# Total Quality and System Dynamics: Complementary Approaches to Organizational Learning

Daniel H. Kim†
E40-294
MIT Sloan School of Management
Cambridge, MA 02139
(617) 253-1587

## Abstract

Total Quality (TQ) has received a great deal of attention in the business world in recent years. American companies, slow to embrace it a t first, are joining in the TQ movement as they become convinced of its ability to enhance competitiveness. TQ is based on a philosophy and set of tools that focus on continuous improvement, and the fuel that drives the quality improvement engine is measurable data. TQ can be viewed as an effective means for advancing organizational learning whose current bag of tools are especially well-equipped to advance learning at the *operational* level. These TQ tools, however, are not as effective in dealing with problems that are ill-defined, where variables are fuzzy and hard to quantify or measure, where time delays are long, and where the system is loosely coupled but highly inter-related. These types of issues are precisely the ones for which system dynamics is well-suited—issues of a dynamically complex nature where feedback loops drive the behavior of interest. Complementing the TQ approach, system dynamics focuses on advancing organizational learning at the *conceptual* level. Organizational learning, however, requires learning at both the conceptual and operational level. This paper briefly lays out the background of both fields, compares their common holistic approach, and provides examples of possible integration of the two approaches to enhance organizational learning

## Introduction

*Organizational learning* is gathering increasing notice in the business world, an interest driven by competitive forces that are reshaping entire markets on a global level. From returning phone calls to manufacturing cycle times to product development times, there is pressure for everything to be reduced to shorter and shorter time intervals. Harvard Business Review (July/August 1988) published an article on "Time—the next source of competitive advantage," which advocates time-based management strategies. Fortune (Feb. 13, 1989) featured an article called "How managers can succeed through speed" with examples of how Honda has cut their new car development time from 5 to 3 years and how Motorola has cut orders-to-finished-goods time of its pagers from 3 weeks to 2 hours. Davis (1987) writes about trends towards zero cycle times, mass customization, and instantaneous production/consumption of products. As changes in the marketplace occur at ever more rapid rates and customer expectations on quality and delivery continue to rise to higher and higher levels, managers now realize that change is no longer an option but a necessity. The speed with which one does things, however, does not directly translate into organizational learning—increased speed is the *result* of organizational learning, not necessarily its *cause*.[1]

How quickly an organization can adapt to the changes dictated by its environment or initiate changes of its own is largely dictated by the organization's ability to learn. If an organization is set

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[1]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 and of itself, however, does not guarantee that learning takes place. One could, in fact, simply make mistakes faster and with more frequency.

in its ways, then learning is unlikely to take place and change will be slow in coming. Ray Stata (1989), chairman of a leading manufacturer of linear circuits, argues "that the rate at which individuals and organizations learn may become the only sustainable competitive advantage, especially in knowledge-intensive industries." He goes on to define organizational learning:

> 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.[2]

To be lasting and significant, organizational learning must occur at an *operational* level *and* at a *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/her job. Learning at the *conceptual* level means changing one's mental models about how the world works. It includes changes in the way one thinks about a problem by reframing it in a different context and exploring the implications.

The Total Quality [4] (TQ) philosophy contains both aspects of organizational learning. TQ embodies a total commitment to satisfying the requirements of consumers by developing, designing, and producing high quality products. At the conceptual level, TQ has forced managers to abandon old mental models of viewing quality/cost and quality/productivity as either/or decisions. TQ is 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 learnings at the operational level. Quality has improved through the use of statistical quality control (SQC) which helps lower production costs through smaller variances and 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.

As quality continues to improve at companies engaging in TQ activities, there is no doubt that a great deal of learning continues to take place at the operational level. For example, learning new methods of soldering a joint or assembling an engine are tried, tested, and absorbed into the organization's memory. Aside from the initial mental breakthrough required at the outset of instituting TQ, 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 with which to reframe problems in a totally different context.

Systems Thinking (ST) represents a school of thought whose strength lies in the conceptual plane, where current TQ methods may be less than effective. Although there is no universally accepted definition of what is meant by Systems Thinking, the term will be used to represent a

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[2]There are about as many definitions of organizational learning as there are individuals writing about the subject. For a brief overview of other definitions and perspectives, see Fiol & Lyles (1985) and Canegelosi & Dill. (1965). Although I take issue with the assertion that an organization can only learn as fast as the slowest link (see section on Learning Cycle Time), this definition is salient for the issues discussed in this paper.

[3]Senge [1989a] makes a similar distinction between instrumental learning, adjustments in behavior to cope with changing circumstances, versus generative learning, changes in predominant ways of thinking.

[4]There are many different terms in common use at different companies, such as QIP (Quality Improvement Process), TQC (Total Quality Control), EI (Employee Involvement), CWQC (Company Wide Quality Control), etc. 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 TQ or Total Quality.

school of thought whose focus is more on the whole system rather than the individual parts. Specifically, the tools and methodologies of System Dynamics constitutes the core of what is referred to as Systems Thinking in this paper.

As with Total Quality, ST also contains both elements of organizational learning described above. On the conceptual level, ST focuses on making mental models explicit, exposing them to challenge, and building new models based on new insights gained from this process. ST 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 a specific policy choice. The weakness of ST lay in specifying operational procedures or methods to effect a desired change in procedure or structure. Managers may gain a terrific insight that reducing time pressure is a high leverage point for reducing turnover which, in turn, increases productivity, but they are given little guidance about the specifics of how to accurately measure each of the variables, implement changes, and monitor progress. ST falls short at the *operational* level.

Organizational learning must advance on both the operational and conceptual level. One without the other is like trying to run a marathon with one foot nailed to the starting line. Total Quality and Thinking have complementary strengths that can greatly enhance an organization's ability to achieve higher levels of performance through a more balanced learning process. This paper attempts to outline the nature of the contribution of integrating these two approaches and provide some specific examples of how tools from both can complement each other.

### Brief History of Total Quality

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, they 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. Edward Deming, a recognized expert in the field of sampling, to give a seminar on statistical quality control for managers and engineers.

Although the tools proved to be valuable for production problems, managing the process of getting workers to use them effectively was problematic. 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.

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 keep defects from being produced 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 include the entire company in quality control activities. QC was no longer the province of inspectors performing an isolated function, but a company-wide activity which involved all divisions and all employees.

QC Circles grew out of the important role workers played in the actual manufacture of products. The cornerstone of the QC Circle lay in education mixed in with on-the-job application of the tools that were learned. It was based on a strong belief in voluntarism which contributed to a slow start in terms of initial number of activities, but later mushroomed rapidly as early success stories spurred other companies to follow suit.

The results of Japanese TQ activities require little elaboration. In the space of a few years, Japanese car makers have brought Detroit to their knees by grabbing an ever increasing share of the U.S. market. They have practically wiped out many U.S. industries such as steel, semiconductors, motorcycles, televisions, cameras, and threaten the entire consumer electronics industry. They have penetrated every market they have entered with superior quality products in workmanship as well as design. Since the early 70's, Japanese car makers have increased their share of the U.S. automobile market almost every year by producing fuel efficient and higher quality cars. Japanese semiconductor manufacturers currently supply 85% of the worldwide memory chip market. The U.S. steel industry's share of the world market has shrunk dramatically in the last decade while the Japanese steel industry has expanded its share during the same period.

There has been much debate and reflection about why the U.S. slept for so long before perceiving the value of TQ and the threat of Japanese competition[5]. The purpose of this paper, however, is not to further that debate. Although such issues as national culture, work ethic, and governmental involvement may be factors that are important in determining *how* TQ is accepted or used, I feel that they are not crucial for understanding *what* TQ is. Debates on the reasons why Japanese industries successfully engaged in TQ activities may never be settled, but there is no doubt as to the role the TQ revolution played in sweeping Japan onto the world economic stage as a major player. This paper attempts to distill substance and principles from the plethora of stories and myths woven around the Japanese way which often present a distorted view of TQ 's usefulness and transferability.

Although it has taken some strong convincing, many U.S. manufacturing firms have bought into the TQ way of conducting business and have made significant strides towards improving quality. AT&T 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 TQ activities which have helped reduce defects, cut cycle times and improve customer satisfaction. Computer and semiconductor manufacturers have also instituted TQ in their organizations. Analog Devices, a leading manufacturer of linear integrated circuits, has included Quality Improvement objectives in their strategic planning and bonus incentives. At Hewlett-Packard's Lake Stevens, Washington facilities, they have cut failure rates for their 30 products by 84% and manufacturing time by 80% over the past three years. In recognition of their crusade for quality, Motorola received the first annual Malcolm Baldridge National Quality Award, America's equivalent of Japan's prestigious Deming Prize.

The philosophical underpinnings of TQ are holistic in nature—it attempts to involve employees at all levels to promote the well being of the company as a whole. TQ is both an all-encompassing philosophy about the whole enterprise of running a business and a set of specific statistical tools applied at the lowest levels of an organization. It is this blend of the micro and the macro which makes it such a potent discipline—either element by itself would not be revolutionary. Without this philosophy, TQ is reduced to a bag of tools which is applied to problems only as they arise—simply helping to fight fires. Without the statistical tools, TQ is nothing more than a guiding light to a goal that offers no help for navigating the terrain. TQ 's success lay in linking the lofty goals for top management with a set of tools for the operators to achieve those goals.

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. The tools and methodology of TQ gained widespread acceptance because they fit in with the traditional model of problem solving that is based on reductionism and analysis. It is indisputable that the application of the traditional TQ tools[6] to manufacturing has proven highly successful. Reduction in number of defects, shortening of cycle times and increasing throughput in the manufacturing process have all been accomplished steadily and with remarkable efficiency through the TQ process.

[5] In his book, *What is Total Quality Control?*, Kaoru Ishikawa, a highly regarded QC expert in Japan and abroad, discusses at length his reasons why U.S. QC efforts have lagged behind those of the Japanese. He touches on a wide range of themes including Taylorism, religion, differences in writing systems and democratization of capital.

[6] 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's *Guide to Quality Control*. There is also an intermediate set of statistical methods which 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 multi-variate analysis and various methods of operations research.

## Organizational Learning

*All* organizations learn whether they consciously choose to or not—it is fundamental requirement for their sustained existence. The extent to which one consciously manages the learning process, however, varies greatly among companies. Some organizations are quite deliberate in their efforts to advance organizational learning, developing capabilities that are consistent with their objectives. Others make no focused effort, acquiring habits that are counter-productive towards achieving stated goals. *Superstitious learning* can occur when an experience is particularly compelling but the connections between actions taken and outcomes produced are mis-specified or not close together in space and time (Levitt & March, 1988). Organizations can suffer from *competency traps* when they accumulate experience in an inferior procedure with which they have had initial favorable results, thereby keeping experience with a superior procedure inadequate, making it unattractive to use.

Any discussion of organizational learning must address the following four major components: inputs, learning processes, memory, and outputs. The inputs include information and actions from both within and outside of the organization. The learning processes include filtering what inputs are allowed in as well as the way in which those inputs and memory are used to produce outputs (or produce no output at all). Memory represents the organizational maps and memory described by Argyris & Schön (1978) which captures the organizational routines, operating assumptions, and standard operating procedures which govern much of the day-to-day behavior of its members. Outputs are the "learnings" of the organization which adds to, deletes from, or changes its memory (e.g. new operating procedures are created) and also affects its individual members directly (e.g. new operating procedures are implemented). In addition, the ability to unlearn is also an important element of organizational learning (Hedberg 1981). Although the above description implies a distinctness to each part; in reality, the boundaries are quite blurred.

### *TQ as a Vehicle for Organizational Learning*

The TQ mission is not just about improving production steps and reducing cycle times; *TQ is a thought revolution in management* (Ishikawa 1985, Ozawa 1988). Rephrasing the statement, I would state that TQ is about changing the mental models of management in order to enhance an organization's capability to determine its own future—revolutionizing management's way of thinking. This change requires more than a one time shift in thinking; it means a continuous rethinking of the way managers think. Sustaining this thought revolution requires not only the continual improvement activities in which many firms are engaged but also the changing of the common knowledge and mental models shared within an organization; it requires *organizational learning*.

TQ, along with its tools and methods, is well-suited to advance organizational learning by being very clear about the role of each of the components described above and addressing them explicitly. Inputs include the people who are working on the problem at hand, data about the problem, and resources devoted to solving the problem. Outputs are often the resulting solutions of the TQ effort that reduce cycle time and defects or increase customer satisfaction and sales. Memory consists of such things as new machine tolerances, specifications, and operating procedures but can also include new visions, values and goals. At the heart of it all is the learning process driven by Deming's PDCA (Plan-Do-Check-Act) cycle. The paradigm is based on a process of continual improvement by cycling through the PDCA problem solving loop. Transfer of learning from individual to organizations is managed through an organization-wide TQ effort which is designed to facilitate the sharing of learning in one setting with the rest of the organization. (Need to use a case example to illustrate the above paragraph.)

The above account suggests that TQ addresses the area of organizational learning thoroughly and efficiently by touching all the bases and advocating an iterative process of improvement rather than a one-shot deal. This description, however, does not represent the whole story since learning occurs at many different levels, and being proficient at one level does not guarantee proficiency at another.

*Operational and Conceptual Learning*

As mentioned earlier, there are at least two fundamentally different levels of learning at which an organization must be equally adept—the operational and the conceptual. The distinction between the two levels of learning is not crystal clear and the choice of what specific items falls under which category may be somewhat arbitrary. Both levels of learning involve the same four components already mentioned, and both must also deal with the individual/organizational learning issue. The two however, represent fundamental differences which make it worthwhile to separate them.

In plain terms, *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, re-tooling a machine, etc. Operational learning emphasizes the *how* of doing things.

TQ is very well-equipped to advance learning at the operational level. The seven tools of TQ (pareto chart, cause and effect diagram, stratification, check sheet, histogram, scatter diagram, and control charts) are relatively easy to understand with well-defined guidelines for the use of each tool. Through the use of control charts and pareto analysis, for example, operators can understand and improve their production steps. Under the TQ umbrella, engineers can design experiments and collect data on the factory floor to better understand manufacturing processes and make improvements on them. Improvement through operational learning involves an incremental process whereby a particular problem is whittled down bit by bit. All such improvement efforts, however, are bound within the current definition of the problem under investigation.

*Conceptual learning*, on the other hand, emphasizes the *why* of doing things—that is, it has do with the *thinking* behind the actions. Conceptual learning deals with issues that challenge the very nature or existence of prevailing conditions, procedures, or conceptions. The perspective of conceptual learning is not limited by the current framing of the issue; it is possible to go beyond and reframe the issue in a totally different way. There are opportunities for discontinuous steps of improvement where reframing of a problem will bring about radically different potential solutions

TQ also promotes a certain degree of organizational learning at the conceptual level since shared mental models of what is achievable change as improvements are made, mindset of workers shift from maintaining the *status quo* to looking for improvement opportunities, and new methods and techniques supplant the old accepted ways of doing things. At the managerial level, however, there seems to be little opportunity for similar ongoing learning. It appears that the thought revolution in management is a discontinuous one-step break from the past, after which managers settle into the new TQ orientation and assume the role of supporting improvement activities throughout the company. TQ provides limited methods and tools for organizational learning at a deeper level whereby managers can gain a better understanding of their organization and improve the way they manage. That is, TQ is very good for enhancing learning at the operational level but provides limited help in the way of advancing management thinking at the conceptual level.

*Learning Cycle Time*

In addition to levels of learning, 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 such 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. Reducing the learning cycle time for a particular area requires eliminating all unnecessary delays (information, processing, and material) in that area. Shorter manufacturing cycle times help to reduce learning cycle times by eliminating one source of delay, but there are many other factors that are also important. In addition, faster and more frequent iterations can lead to random drift rather than improved performance by continually modifying a situation before it can be comprehended (Levitt & March, 1988).

As the pace of change continues to increase, the importance of learning cycles grows as well. Differential rates of learning exist within an organization as is true with the rest of the environment.

Learning cycle times do not have to be the same throughout an organization and probably would be undesirable to have them be so. An organization's overall rate of learning is not necessarily gated by its slowest link, but determined by the composition of its portfolio of learning rates and the relative importance of each rate. It is absolutely critical that those parts of the organization with the fastest learning rates be precisely where the organization needs to be learning the fastest, i.e., in the areas of critical importance to its strategic future. This need for faster learning cycle times poses a dilemma since most issues of strategic importance have inherently long time horizons (or cycle times) associated with them making it difficult to reduce the time delays by very much. In the area of new product development, for example, the time for development is usually on the order of years which is much too long to try to learn through multiple iterations in real time.

*System Dynamics and Organizational Learning*

Systems Thinking, like TQ, also advances organizational learning but with different areas of strength. Although both approaches embrace a holistic view of organizations, Systems Thinking's underpinnings are more conceptual in nature. ST approaches problems from the basis of the whole, rather than breaking up the whole into its individual pieces and trying to understand each part. Where TQ focuses on *analysis* of the separate parts that make up the whole, ST strives for *synthesis* of its constituent parts and that of the whole with its environment. According to ST, 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, for example, the manufacturing function is expected to operate as efficiently as it can. The same goal holds for marketing, accounting, engineering, etc.

System dynamics is a field within ST that provide a methodology and framework for synthesizing disparate types of variables that have traditionally been thought of as being too "fuzzy" to measure (and therefore unusable) for understanding complex systems. System dynamics is rich in the area of conceptualizing and synthesis of complex systems and is well-suited for helping managers make their mental models explicit in order to begin the process of gaining a more systemic view of their organization. System dynamics, however, is not very good at the operational end of things, possessing no simple tools that can be used at the operational level to actually make the improvements that are indicated by a system dynamics study.

System dynamics modeling often provides a richer perspective on a problem or issue, a theoretical framework for what to be collecting data on, and a set of policy options that are preferable to other alternatives. It does not, however, provide a detailed list of specific steps one must take in order to implement one policy over another. Where SD is deficient is precisely where TQ is strongest—operations and implementable methods. Although SD provides a powerful and rich set of theories with which to gain systemic insights about a problem, it offers little in terms of specific operational recommendations that would be useful for front line workers on a day to day basis.

*Complexity Matrix*

As I have argued above, TQ works quite well in certain areas and not so well in others. In particular, current TQ tools and methods are poorly-equipped in tackling a class of problems which Ackoff (1981) labels as a *mess*. Ackoff's explanation for his choice of term follows:

> I am going to call this thing a mess. Then we say that what reality consists of are messes, not problems.
>
> Now what is a problem? Let's take a mess for a moment, which is what you're confronted with in the morning when you come to work, and let's analyze it. Remember what analysis is—to take something apart. So if we take a mess and start to break it up into its components, what do we find that those parts are? The parts are problems. Therefore, a problem is an abstraction obtained by analyzing a mess.
>
> Then 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.[7]

Figure 1 is an attempt to classify "problems and messes" into a matrix based on Organizational Complexity (the number of units and level of complexity of their inter-connections) and Current Cycle Time of Project (magnitude of delays within the system). TQ efforts that deal with problems involving a high degree of organizational complexity and long time delays provide opportunities for improvement and enhanced learning. "Fuzzy" variables often accompany Ackoff's "messes" because such systems are rarely clear-cut or well-defined. The following paragraphs highlight some of the shortcomings of TQ involving organizational complexity, long time delays, and fuzzy variables.

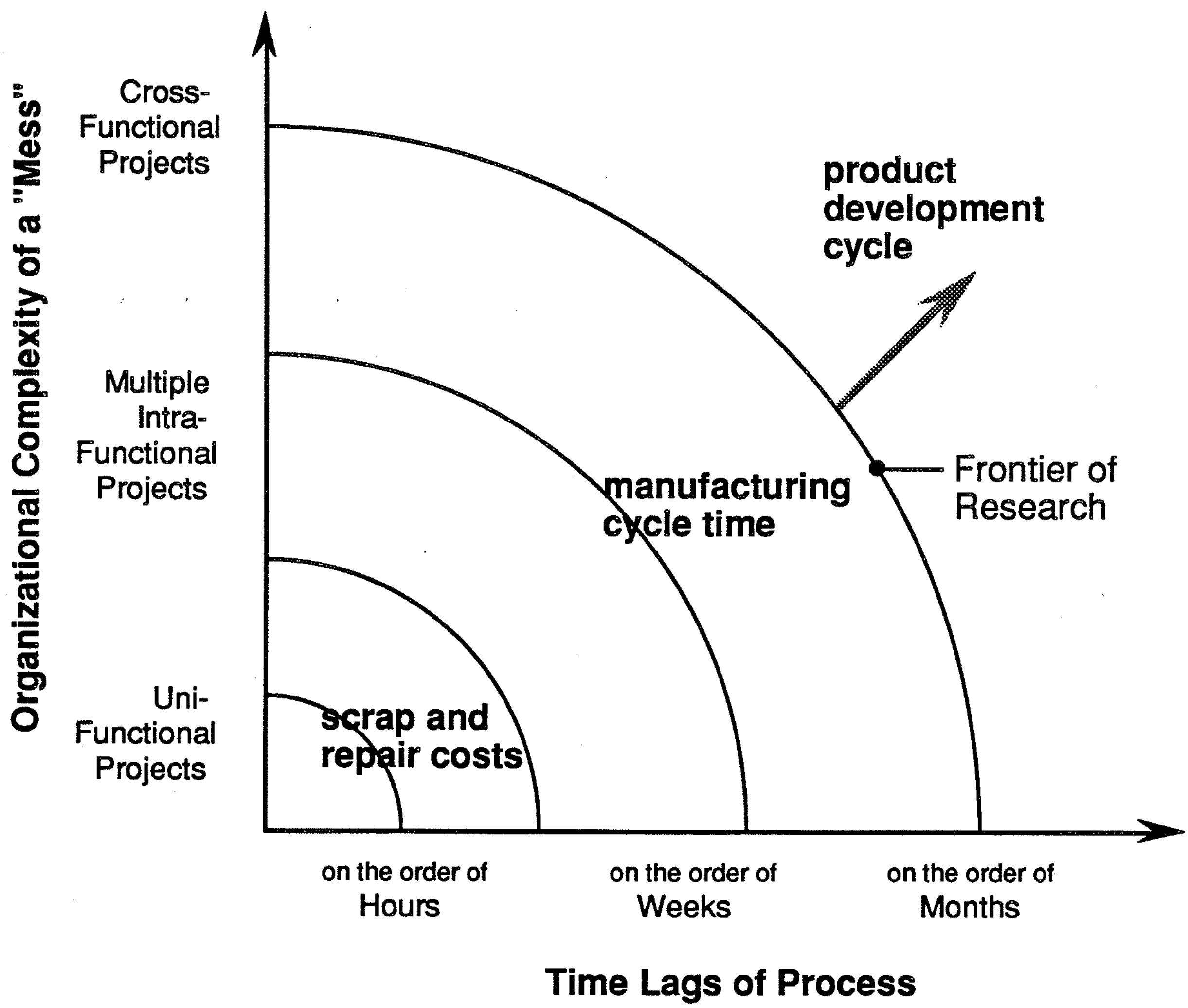


**Figure 1. Complexity and Time Lags of Organizational "Messes"**

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[7]This is taken from an essay by Russell Ackoff entitled, The Second Industrial Revolution.

*Organizational complexity*. Many of the 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 most of the 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, where other functional units in the organization slowly buy into the TQ philosophy after its value has been proven. This buy-in process progresses at a slow pace, taking longer and longer as it involves increasing levels of cross-functional cooperation. In fact, Schneiderman (1988) observed that the rate of improvement in a wide range of TQ projects is primarily a function of the organizational complexity of the project, not the specifics of the project itself. Although TQ teams have tackled cross-functional problems, it is questionable how successful they have been at implementing lasting solutions. For example, a manager at one of the big three auto companies told a story of how a team had put together a solution which, after a long process, "solved" the problem only to have the same problem reappear months later with a vengeance.

*Time Delays*. Another attribute of early TQ 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 which 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 their implications on the process as a whole.

*Fuzzy variables*. According to Juran (1982), the three laws of TQ are look at the data, look at the data, and look at the data. Hard, measurable data is the fuel that drives the TQ engine. Getting good, reliable data is not an easy thing to do, even on mechanical processes which 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, i.e. fuzzy. Fuzzy variables include such notions as Effect Of Time Pressure On Productivity, Effect Of Delivery Delay on Demand, and other pieces of information that may be available only at the intuitive level. Issues revolving around fuzzy variables are likely to increase as the service industries begin looking for ways to apply TQ.

## Integrating Total Quality and System Dynamics

Organizations must be able to effectively tackle the whole range of messes in the complexity matrix which means being able to identify high leverage points *and* act upon them. One way of achieving this ambidexterity is to interweave system dynamics with the Total Quality approach to organizational intervention. Figure 2 represents an attempt to integrate Total Quality and Systems Thinking into such an integrated continual learning process.

The model within the top dashed 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. Clearly, more could be done on the implementation side of things.

The bottom dashed box represents a typical TQ process of making 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 are then analyzed and actions are taken to correct any discrepancies. Although the PDCA cycle can work very well in implementing new requests given from above and in maintaining control over current processes, it is relatively weak on identifying the high leverage areas to drive the whole process.

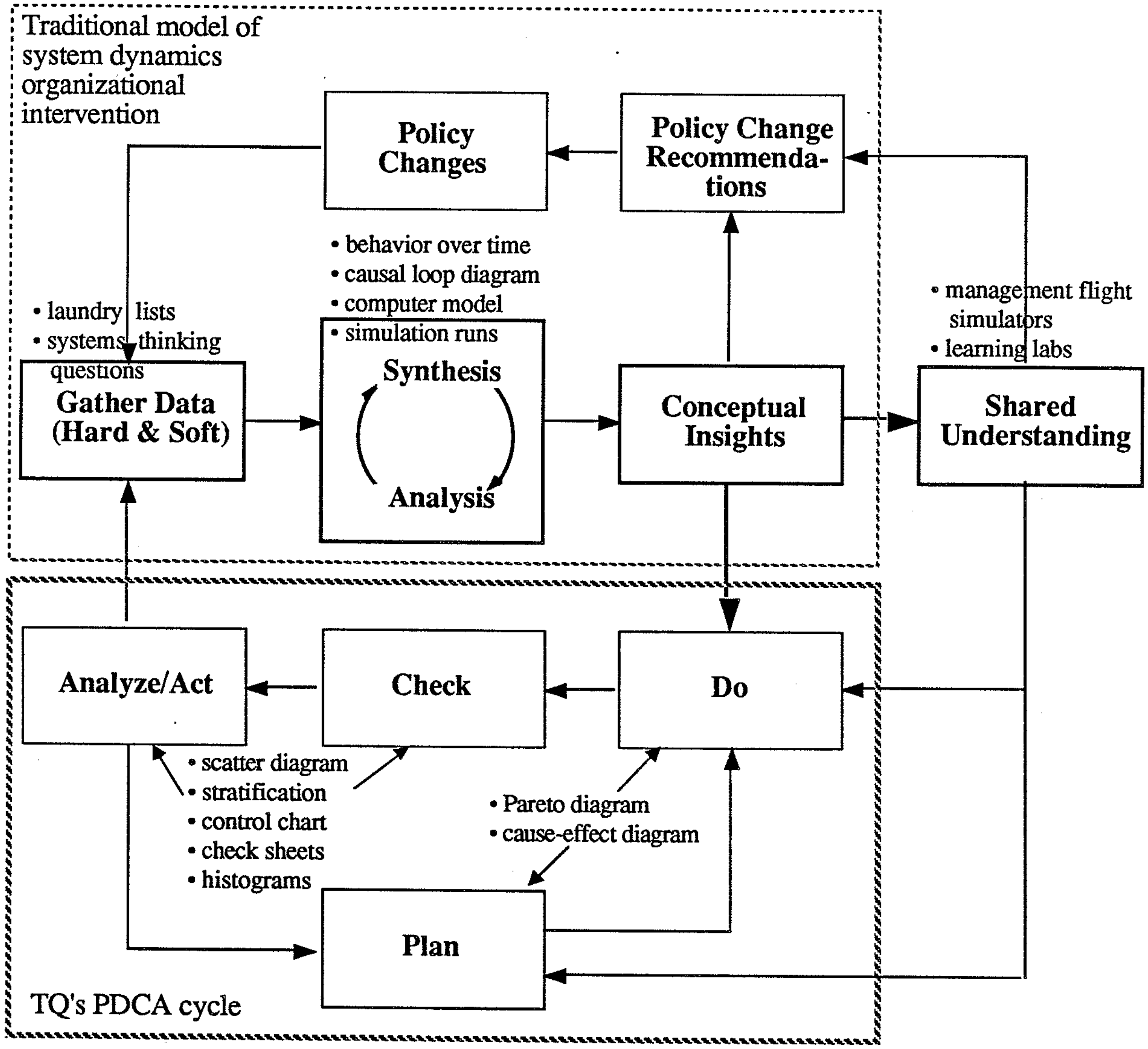



**Figure 2. Organizational Intervention Model**

Linking these two processes as shown in Figure 2 means integrating conceptual learning with 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[8] can enhance the PLANning and DOing steps by providing a common base of conceptual models. Having greater shared understanding can also facilitate the buy-in process on policy change recommendations. Conceptual insights such as "eroding goals" and "worse before better behavior" can help those involved in the DOing to see how their specific actions relate to the overall system. The analysis and action produced through the PDCA cycle should generate new data which would feed into the data gathering process as well as the next cycle of the PLAN.

Although the tools of TQ have been identified with the TQ steps and the ST tools with the modeling steps in the figure, both sets of tools can and should be used in a more integrated way. Before looking for opportunities to integrate the tools, however, we need to have a clear idea of the kinds of tools ST has to offer. Unfortunately, there is no explicit set of tools that is analogous to

[8]Management Flight Simulators and Learning Laboratories are explained later in the paper.

the tools of TQ which can be readily used by a lay audience. In order to facilitate the integration suggested in the above model, system dynamicists need to build a common library of tools which managers can apply relatively quickly to their own systemic issues. Rather than clumping everything into something intimidating as "the model building process," there needs to be a clear migration path that begins with very simple tools and builds up to more sophisticated ones. At each stage, however, the benefits of using each tool as well as the context in which its use is appropriate should be clear.

*Development of System Dynamics Tools*

One of the greatest strengths of TQ lie in its ability to educate the masses in using the tools of TQ. Each of the Seven Tools of Quality and the Seven Management Tools for quality is well-developed and documented. Under the guidance of JUSE, training in the use of the tools has been standardized so that large groups of people can be taught with relative ease. By translating sophisticated methods like statistical process control (SPC) into easily understood tools like control charts, histograms, check sheets and scatter diagrams, they have made SPC accessible to the masses.

As a first step towards codifying an explicit set of system dynamics tools, the chart in Figure 3 contains ten different tools that are currently used in one form or another in system dynamics (the fishbone diagram replaces the use of laundry lists as a brainstorming tool). The tools are divided into four distinct levels. Level I is simply a brainstorming tool, requiring no advance preparation or training. As one moves up the levels, however, the amount of training that is required can be quite considerable. Of course, the amount of training needed for each level depends a great deal on whether the person is applying the tools to his or her own issues or simply consuming what someone else has created. Doing the former obviously requires a lot more effort than the latter. In any case, system dynamicists need to clarify and meet the requirements of both types of users.

This summary diagram is the tip of the iceberg; much remains to be done. All ten tools need to have some well-tested guidelines for their use. The settings in which they are and are not useful must be clearly identified as well as the enabling organizational factors that are necessary for their successful use. Each tool should also have several case examples of how that particular tool was applied successfully and include detailed discussions of any obstacles encountered.

Efforts are currently underway to develop some of the tools in the chart. Innovation Associates, a management consulting firm in Framingham, Massachusetts, for example, has been gaining experience in the use of "systems templates" where managers can quickly identify their own cases of "shifting the burden" or "eroding goals" by filling in pre-defined boxes without knowing the mechanics of causal loop diagramming. The development of Management Flight Simulators (MFS's) and Learning Laboratories (LL's) is part of an ongoing research effort at the MIT Sloan School of Management to develop more effective ways to transfer systems thinking skills to an organization. Although it is important to fully develop all of the tools outlined in Figure 3, MFS's and LL's are of particular importance because of their role in building shared understanding. The reasons for this are discussed in the following section.

*Learning Systems and Virtual Worlds*

Three important elements of learning are 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 bats, balls, and gloves, the 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. A major league team would not dream of playing a regular season game without having many practice games. Airlines would never risk multi-million 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 has been the rule.

On-the-job learning was adequate for managing in a world where change, though accelerating, still occurred across generations rather than within generations—lessons learned in one generation were valid for that generation. In Donald Schön's book, *Beyond the Stable State*, he points out

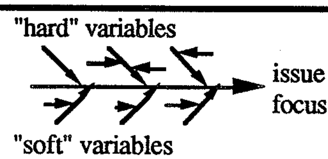
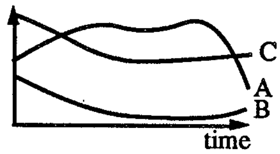
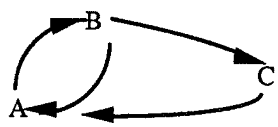
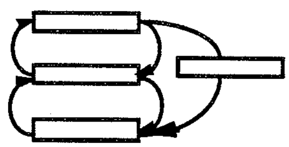
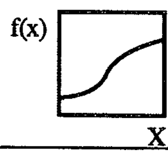
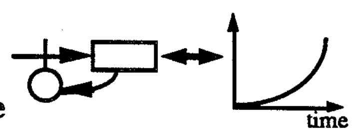
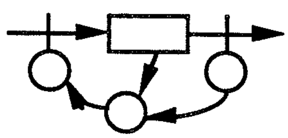
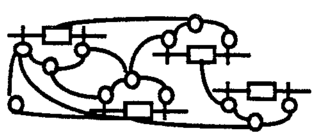
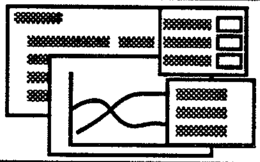
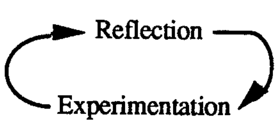
| Tool | | Description |
|---|---|---|
| **I** 1. **Fishbone Diagram** |   | Brainstorming tool for capturing free flowing thoughts in a structured manner, distinguishing between hard and soft variables that affect the issue of interest. |
| **II** 2. **Behavior Over Time Diagram** |   | Using some of the main branch variables from the fishbone diagram, graph the behavior of each one over time taking into account any inter-relatedness in their behavior—(reference modes). |
| 3. **Causal Loop Diagram** |   | Draw out the causal feedback loop structure using the fishbone and behavior over time diagrams and identify reinforcing and balancing processes. |
| 4. **System Archetypes** |  | Identify common system structures that fit one of the recurring system archetypes such as eroding goals, shifting the burden, limits to growth (compensating feedback), fixes that fail (policy resistance), etc. |
| **III** 5. **Table Function** |   | Represent the effect of one variable on another graphically by plotting the relationship over the entire range of values that the X variable may theoretically operate. |
| 6. **Atoms of Structure** |   | Library of simple structure-behavior pairs that represent basic dynamic structures that can serve as building blocks for developing computer models, e.g. exponential growth, delays, smooths, S-shaped growth, oscillations, etc. |
| 7. **Policy Structure Diagram** |  | Conceptual map of the decision making process that is embedded in the organization. Focuses on the factors which are weighed for each decision point. Build library of generic structures. |
| **IV** 8. **Computer Model** |  | Map all the relationships that have been identified as relevant and important to the issue at hand in terms of mathematical equations. Run policy analyses through multiple simulations. |
| 9. **Management Flight Simulator** |  | Provides "flight" training for managers through the use of interactive computer games based on a computer model. Through formulating strategies and making decisions to achieve them, help connect consequences to decisions made. |
| 10. **Learning Laboratory** |   | A managers' practice-field equivalent of a sports team where active experimentation is blended with reflection and discussion using all the systems thinking tools from fishbone diagrams to MFS's. |

**Figure 3. Ten Systems Thinking Tools**

that a major disruption occurred when the pace of change crossed into the intra-generational state—lessons learned became obsolete within the same generation. As the world grows increasingly more complex, problems take longer to solve, and the proposed solutions have shorter lives. In fact, Ackoff (1981) posits that solutions are often stillborn because problems change so rapidly that solutions, when found, are often no longer relevant.

One of the consequences of such rapid change is that managers are forced to make decisions with equal rapidity or be left behind. However, the complexity of the problems makes it imperative that managers take more 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 since change makes yesterdays' lessons obsolete? At a more macro level, how can organizations remain viable given this paradoxical dilemma? Although in real life this simultaneous need for both the compression and expansion of time can not be fulfilled, in what Schön (1983) refers to as *virtual worlds*, it is a possibility. The management flight simulator and learning laboratory are two implementations of such a virtual world.

*Management Flight Simulators*

Experimental data on decision making performed within complex feedback environments suggests the need for a manager's equivalent of a pilot's flight simulator. Sterman (1989) demonstrates how subjects are insensitive to the feedback from their own decisions to the environment in a production distribution simulation game leading to grossly sub-optimal behavior. Moissis's (1989) 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, Diehl (1989) found that varying the strength of feedback (in either the positive or negative direction) had a detrimental effect on performance.

One of the first management flight simulators (MFS) used on a large scale is the People Express MFS which was used by the entire entering class of Sloan masters students (approximately 180) at the MIT Sloan School of Management.[9] The simulator required each player to make up to five decisions on a quarterly basis as he/she tries to manage the growth of a start-up airline whose structure is modeled after the now defunct People Express airline. Spreadsheets, graphs, and internal management reports containing competitor and market information were provided on a quarterly basis. Through repeated trials of launching a start-up using various strategies, the students gained simulated experience of the same kinds of dynamics which People Express actually experienced.

While the MFS by itself is valuable for bringing an experiential and dynamic aspect to an otherwise lifeless and static case, there are limitations to its usefulness as a stand-alone tool. 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 the conceptualizing of the model may result in a shallow understanding of the dynamics, 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 (Bakken 1989); there needs to be more explicit discussion of the theory underlying the MFS. Thus, the value of the MFS as a learning tool can be extended through the development of an environment within which one can replicate the conceptualization phase of the MFS development, structure various scenarios to highlight specific dynamic lessons, and create an environment in which the MFS serves as an experimental tool for learning.[10]

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[9]The People Express MFS runs on an Apple Macintosh computer. For a copy of the software and documentation, write to John Sterman, E40-294, M.I.T., Cambridge, MA 02139.

[10]See 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 Roberts (1983).

*Learning Laboratories*[11]

A learning lab (LL) can be viewed as a manager's equivalent to a sports team's practice session. The LL is a managerial "practice field" where one can test out new strategies and policies, reflect on the outcomes, and discuss pertinent issues with others in the group. It is a place where a manager can not only accelerate time by simulating a model (or virtual world) of a real life system over long time periods but also slow down the flow of time at each decision point. Kim (1989) describes the implementation of such a LL in a major insurance company. The Claims Learning Lab (CLL)[12] is where claims managers from all over the country participate in a three-day workshop designed specifically for explicating and testing managers' mental models on which they base they base their decisions. At the core of the CLL is a computer-based system dynamics model of the claims function which serves as a manager's analog of a flight simulator. The management flight simulator (MFS) provides the opportunity to make decisions and observe outcomes that span a period of years or decades, reflect on the results and draw inferences, then test them explicitly on the MFS.

The LL provides a unique forum in which operating norms and assumptions can be questioned in a non-threatening way, via the game model, without the presence of an outside intervention specialist. In the CLL, for example, although the company professedly emphasized pursuing high quality standards[13], the behavior in the games showed that controlling expenses dominated people's actions. 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* knowing that I really need to!" In many cases where there was extra adjuster capacity, people chose to either cut staff or push for more production to reduce expenses instead of pushing for reductions in settlement size.

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

## Summary

Total Quality is about changing the way in which managers think about their business which, in turn, leads us to the notion of *organizational learning*. One part of that learning process occurs at the operational level—implementing better production methods, reducing the number of components—which TQ addresses quite well with its set of statistical tools. The other part of that learning process occurs at the conceptual level—thinking more systemically about the organization, understanding the consequences of the interaction of multiple functions over a long period of time—which TQ is not well-equipped to address.

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. Integrating TQ and system dynamics can transform problem-solving organizations into learning organizations by addressing both the *thinking* and *doing* aspects of the learning process.

*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* manage the learning process to ensure that areas of strategic importance are not neglected. This is accomplished, in part, through the embedding of *learning systems* which serve as catalysts and refueling centers for continually enhancing the

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[11]A major portion of this section is comprised of direct excerpts from Kim [1989].

[12]For a detailed description of the development of the CLL, see Senge [1988b].

[13]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 due to poor quality adjusting.

capabilities of the organization via its members. Management flight simulators and learning labs are examples of such learning systems.

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