contact professor John Sterman at the M.I.T. Sloan School of Management (617-253-1951) for copies of computer simulators on People Express, managing product life cycles, real-estate management, and supertanker management. For software to build simulators, see S**4™ from MicroWorlds, Cambridge, MA, and Powersim from Powersim Corporation, Herndon, VA. For microworlds, see *People Express*, *Beefeater*, and *Service Quality* from MicroWorlds, Cambridge, MA.

10. Learning Laboratory
See Kim, Daniel (1989) "Learning Laboratories: Designing a Reflective Learning Environment," *Proceedings of the 1989 International System Dynamics Conference,* Stuttgart, Germany: Springer-Verlag.

Managers should be responsible for enhancing the quality of their *thinking,* not just the quality of their *doing.* Unfortunately, the latter has traditionally been much easier to measure and has thus garnered most of the attention. Corporate Information Systems (CIS) must play an integral part in this transformation of manager as researcher. CIS needs to help us rethink how traditional management control systems are designed, what they intend to measure, and what consequences such systems have for the company as a whole.

CIS also plays a vital part in helping managers design experiments from which they can learn to manage more effectively. Managers must possess the skills and inquiring perspective of a researcher and view their job as one of active experimentation. Unfortunately, experimentation in organizations usually means, "Hey, I'm just trying something new, so don't hold me accountable," or "Let's see what happens." In such a setting, there is little opportunity for learning through experimentation.

Real experimentation in organizations means that managers actively formulate hypotheses and conduct "controlled" experiments to test them. Just as TQC provided workers with the tools and freedom to approach their work more scientifically, systems thinking provides managers with tools and a framework for continual learning. The SQM model emphasizes the dual nature of managers' new work—rethinking issues and testing actions on the conceptual plane as well as the operational plane.

Notes

1. There are many different terms in common use at different companies, such as QIP (Quality Improvement Process), TQ (Total Quality), EI (Employee Involvement), CWQC (Company-Wide Quality Control), and so forth. Although there are differences among some of these, they are usually variants of the same theme—improve the quality of product and services to customers through a company-wide focus on quality— and will be collectively referred to as TQC or Total Quality Control. If the reader is unfamiliar with TQC, a brief description is included in the sidebar on page 4.
2. Quality experts such as Edwards Deming and Joseph Juran estimate that upwards of 80 percent of defects are controllable by management, not by the operators.
3. P. M. Senge makes a similar distinction between instrumental learning (adjustments in behavior to cope with changing circumstances) versus generative learning (changes in predominant ways of thinking) (1989).
4. As Senge points out in "Leaders' New Work: Building the Learning Organization," (Sloan Management Review, Fall 1990) the word *learning* has become synonymous with taking in information or learning to adapt to changes. He differentiates that concept from "generative" learning—the capacity to create new solutions.
5. This statement does not deny a connection between speed and organizational learning—they are inextricably linked. It is true, for example, that faster manufacturing cycle times allow for more iterations during a fixed period of time, which provides the opportunity for more learning to take place. The faster turn time in itself, however, does not guarantee that learning takes place. One could, in fact, simply make mistakes faster with more frequency and not learn anything from it.
6. For an in-depth history of quality in America, see D. Garvin (1988).
7. There is a set of tools that is often referred to as the Seven Tools of Quality Control; namely, Pareto chart, cause-and-effect diagram, stratification, check sheet, histogram, scatter diagram, and control charts. For a complete handbook on these seven tools, see Ishikawa, Kaoru (1982). There is also an intermediate set of statistical methods that includes theory of sampling surveys, statistical sampling inspection, methods of statistical estimates and tests, methods of utilizing sensory tests, and methods of design of experiments. More advanced methods require the concurrent use of computers and include multivariate analysis and various methods of operations research.
8. Although there is no universally accepted definition of what is meant by systems thinking, the term will be used to represent a school of thought whose focus is more on the whole system rather than the individual parts. Specifically, the tools and methodologies of system dynamics constitute the core of what is referred to as systems thinking in this paper.
9. Management flight simulators and learning laboratories are explained later in the report.
10. See P. M. Senge (1989b) for a description of the process of working with the managers. For a description of the claims learning-lab design, see D. H. Kim (1989).
11. For example, subsidized housing of inner-city neighborhoods was meant to solve the problem of inadequate housing for the poor but produced the opposite effect in the long run. See Alfeld, Louis Edward, and Alan K. Graham (1976).
12. A simple but illustrative example of this is the story of Helen Keller, whose parents, through their sympathetic actions to protect her from the world, undermined her personal development and made her totally dependent on them.
13. The distinction between dynamic thinking and structural thinking was made explicit by Barry Richmond.
14. Other MFSs that have been developed include *Claims Management, Product Lifecycle Management, Real Estate Development, Supertanker Market Management, New Product Development Management,* and *Service Quality Management*.
15. The *People Express* MFS runs on an Apple Macintosh computer. For a copy of the software and documentation, contact John Sterman, E40-294, M.I.T., Cambridge, MA 02139.
16. See J. D. Morecroft (1988) for an overview of the recent evolution of system dynamics models from simulation tools to interactive role-playing games and microworlds. For a discussion on applications to the classroom, see N. Roberts (1983).
17. In the game, higher quality means lower settlement costs. This represents the notion that the easiest (and lower service quality) way to settle a claim is to simply pay more dollars—it takes time and energy to find out the real value of a claim. The underlying assumption is that current settlement costs are too high relative to their intrinsic value owing to poor quality adjusting.

References

Abdel-Hamid, T. K. and S. E. Madnick (1986) "Impact of Schedule Estimation on Software Project Behavior," *IEE Software,* July, pp. 70–75.

Ackoff, Russell L (1981) *Creating the Corporate Future: Plan or Be Planned For.* New York: Wiley & Sons.

Alfeld, Louis Edward and Alan K. Graham (1976) *Introduction to Urban Dynamics.* Cambridge, MA: Allen–Press.

Argyris, Chris & Donald Schön (1978) *Organizational Learning: A Theory of Action Perspective.* Reading, MA: Addison-Wesley.

Baker, E. M. (1989) *Dialogue,* Winter.

_____ (1989) "The Chief Executive Officer's Role in Total Quality: Preparing the Enterprise for Leadership in the New Economic Age," Conference on Quality, Madison, Wisconsin, April 19–21.

Bakken, Bent (1989) "Learning in Dynamic Simulation Games: Using Performance as a Measure," *Computer-Based Management of Complex Systems: Proceedings of the 1989 International Conference of the System Dynamics Society.* Edited by P. Milling and E. Zahn, Berlin: Springer-Verlag.

Canegelosi, Vincent E. & William R. Dill (1965) "Organizational Learning: Observations Toward a Theory," *Administrative Science Quarterly,* 10, 175–203.

Crosby, P. B. (1979) *Quality Is Free.* New York: McGraw-Hill.

Daft, R. L., & K. E. Weick (1984) "Toward a Model of Organizations as Interpretation Systems," *Academy of Management Review, 9,* 284–295.

Davis, Stanley (1987) *Future Perfect.* Reading, MA: Addison-Wesley.

Deming, E. D. (1986) *Out of the Crisis.* Cambridge, MA: MIT Center for Advanced Engineering Study.

Diehl, Ernst (1989) "A Study of Human Control in Stock-Adjustment Tasks," System Dynamics Group D–memo 4030, MIT Sloan School of Management, Cambridge, MA.

Drucker, Peter (1990) "The Emerging Theory of Manufacturing," *Harvard Business Review,* May/June.

Dumaine, Brian (1989) "How Managers Can Succeed Through Speed," *Fortune,* February 13, pp. 54–59.

Fiol, C. M., & Lyles, M. A. (1985) "Organizational Learning," *Academy of Management Review,* 10 (4), 803–813.

Forrester, J. W. (1971) *"Counter-Intuitive Behavior of Social Systems,"* Technology Review, 73 (3), pp. 52–68.

Garvin, D. (1988) *Managing Quality.* New York: Free Press.

Hedberg, Bo (1981) "How Organizations Learn and Unlearn," In Nystrom, P.vC. & Starbuck, W. H. (eds.) *Handbook of Organizational Design.* London: Oxford University Press.

Hutchins, D. (1986) "Having a Hard Time with Just-In-Time," Fortune, June 9, pp. 64–66.

Ishikawa, Kaoru (1982) *Guide to Quality Control.* Ann Arbor, MI: UNIPUB.

_____ (1985) *What Is Total Quality Control?* Englewood Cliffs, NJ: Prentice-Hall.

Juran, Joseph M. (1964) *Managerial Breakthrough.* New York: McGraw-Hill.

_____ (1985) *Management of Quality.* Juran Institute.

_____ (1974) *Quality Control Handbook,* 3rd Edition. New York: McGraw-Hill.

_____ (1982) *Upper Management and Quality,* Fourth Edition. Wilton, CT: Juran Institute, Inc.

Kim, Daniel H. (1989) "Learning Laboratories: Designing Reflective Learning Environments," *Computer-Based Management of Complex Systems: Proceedings of the 1989 International Conference of the System Dynamics Society.* Edited by P. Milling and E. Zahn. Berlin: Springer-Verlag.

Levitt, Barbara & March, James G. (1988) "Organizational Learning," *Annual Review of Sociology,* 14, pp. 319–340.

Mizuno, Shigeru, ed. (1988) *Management for Quality Improvement.* Translated by Productivity Press, Cambridge, MA. Original Japanese edition, *Kanrishi to Sutaffu no Shin-QC-nanatsu-dogu,* published by JUSE Press, Ltd., Tokyo, Japan, 1979.

Moissis, Alexander A. (1989) "Decision Making in the Insurance Industry: A Dynamic Simulation Model and Experimental Results," unpublished Sloan School of Management Master's Thesis at M.I.T., Cambridge, MA.

Morecroft, John D. W. (1988) "System Dynamics and Microworlds for Policymakers," *European Journal of Operations Research,* 35, pp. 301–320.

Ozawa, Masayoshi (1988) *Total Quality Control and Management.* Tokyo: JUSE Press.

Roberts, Nancy (1983) "Testing the World with Simulations," *Classroom Computer News,* 3 (3).

Schneiderman, Arthur M. (1988) "Setting Quality Goals," *Quality Progress,* April, pp. 51–57.

Schön, Donald (1971) *Beyond the Stable State.* London: Temple Smith.

_____. (1983) *The Reflective Practitioner.* New York: Basic Books.

Schonenberger, R. (1982) *Japanese Manufacturing Techniques.* New York: Free Press.

Senge, Peter M. (1989a) "Organizational Learning: New Challenges for System Dynamics," D–memo 4023, System Dynamics Group, MIT Sloan School of Management, Cambridge, MA.

______ (1989b) "Catalyzing Systems Thinking Within Organizations," *Organization Development,* F. Masarik, Ed.

______ (1990) *The Fifth Discipline*, New York: Doubleday.

Sherkenback, William W. (1986) *The Deming Route to Quality and Productivity.* Washington, DC: Cee Press

Shiba, Shoji (1989) Lectures given at Massachusetts Institute of Technology, May 9, 11, & 12.

Stalk, George (1988) "Time: The Next Source of Competitive Advantage," *Harvard Business Review,* July–August, pp. 41–51.

Stata, Ray (1989) "Organizational Learning: The Key to Management Innovation," *Sloan Management Review,* 30 (3).

Sterman, John D. (1989) "Modeling Managerial Behavior: Misperceptions of Feedback in a Dynamic Decision Making Experiment," *Management Science,* 35 (3), pp. 321–339

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Daniel H. Kim is cofounder of the MIT Center for Organizational Learning and Pegasus Communications, Inc., and publisher of *The Systems Thinker*®. This volume was formerly published as part of the *Special Report Series*, and has been reformatted for this edition.

Suggested Further Reading

Learning Fables (available in soft cover or as e-books)

Outlearning the Wolves: Surviving and Thriving in a Learning Organization
Shadows of the Neanderthal: Illuminating the Beliefs That Limit Our Organizations
The Lemming Dilemma: Living with Purpose, Leading with Vision
The Tip of the Iceberg: Managing the Hidden Forces That Can Make or Break Your Organization

Systems Thinking for Kids

When a Butterfly Sneezes: A Guide for Helping Kids Explore Interconnections in Our World Through Favorite Stories
Billibonk & the Thorn Patch
Billibonk & the Big Itch

The Pegasus Workbook Series

Systems Thinking Basics: From Concepts to Causal Loops
Systems Archetype Basics: From Story to Structure
Volumes in the Innovations in Management Series
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Designing a Systems Thinking Intervention
From Mechanistic to Social Systemic Thinking: A Digest of a Talk by Russell L. Ackoff

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Guidelines for Daily Systems Thinking Practice
The Do's and Don't's of Systems Thinking on the Job
Palette of Systems Thinking Tools
Guidelines for Drawing Causal Loop Diagrams

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