

ASQ STATISTICS DIVISION Special Publication

STATISTICAL THINKING: METHODS AND ROLES FOR THE PAST, PRESENT, AND FUTURE

WILLIAM F. RODEBAUGH

Introduction

In the last Special Publication edition, we explored topics that were very near to me – the topics of Six Sigma and Lean methodology. The discussion was around some more advanced themes in the field such as the combination of Lean and Six Sigma, the use of ‘pull’ theories in aligning corporate improvement programs, and also a highly analytical segment regarding the maximization of supply chain effectiveness.

It was indeed Six Sigma that led me to venture into the world of statisticians and quality professionals. Statistics was a necessary part of my engineering and business education, but it was my time as a Six Sigma practitioner and then consultant where I began to truly understand the great history and power of statistics. Beyond the tools and techniques, which I do my very best to apply appropriately and correctly, are the wonderful people in this sphere. I have had the fantastic opportunity to work along side David Bacon, Søren Bisgaard, Ron Snee, and Steve Zinkgraf, and also meet many others at various ASQ events. I also had the pleasure to present on the same docket as Stu Hunter at a local ASQ quality symposium a few years back. They all impacted me.

As the theme of this publication was trying to gain clarity, I remembered the opportunity that I had in this past year’s Fall Technical Conference to hear Stu Hunter talk through the history of this event and weave it into the dynamics of the statistical profession over the years. In order to share this talk with more people, it is included in this presentation. A discussion entitled ‘Methods for Business Improvement – What’s on the Horizon?’ by Ron Snee is included in the publication as well.

With these two segments there is an historical perspective of the tools and techniques and the roles and responsibilities of the quality professional. Both articles challenge us to be prepared to not only continue along the journey, but also to accelerate the pace, in order to impact the people and the processes that we deal with everyday. Statistical thinking should continue to impact those around us.

Fall Technical Conference

Keynote Address

J. STUART HUNTER

Columbus, OH

10/12/06

Overview

The following is the keynote address delivered by Stu Hunter at the most recent Fall Technical Conference. This is both a personal view of the history of the Fall Technical Conferences as well as a look at the changing world of statistics and statistics education through the years.

Celebrating the 50th?

When Connie Borrer asked me to be the keynote speaker for the 50th anniversary of the Fall Technical Conference (FTC), my first reaction was bewilderment. The FTC cannot be fifty years old; that would make it older than *Technometrics*. To recite a little history, *Technometrics* was born of conversations at the Gordon Conferences on Statistics starting back in 1956-1957 and in 1958. *Technometrics* was launched by the ASQC and the ASA in 1959, that's forty-seven years ago. So when was the first FTC?

The first Chemical Division technical conference was held in 1956 (I believe I was one of the speakers), and this ASQC Division conference does proceed the launching of *Technometrics*. At that time the ASA SPES section was only a two year old foundling, just getting its act together.

The first real FTC in my view, the first conference co-sponsored by the Chemical Division of ASQC and the SPES of the ASA, was held in October, 1970. That conference was organized largely by Dick Freund, who had long lamented that although *Technometrics* was co-sponsored by the ASA and ASQC, there were no corresponding joint meeting efforts.

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Now 1970 would make the FTC thirty-six years old, not fifty years old. A difference of fourteen years would make both me and the FTC much younger. No wonder I prefer the 1970 origins! The FTC leadership claims that today's meeting to be their 50th anniversary, and so be it. Celebrating a 50th anniversary is always a great event whoever is counting. It's time to cheer.

Looking Back (1950s through 1980)

I suppose a 50th anniversary requires a bit of looking back.

- In 1956, we placed most of our data on punch cards.
- Response surface methods were in their infancy.
- The XTX matrix was used to characterize experimental designs as orthogonal or rotatable, but not yet as D or G or I optimal.
- In 1957, Evolutionary Operations was born.
- In 1958, survival functions appeared on the reliability front.
- In 1959, the Cusum chart arrived.
- In 1961, the notation for fractional factorials, the $2k\text{-pIV}$, and the ideas design resolution and projection appeared.

The next two decades proved equally exciting. We learned about data transformations (1964), fast Fourier transform (1965), mixture designs (1965), ARIMA models (1970), box and whisker plots (1977) and in robust product design (1980) by an engineer from the Far East, Genichi Taguchi.

Newer Topics (1980s through today)

Over the past two decades several new topics have surfaced.

- There is a growing interest in all things Bayesian.
- Jackknife and bootstrap terms have come to our attention.
- Meta analyses arrive along with sequentially augmented experimental designs.

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- New developments in reliability are here, thanks to Bill Meeker.
- Multivariate Times series analyses have appeared.
- One also hears a lot about spatial modeling, wavelets, fuzzy sets and data mining.
- On the computing front we are forced to learn about Markov Chain, Monte Carlo simulations, and Gibbs sampling.

Clearly the frontiers of statistics along with those of computing have advanced. The challenge to this audience, those of us identified as applied statisticians and Quality professionals is to keep abreast of a rapidly changing environment. I note with pleasure that at this 2006 FTC we do have papers concerned with bootstrapping, data mining, multivariate time series, and meta-modeling. Bravo!

Continuing Education

In the early 1960's continuing education was the outstanding characteristic of the Chemical Division, the parent of the present CPID and Stat Divisions of ASQ. It was called the "fireball division" by the executive councils of the ASQC. The division gave literally dozens of short courses on simple design of experiments, regression, fractional factorial designs, RSM, and evolutionary operation. (Incidentally the money raised from these earlier courses helped finance *Technometrics*.) More interesting events perhaps were the four day Recent Advances courses sponsored by the division and held in London, Ontario. These sessions featured such notables as George Box, George Barnard, Cuthbert Daniel and Bill Cochran. Education of the membership was the priority of the division, and again it is a pleasure to note that the tradition has continued. This year's FTC has provided short courses on Bayesian data analysis, logistic regression, R software, and statistical consulting.

But I have a question, are the sponsoring societies of the FTC doing enough today in continuing education either for those for whom we work and consult or for ourselves?

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The answer is only partially “yes.” For the non-statistical quality worker, the Six Sigma Green Belt and Black Belt certification programs do provide an education in basic statistics, in the classical topics of Shewhart charts, sampling, regression and design of experiments. Unfortunately, more up-to-date topics such as time series and the collection and analysis of large masses of data are largely neglected. For example, isn’t it time the Black Belt trained quality engineer learn to start thinking about their process dynamically and start employing some of the Box-Jenkins ARIMA models? Ah you say, that’s getting rather sophisticated for the production floor. But is it? Most Six Sigma Green Belts and Black Belts are familiar with the EWMA used as another kind of Shewhart chart under the Shewhart model $y = \eta + \varepsilon$. What about the same EWMA statistic employed under the more realistic, time dependent model $y_t = \eta_t + \varepsilon_t$. The EWMA is now becomes the (0,1,1) ARIMA model and has the same mathematical structure as a first order difference equation. Did you notice the dynamics entering the picture? The EWMA then becomes a Kalman filter, capturing the signal – the present location of the mean – leaving what remains as residual noise. If the present estimate of the mean is far from target, then why don’t you do something about it? How about adjusting the process so that it is back on target? This use of this simple time series model, the EWMA, for feedback control was recommended by Box & Jenkins in 1970. It is time we moved this wonderful tool onto the production floor.

Now what about the continuing education of the applied statistician and the Quality professional? Of course, we can attend short courses on specific new topics of interest. To keep abreast we read the technical literature: *Technometrics*, *the Journal of Quality Technology*, *Quality Engineering* and the statistics roundtable in *Quality Progress*. We purchase books, say George Box’s latest, *Improving Almost Anything*. However, as we all know, self learning from a textbook requires hard work before reading leads to understanding. Of course, we attend the meetings of our societies. There we have the opportunity to sample a smorgasbord of topics, old and new, often wishing we could dine in two places at once. Unfortunately each paper we attend lasts perhaps a half hour, with

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little or no time for discussion. Attending these events are much like watching fireworks *oooh, ahhh*, and one leaves with little or no recollection of what transpired unless a copy of the power point presentation is kept. Going to the meetings is a necessary yet difficult way of keeping abreast of a lively growing field.

The Gordon Conferences

Starting in the early 1950's the Gordon Conference on Statistics in Chemistry and Chemical Engineering met annually, usually in New Hampton, New Hampshire. The Statistics Gordon Conference was only one of many similar conferences sponsored by the AAAS. The statistics conference met for four-and-a-half days and offered a single lecture, one each morning and evening, nine lectures in all. Each lecture reviewed a recent development in statistics, with some topics still waiting to be published. Each lecture was followed by another ninety minutes of questions and answers, cut and thrust, from an active participating audience. These presentations and discussions proved to be exceptional learning experiences. One left the conference alerted and enabled in what was new in the profession.

But there was more. The afternoons and late evenings were spent getting to know one another, bull sessions which lasted into the early hours of the morning. As a young statistician attending the Gordon Conferences I met the leaders of the day, and not just for fleeting moments but in real interactions. I spent time with folks like Maurice Kendall, John Wishart, David Cox, Henry Scheffe, Will Dixon, David Finney, H O Hartley, and Frank Wilcoxon, along with folks like Box, Kempthorne, Youden and Cuthbert Daniel. I got to know the players and the coaches and became a full member of the team.

The Gordon Conference brought together diverse personalities and ideas in a learning environment. The speakers came to enlighten – to teach – a very special audience of sincerely interested attendees, the players, those of us who were working statisticians and fledgling academics.

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We went away with an understanding of what was new and potentially applicable. And the coaches, the speakers, those creative individuals who push the frontiers of knowledge, had a chance to mingle with the players, those of us destined to apply their ideas. The profession grew and everyone profited.

Now for the bad news. The Gordon Conferences on Statistics were sponsored yearly by the AAAS starting in the 1950's up until the mid 1990's. The conference was then placed on a once every two year schedule. The last conference was held in 2004. There was no conference in 2006 and none are planned for 2007. The Gordon Conference on Statistics has apparently vanished. That's really bad news.

On losing the Gordon Conference on Statistics, I feel we have lost a part of our professional DNA, that part that helped keep us continually young. Certainly our current short courses, our journals, and our meetings are essential to our present health, but what of our growth, our diversity, and our future strength and vitality?

A challenge facing the statistics and quality professionals fifty years ago was to establish a journal combining the interests of both parties. That challenge was met when *Technometrics* was born. Fifty years later the FTC continues to represent and to serve the needs of that very same audience. Of course when human beings turn fifty, they begin to contemplate their retirement, the last of life for which the first was made. They become introspective and wish to be surrounded by familiar things. However, the FTC at fifty years of age, and especially its sponsoring societies, has to be different. They must resist retirement and satisfaction with familiar things. They need to pursue new topics and new applications. They need to identify teams full of new players and new coaches.

In short, they must be sure to re-new their fountain of youth. Thus, like Ponce DeLeon in search of his fountain of youth, I believe the Quality and statistics fraternity needs to identify and enhance its own sources of youth. To that end I believe we must have a conference akin to the Gordon Conference. It should meet in a rural locale far from the distractions of a large city. It

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should offer the profession's finest talent the opportunity to address, with ample time for exposition and questions, statisticians from the manufacturing and the service industries, along with young academics. The ambiance should be that of the past statistics Gordon Conferences with time for "getting to know you." Perhaps NISS, or the National Institute of Statistical Sciences might replace the AAAS as the sponsoring organization. No doubt establishing such a conference would create many difficult financial and organizational problems. But then I note that is a situation not too dissimilar from the one faced fifty years ago by those who felt the need for an annual technical conference and for a new journal.

In conclusion, a 50th anniversary offers the opportunity to look back and as we do we can take pride in our accomplishments. It is also a time to look forward and to consider new challenges. And here's a challenge: let's have our very own conference, our own "Gordon" on statistics.

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Methods for Business Improvement – What’s on the Horizon?

RONALD D. SNEE

Abstract

This article looks at current trends in the development and use of business improvement methodology. It is conjectured that the next generation of improvement methodology will integrate the best aspects of currently used approaches such as Lean manufacturing, Six Sigma, ISO 9000 and Baldrige assessment thereby streamlining the improvement methodology and increasing the effectiveness and efficiency of the approach. It is argued that the resulting approach needs to be more than just a methodology for conducting improvement projects. Type of culture (business and ethnic), function, leadership, management systems, and other factors must also be taken into account. The characteristics of a holistic approach to improvement that accomplishes these goals are presented.

The Need to Improve

Twenty-seven years ago the broadcast of the NBC white paper “If Japan Can Do It, Why Can’t We?” provided a wake-up call about the need to improve business performance. Since that groundbreaking broadcast, the drive for improvement has steadily accelerated and we’ve become ever vigilant for new ways to achieve it. This article looks at the current direction of the development of improvement methodology and what we can expect to see in the future. It is clear that statisticians and quality professionals have made major contributions to the field in the past and will continue to do so in the future.

The massive changes we are seeing today are being fueled by global competition and the widespread use of information technology. As Thomas Friedman (2005) tells us his *New York Times* bestseller, *The World is Flat*, information technology has leveled the playing field, making it easier for countries and individuals around the world to compete more effectively.

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Global competition and information technology are forcing changes in all aspects of our society: business, government, education, health care. Customers are demanding more. In order to successfully respond to these needs we have to change how we work and manage. A new paradigm is in play. We now have two jobs: to do our work and to improve on how we do our work.

This new paradigm presents businesses with some pressing needs, including:

- Faster market introduction of products
- Processes that are more compliant with federal, state and local standards
- Delivery of products and services to customers on time and in-full
- Improved throughput, cost/unit, capacity and margins
- Improved yields – fewer defects and less rework and scrap
- Increased equipment uptime and better plant utilization
- Robust products, processes and analytical methods

The question remains: “how do we respond to these challenges and the need to change”?

Business improvement methodology has been evolving over the last 100 years reaching back at least to the work of Frederick Taylor around the turn of the 20th century. Statistics and statisticians have played a major role in these developments (Snee 2004c). The reason for this central role is the omnipresence of variation, which affects the quality, cost, delivery and customer satisfaction that results from the processes that produce products and services (Snee 2006c).

The definition for statistical thinking developed by the ASQ Statistics Division puts variation at the heart of process performance (ASQ 2004): “Statistical Thinking is a philosophy of learning and action based on the following fundamental principles:

- All work occurs in a system of interconnected processes
- Variation exists in all processes, and
- Understanding and reducing variation are keys to success”

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This definition elevates the importance of focusing on the process, as the context for the problem to be solved, as well as on variation and the associated data (Hoerl and Snee 2002).

A major focus of today's business improvement methodology is the use of Six Sigma and Lean manufacturing techniques. Process thinking and statistical thinking are central to those methods (Snee 2005b). Companies, particularly pharmaceutical companies, are recognizing the importance of process understanding to effective process control and improvement. Understanding process variation leads to better process understanding, which results in more predictable and sustainable process performance (Snee 2006b). Significant improvements and bottom line results are being obtained (Snee 2004a).

Where is all of this going? What's next? What's on the horizon?

Some Important Trends

Consider the trends already underway and what they tell us about the improvement needs of business (Snee 2004c, 2006a).

Many companies are working to utilize the strengths of both lean manufacturing and Six Sigma. Lean principles help deal with improving process flow. Six Sigma approaches help with reducing process variation, improving process control and achieving process optimization. Both approaches are used in reducing various aspects of cycle time and waste. There are also opportunities to also integrate the benefits of Baldrige assessment and ISO 9000 with these approaches to business improvement.

More and more improvement opportunities are being discovered beyond the factory floor (Snee and Hoerl 2005). Major bottom-line savings are being generated by improvements in processes such as billing, accounts receivables, human resources, legal, finance and travel. Many working in the improvement field believe that there is as much opportunity to improve outside of manufacturing as there is within manufacturing.

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For the long term, organizations want to make improvement part of how they run their businesses but few have succeeded in doing so. Approaches to integrating improvement with the running of the business (Snee and Hoerl (2005)) rely heavily on the use of data, summarized and reviewed at various levels on management to control and improve processes as well as design or redesign new processes.

Companies are also using improvement methodologies to help their suppliers provide better raw materials and information and to help their customers be more successful under the mantra “At the Customer, for the Customer.” As a result, suppliers and customers are teaming to gain the benefits of improvement.

Many organizations are using improvement approaches, such as Six Sigma, as a leadership development tool. Jack Welch (2005) points out that “Perhaps the biggest but most unheralded benefit of Six Sigma is its capacity to develop a cadre of great leaders.” Companies such as Honeywell, GE, DuPont, 3M, and American Standard are requiring Six Sigma Green Belt and in some instances Black Belt certification for management promotion. This approach makes sense when we realize that the job of leaders is to help an organization move from one paradigm of working to another paradigm. Changing how we work means changing our processes. Lean Six Sigma provides the concepts, methods and tools for improving processes. Thus Six Sigma provides leaders with the strategy, methods and tools for changing their organizations. This is a key leadership skill that has been, heretofore, missing from leadership development.

There are also opportunities to make greater use of information technology in streamlining and making improvement methodology more effective (Snee 2006a). Information technology will no doubt be used to enhance the efficiency and effectiveness of the deployment of Six Sigma, just as user-friendly statistical software has enabled Six Sigma to improve the efficiency and effectiveness of data collection and analysis.

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Can all of these developments in improvement methodology be fit together? If so, how can they fit together? The most promising answer, laid out below, lies in a holistic approach to improvement.

Holistic Approach to Improvement

Lean, Baldrige, ISO 9000 and Six Sigma are all effective approaches to improvement, but for maximum benefit these disparate strands need to be woven into a single fabric. A focus on the process, what Hammer (1996) calls a process-centered organization, is central to this integration (Snee and Hoerl 2003, 2005). But there is more. The methodology must work in all aspects of the business – billing logistics, HR, manufacturing, R&D, etc.

Four factors are needed for successful improvement Snee and Hoerl (2003):

- Top management support and involvement
- Top talent
- Supportive infrastructure
- Personnel – Champions, Improvement Masters, Team Leaders, etc.
- Management systems
- Improvement methodology

In the past, most attention has been paid to the methodology with some attention to management “commitment.” Experience has shown that success results when top management is involved, not just committed. Successful improvement approaches have unique role for top management to play (e.g., strategy, goals and reviews) and provide the needed training to develop the needed skills.

Success results when top talent is involved in the improvement projects. Improvement requires changing things. Because change is arguably the most difficult job in any organization, top talent is required to lead it.

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Because management systems are essential to sustained improvement, greater emphasis on the development of supporting management systems (e.g., communication, recognition and reward, project selection) is also needed.

Putting all of those factors together suggests that a holistic approach to improving the business should have the following characteristics:

- Works in all areas of the business – all functions, all processes
- Works in all cultures, providing a common language and tool set
- Can address all measures of performance – quality, cost, delivery and customer satisfaction
- Addresses all aspects of process management:
- Process design/redesign, improvement and control
- Can address all types of improvement – streamlining, waste and cycle time reduction, quality improvement, process robustness, etc.
- Includes management systems for improvement
- Plans, goals, budgets, and reviews
- Focuses on developing an improvement culture:
- Uses improvement as a leadership development tool

Thus a holistic approach is more than just a methodology for conducting improvement projects. The type of culture (business and ethnic), function, leadership, management systems, and other key elements of the business must be taken into account.

Project Selection and Sustaining Improvement

Project selection and sustaining improvement are arguably the two most difficult aspects of business improvement (Snee 2001a, Snee and Rodebaugh 2002). Project identification and selection is greatly enhanced assessing where the pain is (sources of poor process performance) and what needs to be done to achieve business goals and objectives and combining that analysis with value

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stream mapping to identify ways to speed up the process and reduce waste and cycle time. As you do so, you integrate the Lean and Six Sigma methodologies. It is also important to integrate financial analysis of the projects with the project selection process. This enables you to evaluate what the project is worth before you start and to determine the actual value of the process improvements once they have been implemented.

The key to sustainability is to plan for sustaining the gains in the beginning by putting in the management systems, discussed above, to support and guide improvement (Snee 2006a). Improvement must be sustained at the strategic level by creating management systems that support the improvement system and at the tactical level by establishing control plans and audit procedures to enable the organization to hold the gains of individual projects.

Learning from Past Mistakes

George Santayana admonished us many years ago that “those who remain ignorant of the past are doomed to repeat it.” Despite what has been learned in the last three decades regarding business improvement, these common mistakes continue:

- Not designing improvement approaches that require the active involvement of top management
- Focusing on training rather than improvement (Snee 2001b)
- Not using top talent to conduct improvement initiatives
- Not building the supporting infrastructure including both personnel skilled in improvement and the management systems to guide improvement
- Not working on the right projects – those that deliver significant bottom-line results
- Not planning for sustaining the improvements at the beginning if the initiative

The holistic approach described here can help eliminate those mistakes. Just as importantly, statisticians and quality professionals can play active roles in the process.

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Roles for Statisticians and Quality Professional in Holistic Improvement

As detailed in Table 1 (Snee 2005a), there are many roles for statisticians and quality professionals to play in improvement. These range from solving critical problems to training and coaching professionals and managers alike, to the promotion of improvement and how it benefits the organization. (For more details on these roles and what they contribute to the successful deployment of improvement programs see Snee 2005a.)

1	Serve as Master Black Belts plan, coach, train, intervene
2	Solve “mission critical” process problems
3	Identify and deploy the most useful Lean Six Sigma approaches and tools
4	Deploy “best practice” process improvement and management approaches
5	Promote Lean Six Sigma and process view
6	Work with Champions and management

Successful implementation of improvement initiatives requires new knowledge, skills and attitudes. Albert Einstein pointed out that “the significant problems we face cannot be solved at the same level of thinking we were at when we created them.” Several key leadership skills are summarized in Table 2. Of critical importance is attaining business acumen – understanding how your business works and how it creates value for the customer and earns money to pay employees and stockholders.

1	Business acumen Understand how business works
2	Strategic planning and deployment
3	Process and systems thinking
4	Stakeholder building
5	Communication – clear, concise & continuous
6	Reviewing and coaching
7	Structured improvement methods like Lean Six Sigma
8	Learn to deal with team & group dynamics
9	Meeting design and facilitation
10	Project planning and management
11	Understanding human behavior

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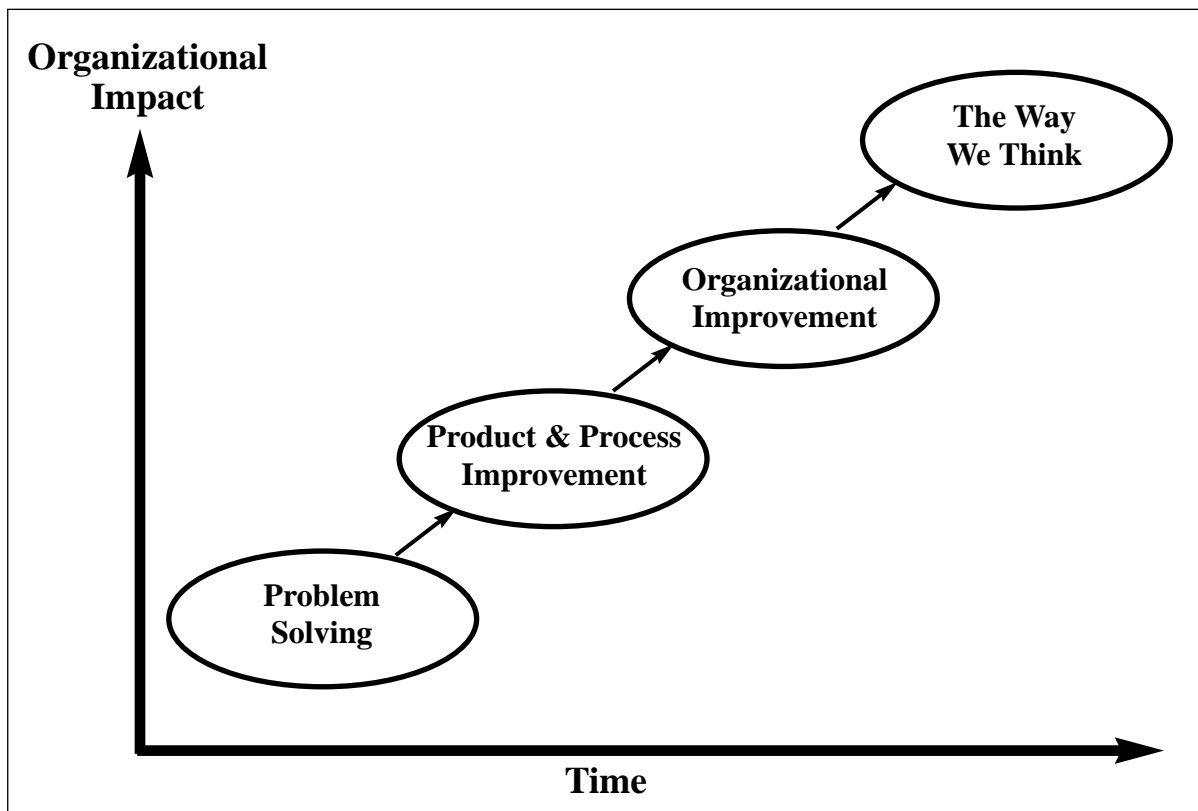
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Statisticians and quality professionals should of course have had considerable experience in applying the statistical tools utilized by Six Sigma and other statistically-based methods. As shown in Table 2, there are also a number of non-statistical skills that also can help them succeed (Snee, 1998).

The Expanding Role of Statisticians and Quality Professionals

As never before, statisticians and quality professionals have opportunities to influence how organizations run their businesses. To succeed in this new role, they must recognize that they are in the culture-change business, which requires that they first help change leadership's thinking through the kind of carefully structured initiatives and principles described here. As the world of statisticians and quality professionals expands from problem solving, to process improvement, to organizational improvement, to organizational improvement, the ultimate culture change – changing how people think – will follow (see Figure 1).



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Becoming a leader is not as daunting a task as it might seem. The essential principles of leadership are simple. As a leader you should (Snee and Hoerl 2004):

- Provide direction – leaders show the way
- Communicate – leaders develop understanding and hope
- Enable, coach, counsel, and provide resources – leaders set people up for success
- Recognize results and reinforce desired behavior – leaders catch people doing things right

For statisticians and quality professionals, bringing about the change in the thinking of management will be the first test of leadership. Lead the leaders and you become one yourself.

To Be Continued

And so the future of business improvement is indeed very bright. The story will continue just as it has over the past 100 years and more. Business improvement methodology will grow and evolve to match the improvement needs of organizations around the world. Statisticians and quality professionals can play a key role in the evolution. The story is “to be continued.”

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