CHAPTER A.1

Good Quality Costs Less? How Come?

At the heart of the process improvement revolution is an idea expressed some 400 years ago by Sir Francis Bacon. He was Lord Chancellor of England, a distinguished philosopher of science, and man of such stature as to be credited by some with writing Shakespeare's plays.

He said "Knowledge itself is power." The application of that profound statement is this: To the extent that we know more about our process, our product, our customers' needs, and about all the operations we perform—manufacturing, billing, invoicing, dispatching, and so forth— and *only to that extent* can we do a better job, make a better product, and so please our customer more.

So process improvement and good quality is produced by knowing more about what we are doing.

Now, perhaps we could learn more about what we are doing if we had more people and spent more money, but the good news is that we don't need to take that route. We have three important resources we can draw on. All of them are free and we can put them together to continuously generate the new information we need to get ahead and stay ahead. These ideas can be applied to improve every industry, every government department, every hospital, and every university; but most of the time they are underutilized or not used at all.

The three resources relate to the following: (1) all human beings are creative; (2) the operation of any system generates information on how it can be improved; and (3) experimental design can increase the efficiency of experimentation many times over. Let's talk about each of these in turn.

From Box, G. E. P. (1990–1991), *Quality Engineering*, **3**(1), 85–90.

Improving Almost Anything: Ideas and Essays, Revised Edition. By George Box and Friends

EVERY PERSON IS CREATIVE

The characteristic that most distinguishes humankind from the rest of the animal kingdom is *creativity*. Just as "fish gotta swim" and "birds gotta fly" every human being possesses creativity and feels the need to use it. If you had been able to look at horses in a field 20,000 years ago and you looked at their present descendants they would be doing about the same things then as now. But this would not be true for human beings, who would have found ways to clothe and shelter themselves, to get clean drinking water, to converse with each other, to write, to transmit messages, . . . and so on and so on, seemingly without end.

Now, not all people have the same degree of technical sophistication, anymore than they have the same height. Indeed, like height, this characteristic will have a hump-shaped frequency distribution as in Figure 1a. In the past only a selected managerial and scientific elite were recognized as licensed to put their creativity to use. These were a small number of people supposed to be in the right-hand tail of this distribution. Now look at Figure 1b. This is a frequency distribution of problems

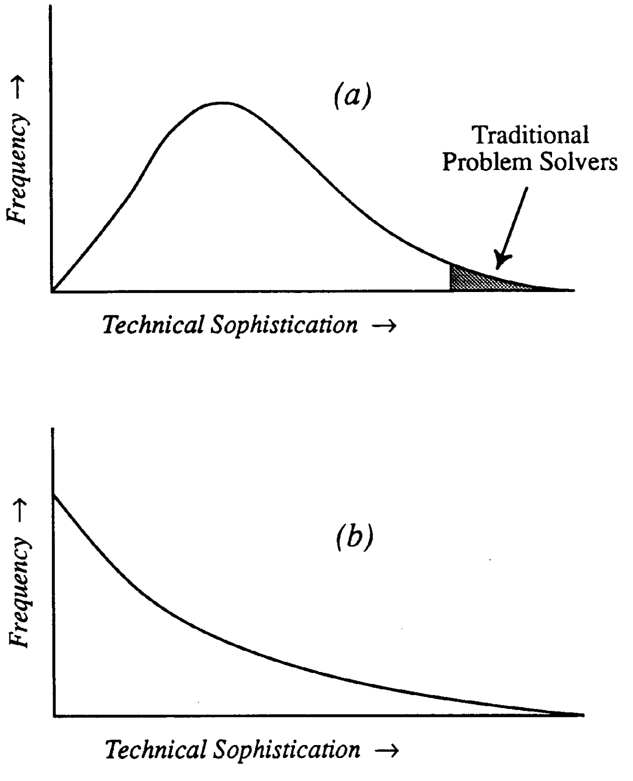

Figure 1. (a) Frequency distribution of workers with a given degree of technical sophistication. (b) Frequency distribution of problems requiring a given degree of technical sophistication for their solution.

that might beset some organization, classified by the degree of technical sophistication needed to solve them. This is a Pareto-like distribution with a large number of problems not requiring a high degree of technical sophistication and the frequency falling off as the problems become more challenging. If you look at these two diagrams together, you see that, under the old system, we threw away the creativity of an enormous number of people. You do not need advanced qualifications to figure out how to ensure that the right screw is delivered to a work station, or the right hospital test results are available when a patient comes in for an examination. And yet such problems not only occur, but *persist*, in very many organizations.

So why then was this potentially vast problem-solving resource not used? It was because, as Dr. Deming said, the people closest to the system often had no expectation that it could be better, or any understanding of how to make it better, and because they believed they were powerless to change it.

To remedy that situation required a radically different management philosophy in which the old idea of a quality control department acting as a quality *policeman* to perform the (hopeless) task of inspecting out bad quality was replaced by the concept of the whole work force acting as quality *detectives* to discover new ways of building good quality into the product and into the process of manufacture.

The essentials required for change were described by W. Edwards Deming in his classic book *Out of the Crisis* (1986). The needed revolution in management philosophy and practice is not easy to accomplish it must ensure that: (a) improvement is each individual person's responsibility; (b) each individual is suitably empowered to undertake that responsibility; (c) appropriate data are collected and analyzed using a set of simple problem-solving tools.

But let us suppose for a moment that you have already had an organization in which the work force can employ their creativity to improve the product and the process. How are they going to get the information to do this? One answer is that a tremendous amount of such information is generated by the operation of the system itself.

EVERY SYSTEM GENERATES INFORMATION

As illustrated in Figure 2, an operating system is like a radio transmitter except that it transmits *information* instead of electromagnetic waves. As is more fully explained in the next chapter, one way in which this transmission of information happens (Box, 1989a) is through the operation of Murphy's Law. The fact that "anything that can go wrong will go wrong" is another way of saying that the system will *tell* us when there's something wrong with it and that if we *listen* we can fix it. If you put these two things together—the creativity of the whole work force and the fact that every system generates information that can be used to improve it—you have an extremely powerful resource for continuous improvement. But how *do* we listen to the process? Like a radio transmitter, you can't hear the message the system is sending out unless you have suitable receivers. For an operating system these receivers are simple devices for collecting and analyzing data—flow charts, check sheets, Pareto diagrams, fishbone charts, graphs, Shewhart charts and so forth. You will find most

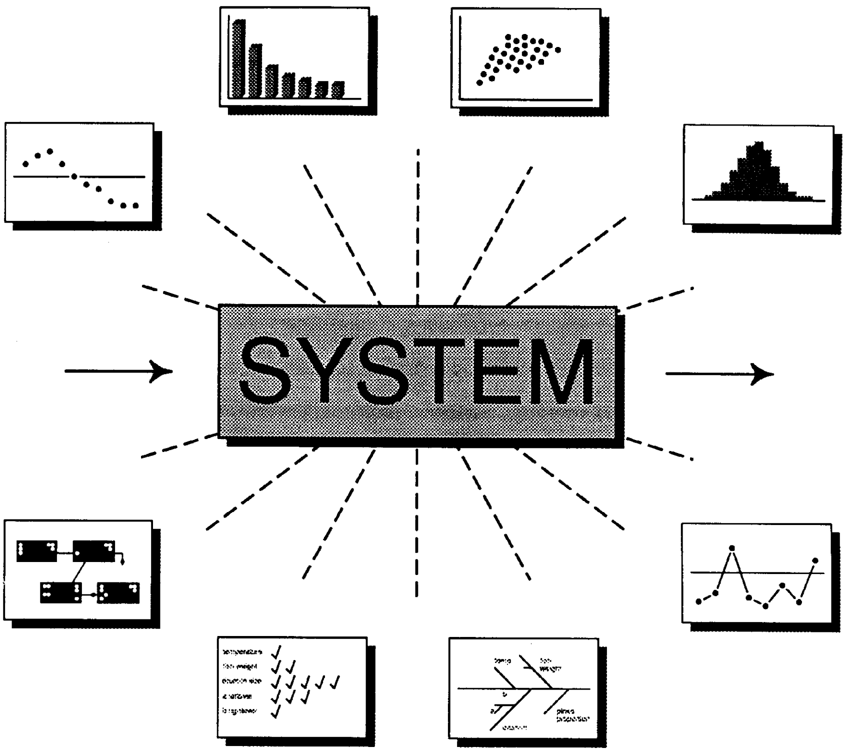

Figure 2. The system transmits information received and interpreted by (reading clockwise from upper left) a run chart, a Pareto chart, a scatter diagram, a histogram, a Shewhart chart, a fishbone chart, a check sheet, and a flow diagram.

of them described and illustrated with real examples in the wonderful book by Ishikawa (1982). Such tools are complemented by elementary experimental design.

Process operators, nurses in hospitals, workers in city government can all learn to use these tools. They can be used, for example, to improve a canning process in a factory, the distribution of medications in a hospital, and the issue of driver's licenses in the Department of Motor Vehicles. You can read about some of these latter applications in a paper that appeared in *Quality Progress* by Box, Joiner, Rohan, and Sensenbrenner (1989) and also, for example, Box and Bisgaard (1987).

The benefits provided by worker participation are twofold. Quality is improved because of the finding and fixing of a very large number of problems, but also, and perhaps equally important, morale is improved. It is enormously satisfactory to be allowed to be creative, and frustrating to be treated merely as a pair of hands. The bird in the cage, once it has overcome its initial disbelief, will find it wonderful to be allowed to fly.

It has been said that more than 85% of quality problems come from the system itself and that "therefore" only management can solve them. But by setting up problem-solving teams led and encouraged by management, the work force, in effect, becomes part of management and is available to help solve these problems. One excellent book about the *team* approach, by means of which this idea may be put into effect, is that by Scholtes (1988).

The idea is nicely summarized in something I saw displayed by the UAW and Ford management:

Tell me—I′ll forget
Show me—I may remember
Involve me and I′ll understand

EXPERIMENTAL DESIGN

The quality improvement tools so far discussed provide ways of listening to the system in its *normal operation* and doing what it tells us to do to improve it. But engineers and scientific management should be tackling deeper questions concerning what would happen if they tried something *different*. To find this out they need to experiment. The recognized method of experimentation used to be the "*one-factor-at-a-time*" method in which each factor was changed in turn while keeping all the rest constant. That way of experimenting became outdated in the early 1920s when Ronald Fisher discovered much more efficient methods of experimentation factorial designs. These were further developed to include fractional designs, orthogonal arrays split plot designs, and response surface methods.

In Chapter B.1 of this book, I discuss a very simple factorial design used by Hellstrand (1989) at SKF for the improvement of the design of a bearing. In this experiment, which was one of a series saving many millions of dollars, three factors—heat treatment, outer ring osculation, and case design—were tested each at two levels. This experiment resulted in a fivefold increase in bearing life, and this factorial design required only a total of eight runs!

Now, for most organizations not only is it true that insufficient attention is given to experimentation, but often the experimentation that is done is done extremely inefficiently. Sometimes not even the one-factor-at-a-time method is used but just "*pick and try*." The extraordinary truth is, that 80 years after Fisher invented modern experimental design, it is still not widely taught in schools of engineering and science in our universities. Industry must help academia to remedy this distressing situation.

Notice that all the things I've talked about—the *creativity of the whole work force*, the *information continually generated by an operating process*, the running of experiments according to the *principles of statistical experimental design*—do not, of themselves, cost anything. The resources are there but are largely unused. They do not require the hiring of more people or the purchasing of more equipment.

Their use does however require *profound reorganization* of management and extensive training that *does* involve considerable expenditure of time and money. But just as teaching a man to fish can provide him with food for the rest of his life, so reorganization and training can set in place a system of continuous improvement that *never ends*.

THE ESSENTIAL MISSING INGREDIENT FOR THE SIX SIGMA REVOLUTION

In the past, although statistical tools had been used in American industry, its successes had rarely permeated the "Bottom Up" transmission of information. The successful projects that came to light were assumed to be isolated cases requiring expensive and specialized talent.

The situation in Japan was different. After World War II, as part of an initiative to help Japanese industry get back on its feet, Drs. Edwards Deming and Joseph Juran lectured in Japan about quality and process improvement. These lectures were attended by some of the most *senior* Japanese executives and they took them very seriously.

Thirty years later the effects were felt here – the excellence of imported Japanese automobiles and almost every other kind of mechanical and electronic device threatened many of our industries with extinction. After Dr. Deming made his television presentation, "If they can, why can't we?" great interest was aroused in American industry. But Deming refused to discuss his ideas with anyone but top executives.

So at last, an authoritative statistical scientist got to talk with higher management in this country and to explain what was wrong with their policies and how they could change. Once the ice was broken such interchanges become more common and eventually produced remarkable results.

Now, if you set a match to a mixture of 74 lbs. of pottassium nitrate and 14 lbs. of carbon nothing of interest would happen. But, had you mixed in a *third* ingredient – 12 lbs. of sulfur – you would have made 100 lbs. of gunpowder and a great deal would happen!

Look again at Figures 1a, 1b and also Figure 2, you will see that

1) Simple problem solving tools, such as are shown in Figure 2, together with elementary experimental design, were available.
2) There existed a large pool of untapped human resources that could be trained to use them to improve processes. But the breakthrough could not happen without the addition of a third vital ingredient.
3) This was when the CEO's of such companies as Motorola, GE, Honeywell and Texas Instruments realized the enormous potential of those two facts and made it clear that everyone in the organization would be trained and expected to use these simple tools for improvement on projects likely to save money.

The explosion that resulted when these three ingredients were combined was called Six Sigma. It produced spectacular results not only in manufacturing and business applications but in such organizations as banks, schools, and hospitals.

It is not my intention to catalog the profound organizational changes needed to bring about such a revolution. These are detailed in such texts as Eckes (2001); Harry and Schroeder (2000); Pande, Neuman, and Cavanagh (2000); and Snee and Hoerl (2003).

An important goal of this book however is to make available in clear and simple language ideas and methods that you may find useful in such efforts.