Why Teaching Belts Isn't Always a Cinch

*By **Paul Sheehy,** Minitab Inc.*

Different organizations teach statistics to Six Sigma belts at significantly different levels of scope and depth. I have seen many Master Black Belts (MBBs) who were highly qualified practical statisticians and others who did not know the difference between a two-sample t-test and a paired t-test.

In general, Black Belts (BBs) are taught to a lower level because they can lean on the MBBs for help. But it is the Green Belts (GBs) and—if I may coin the term—base-level BBs who seem to exhibit the most variation in statistical knowledge.

One disclaimer: Many, including ASQ, believe in a standard body of knowledge all BBs should master. This concept of a certified professional BB is valid, but I'm focusing on GBs and base-level BBs. The toolkit taught to these people might be more appropriately linked to their specific field, factory or office.

If no one in the organization uses design of experiments (DoE), for example, teaching it would be what Toyota executive Taiicho Ohno called "overprocessing waste."

Some organizations teach GBs to the same level as BBs. The rationale is they need the same toolkit because the only difference between them is one works projects part time and the other full time. Other organizations treat GBs as basic team members. These GBs learn the importance of data and the concept of analyze and control, but they may not be permitted access to statistical packages.

This last approach, unfortunately, is logic-based: Statistics can be complicated, have a "use it or lose it" factor and can be dangerous in improperly trained hands. Potential danger lurks in selecting an improper tool, using tests without verifying assumptions, using insufficient sample sizes, using data that aren't trustworthy or misinterpreting the analysis.

Software solutions

Statistical software companies should recognize the fact that most of their users are not statisticians, and their software should provide for input and output in clear terms. Consider the adage that if your only tool is a hammer, every problem looks like a nail. Simply put, software should provide a basic toolkit to a GB and an advanced one to a MBB, and it must be comfortable for either user.

Ideally, you want one software package suitable for beginners and experts. This has two clear advantages. First, as the GBs progress to become BBs and eventually MBBs, the tool they use remains consistent. In addition, MBBs use the same tool whether doing an advanced analysis or assisting a GB.

Software should also, whenever possible, automatically validate assumptions and provide clear warnings in easily understandable language when providing statistical results. For GBs, I am uncomfortable with output that doesn't check assumptions (assuming the user knows how to—and actually does—validate all assumptions), as well as black boxes that give the answer without reporting on data quantity and quality, and the status of the assumptions.

In addition, software should guide or—even better—lead the GBs through a logical sequence of actions that result in a proper analysis. This sequence should consist of data validation, critical graphical analysis, assistance in choosing the appropriate statistical analysis and a crisp conclusion drawn from a properly executed statistical procedure.

Software for GBs should use tests that are robust to common assumptions whenever possible. Here are four examples:

1. Use a Welch's analysis of variance (ANOVA) vs. a classical F-test because the Welch's ANOVA does not require the assumption of equal variances.
2. Automatically default to the use of tests one, two and seven for statistical process control. This matches current research and findings in the statistical community and minimizes false alarms while maximizing the investigation of the process.
3. Clarify when common assumptions are not important, such as the assumption of normality in a two-sample t-test with sample sizes greater than 20.
4. Provide automatic comparisons of level mean differences in a one-way ANOVA instead of providing a single p-value.

Training tips

Training should avoid "stat speak," except when it is absolutely necessary. We should also understand that the typical two-week GB training or even a four-week BB class does not provide sufficient time to teach statistics and supporting statistical software.

As an MBB, I spent seven years instructing BBs and GBs, and I was always stretching to cover the

concepts of lean Six Sigma, change management, project management and reporting, project selection and scoping, financial analysis and reporting, while also conducting in-class project reviews and coaching. I felt unable to provide proper statistical training and practice.

As a Minitab instructor for the past six years, I have found myself on the other side of the issue. About 40% of students in my Minitab classes have served as belts or are being trained as belts. In almost every class, I hear someone say, "Gee, I didn't learn that in my Six Sigma class." I always respond that, given the time allowed, the Six Sigma instructor can only teach the basics.

We do not consider a belt's lean Six Sigma skills to be complete at the end of a few weeks of training; rather, we wait until they have time to apply and improve those skills over a period of time (typically a year or however long it takes for several completed, juried projects).

Why do we then assume all statistical training is complete and mastered in initial training? Statistics, like most other lean Six Sigma components, must be nurtured and augmented over that first year.

We should teach to the right level. One size does not fit all. I have been in many service organizations that do not use traditional continuous gages and thus have no reason to use a traditional gage repeatability and reproducibility analysis. Why teach it?

On the other side of the coin, I was teaching lean Six Sigma to a service organization that said it did not see the value in learning DoE. I convinced the participants that while they were correct that we should not spend the three days in DoE instruction and practice that existed in their organization's manufacturing group's training material, we should have a three to four-hour awareness training so the class would have knowledge the tool exists, what it can do and its basic requirements.

They agreed, and two of the 25 attendees went on to use simple 2^k factorial experiments in their first project.

We should also provide ongoing support to belts. This should include training on how to access help functionality in the software they use. This is a basic tool that is frequently ignored. The first line of action for any belt who is stuck should be the use of help.

The heart of the matter

Statistics is the heart of lean Six Sigma, but it is not the activity to which a belt devotes the most time.

During a project that spans three or four calendar months, a belt may use a statistics or data package for 10 to 20 hours. But statistics is a crucial tool. Without it, how would we quantify our baseline capability and verify it comes from a stable process? How would we know if a change was statistically valid or due to random chance? How would we properly quantify our final state?

Statistics is required—conference sessions proclaiming "Six Sigma without statistics" notwithstanding—but it should and can be made more accessible and easier to learn.

PAUL SHEEHY is a technical training specialist at Minitab Inc. in State College, PA. He earned bachelor's degrees in industrial technology from the University of Southern Maine in Gorham and mechanical engineering from the University of Maine in Orono. Sheehy is a certified Master Black Belt and is lead author of The Black Belt Memory Jogger.

Recognizing Opportunities

*By **Ron S. Kenett,** KPA Ltd., University of Turin*

For more than a decade, Spencer Graves and I co-edited "World View," a monthly column *Quality Progress* magazine started publishing in June 1988. "World View" contributors wrote about quality efforts throughout the world, including Australia, Brazil, India, Israel, Portugal, South Africa and the United Kingdom.

At some point, the magazine's editor decided such a focused view was not needed anymore and notified us the column would be discontinued. Now, papers from authors outside the United States and Canada are integrated as regular QP articles.

I am glad to have received this opportunity to present insights from the other side of the Atlantic. My activities combine consulting with academia, and my point of view is that of a statistician, scientist and management consultant. And from that point of view, I've identified several global challenges to statistics, quality and Six Sigma.

Economic troubles

The recent economic meltdown triggered a process of financial reconstruction that resulted in

major changes to the management of financial institutions and financial transactions. These changes have been labeled "Intelligent Regulation" or "Beyond Basel II" to indicate the need to review the Basel II Capital Accord on International Convergence of Capital Measurement and Capital Standards that regulate the level of capital financial institutions are required to set aside to meet risks.

Statistics can play a key role in this realm. New approaches for improved risk assessment, integrating qualitative and quantitative information with advanced analytics, are now available. They combine natural language processing and ontology engineering with methods such as Bayesian networks to provide more informative risk scores.

A project funded by the European Union produced several demonstration pilots and new technologies in this area.[1, 2] Statisticians should address these issues, which combine the handling of new data structures, including challenges of integration and complex risk scoring.[3]

Bridging the gap

Services computing has become a cross-discipline domain that bridges the gap between business services and IT services. Its underlying technology includes web services; service-oriented architecture; cloud computing; business consulting methods and utilities; and business process modeling, transformation and integration.

The scope of services computing covers the entire life cycle of services' innovation research and includes services modeling, creation, realization, annotation, deployment, discovery, composition, delivery, collaboration, monitoring, optimization and management.

The goal of services computing is to enable IT services and computing technology to perform adaptive business services more efficiently and effectively. This challenging area requires inputs and contributions from statisticians in areas such as using web services,[4] designing effective testing and control mechanisms,[5] and using data on near-misses or incidents to predict events with measurable consequence.[6]

Time to consult

To make a significant impact on business and industry, statisticians such as W. Edwards Deming and engineers such as Joseph M. Juran became management consultants. Deming made many contributions to survey methods, and Juran was very much affected by Walter Shewhart's work and was the major force in teaching and deploying statistical process control in the Hawthorne plant of AT&T's Western Electric.[7]

The point is that to promote the contribution of statistical methods, you need to address management issues. This may require reinvigorating Six Sigma initiatives in service organizations.[8] But such a recommendation needs to be couched in the language of management.

Six Sigma has focused on specific improvements that permit an effective evaluation of return on investment. A general approach, suggesting that increasing the management maturity level in an organization produces more effective and efficient results from a business perspective, has been labeled the statistical efficiency conjecture. The idea was tested with 21 case studies from Europe and Israel discussed within the European Network for Business and Industrial Statistics.[9]

The maturity level of the management of industrial organizations can be summarized and classified using a four-step quality ladder[10] that consists of:

1. Firefighting.
2. Inspection
3. Process improvement and control.
4. Quality by design.

The statistical efficiency conjecture states that organizations with management maturity levels higher on the quality ladder achieve—using statistical methods—a bigger impact on problem solving and improvement initiatives. Therefore, statisticians who want to increase their impact on organizational efficiencies and effectiveness should also help management move from firefighting to process control and quality by design.

Designed solutions

Healthcare offers unique opportunities for statisticians. In considering this application domain, you should include the development of new pharmaceutical products and treatments, the manufacturing of these products and the delivery of healthcare.

Recently, the Food and Drug Administration and the International Conference on Harmonization of Technical Requirement for Registration of Pharmaceuticals for Human Use launched a quality by design initiative. It encourages new drug applications to include a design space and risk-based control strategies.

The basic idea is that pharmaceutical developers should study the behavior of critical quality attributes under variations in the raw material and process control parameters. This area of application is beyond the traditional role of biostatisti-

cians in clinical trials.[11, 12]

Moreover, the FDA also encouragees the application of simulation experiments, Bayesian adaptive designs and data-mining techniques in the critical path of research investigating efficacy and safety of new drug products. These recent developments have created new opportunities for statisticians and quality experts, who can play a key role throughout the life cycle of healthcare services.

Where to go from here

In the future, there will be several areas in which statisticians, quality experts and Six Sigma specialists will find opportunities to contribute to organizations, businesses and industries:

- The restructuring of financial services, including the handling of new data structures, with significant challenges in data integration and modeling.
- The growing impact of web services, social networks and services computing, which call for new web-analytic technologies and dynamic adaptive methods that can be fully integrated in operational systems, such as online recommendation systems or target advertisements.
- The development of methods and tools used for organizational improvement.[13]
- The emergence of quality by design in activities regulated by the FDA. Similar initiatives are relevant in other domains, such as aviation, where development and production is followed by operations and maintenance. The Federal Aviation Administration may also adopt quality by design.

Developments in these areas should be addressed by academia, business and industry. They require new mathematical constructs, improved technological systems and effective methods borrowing from management and cognitive sciences.

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RON S. KENETT is chairman and CEO of KPA Ltd., an international management consulting firm with headquarters in Raanana, Israel, and is a research professor at the University of Torino in Italy. Kenett is past president of the European Network for Business and Industrial Statistics, a senior member of ASQ and a fellow of the Royal Statistical Society.

A System to Stay in Control

By ***Forrest W. Breyfogle III*** *Smarter Solutions*

We all know this: In society, people must control their actions and behaviors, or they might harm themselves or others. Just as we control ourselves and, for example, refrain from striking others when we disagree or get upset, companies must have control mechanisms in place so healthy policies and procedures are followed.

If organizations don't do this, big problems can happen. Consider these recent events:

- BP's oil spill in the Gulf of Mexico.
- Toyota's automobile quality problems and recalls.
- Dell Computer's accounting issues that resulted in costly penalties.
- Lending institutions' foreclosure problems.

Were these companies in complete control? Did they have effective systems in place to guard against conflict and catastrophe? Did they lose focus on what was important?

Usually, management systems organizations focus on achieving goals, which can lead to short-cutting necessary process steps or playing games with numbers (financial and otherwise) to meet management's passed-down objectives. These types of systems can be especially detrimental when a financial reward system is tied to achieving goals.

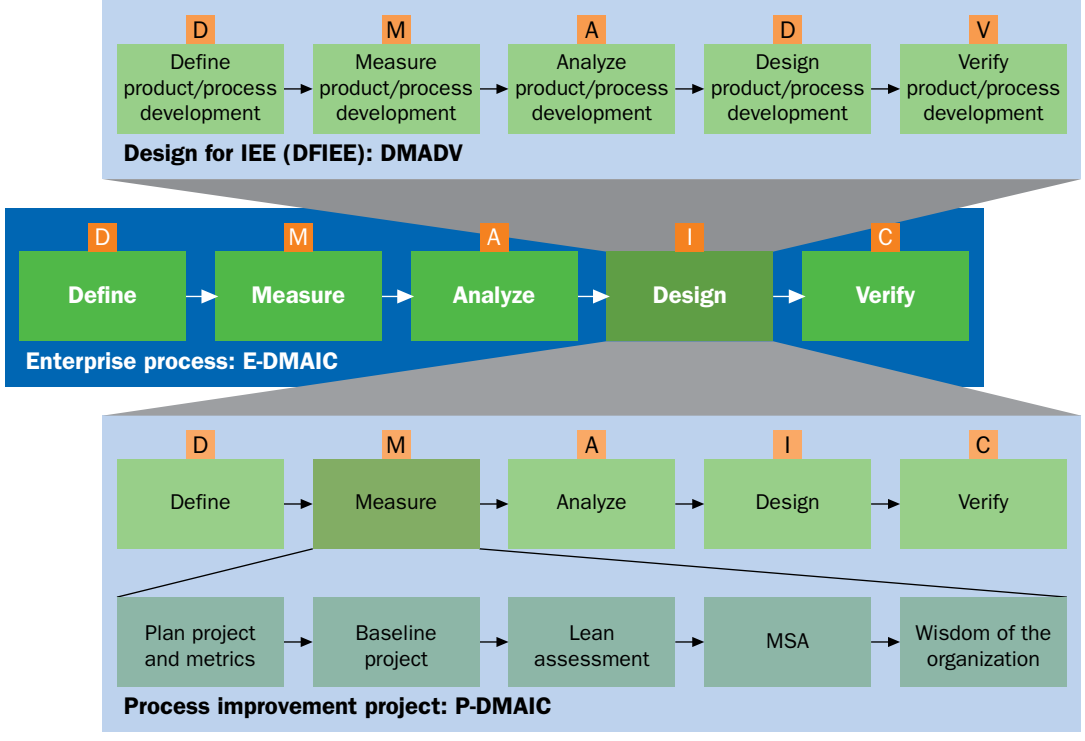
To illustrate how current business management practices can sometimes lead to unhealthy behavior, consider what Lloyd S. Nelson, the director of statistical methods at Nashua Corp., and a prolific author, wrote: "If you can improve productivity or sales or quality or anything else by (for example) 5% next year without a rational plan for improvement, then why were you not doing it last year?"[1]

From Nelson's statement, you could conclude that the commonly used, goal-based red-yellow-green scorecard method has fundamental problems. Potential unhealthy behaviors from these scorecards include wasting resources by fire-fighting commonplace issues as though they were special causes2 and avoiding healthy organizational control procedures to meet the numbers.

To avoid these problems, organizations must work within a no-nonsense, orchestrated management system so the entire business can benefit and achieve the three Rs of business: Everyone doing the right things the right way at the right time. Even when the enterprise environment is interactive and complex, organizations need an effective systematic approach that integrates these healthy business components:

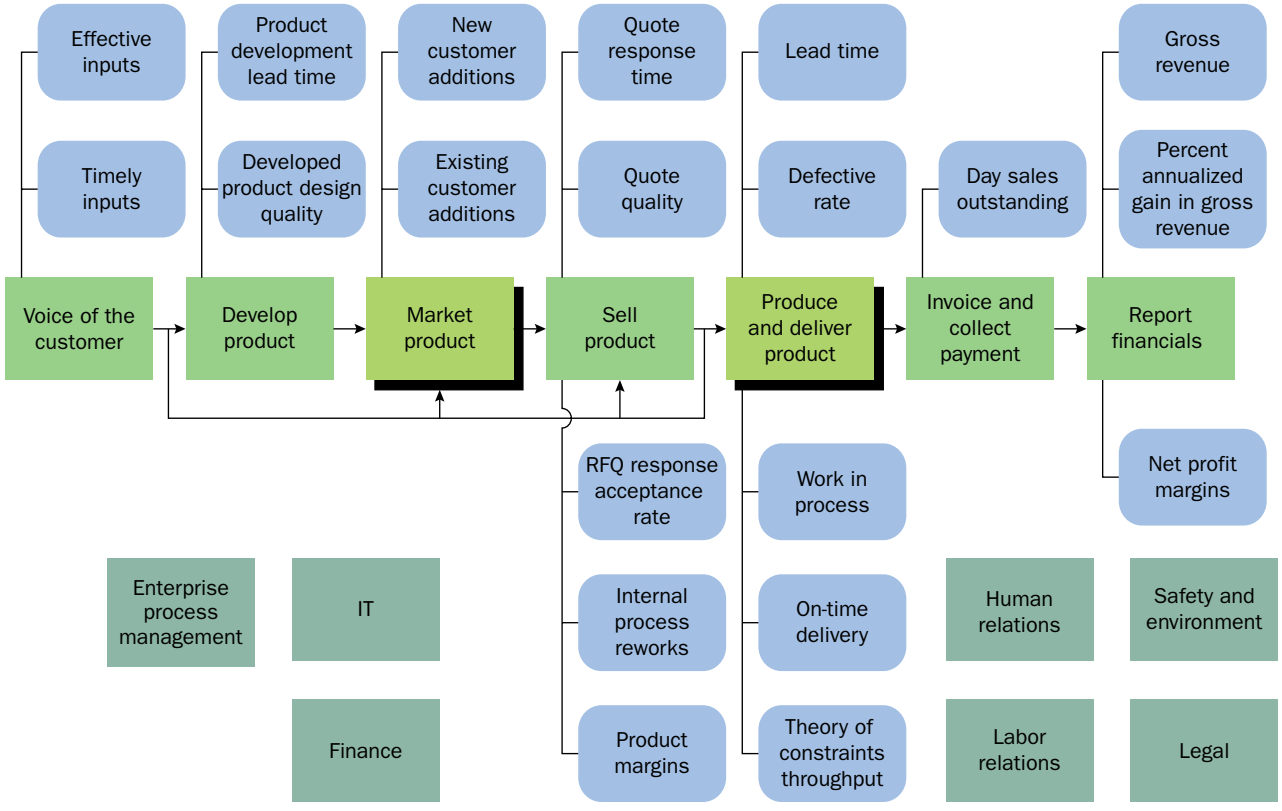
1. Predictive performance scorecards.
2. Analytically and innovatively

Figure 1. **The Integrated Enterprise Excellence (IEE) business management system**



DMADV = define, measure, analyze, design and verify
MSA = measurement systems analysis
E-DMAIC = enterprise process define, measure, analyze, improve and control
P-DMAIC = project define, measure, analyze, improve and control

Figure 2. **Integrated Enterprise Excellence value-chain example**



determined strategies.

3. Process improvement efforts to benefit the entire business.
4. Efficient and effective control mechanisms to avoid problems.

Business control system

In Six Sigma's process improvement roadmap (define, measure, analyze, improve and control [DMAIC]), control is listed as the procedure's last phase. This phase was included so processes do not revert to previous methods after a project was completed and the spotlight taken off the improvement activity.

Similarly, businesses need a control mechanism so documented, agreed-to procedures are followed correctly. There must be an understanding that these procedures will need systematic enhancement over time in a never-ending pursuit of the three Rs of business.

The Integrated Enterprise Excellence (IEE) system (Figure 1) addresses this need to orchestrate overall business operations with process improvement efforts. Within this system, there are two DMAIC roadmaps: project DMAIC (P-DMAIC) and enterprise process DMAIC (E-DMAIC).

In this system, the P-DMAIC roadmap connects with the E-DMAIC roadmap in the business system's improve phase because process improvement projects are one of the two ways to improve the overall enterprise. The other improvement method is through a design project.

In defining the P-DMAIC roadmap execution,[4] some additional drill-down steps are included in the measure phase. I first included these steps in *Implementing Six Sigma*[5] when I attempted to place tools in the roadmap steps as General Electric (GE) did.

For example, GE put tools such as failure mode and effects analysis, flow charting, cause-and-effect diagram and cause-and-effect matrix

into the measure phase. These tools did not seem to relate directly to measure; hence, I collectively categorized these tools as "wisdom of the organization" in the measure phase drill-down. Similarly, I broke down other measure phase components into more descriptive steps.

The E-DMAIC roadmap portion of this IEE system provides the framework for an enhanced business management system that structurally integrates the four desired components of an overall business management system described earlier.

One aspect of the overall E-DMAIC system that addresses organizational control is the value chain, which integrates operational procedures with predictive performance metrics (that is, a component of the define and measure phases of the E-DMAIC system).

Figure 2 (p. 31) shows an example of the IEE value chain in which organization and control procedures are presented by clicking the drill downs of the rectangular boxes, while predictive 30,000-foot-level performance metrics[6] are displayed as a business scorecard by clicking on the oblong boxes.

Aspects of the E-DMAIC control phase activities include:

- Deploying enterprise standardization so important process elements are consistently performed in the best possible way.
- Ensuring effective business process audits and business process management with their documented procedures in the value chain.
- Institutionalizing process-error proofing wherever possible.
- Ensuring the 30,000-foot-level scorecard and dashboard metrics with improvement objectives are tracked and reported correctly and effectively, and incorporated into performance plans.
- Conducting regular monthly management meetings and giving inputs, when appropriate, to how data are presented and analyzed.

The organizations cited earlier might have focused on one primary metric rather than overall enterprise success, which led to significant problems.

A value chain breaks down commonplace organizational silos in which this business fundamental performance map provides scorecards and procedures that have ownership. Linking performance measurements with controls in the value chain provides a framework to prevent unhealthy behaviors, which can lead to detrimental consequences. The system provides structure for organizational movement toward achievement of the three R's of business.

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FORREST W. BREYFOGLE is founder and CEO of Smarter Solutions Inc. in Austin, TX. He earned a master's degree in mechanical engineering from the University of Texas. Breyfogle is the author of a series of books on the Integrated Enterprise Excellence System. He is an ASQ fellow and recipient of the 2004 Crosby Medal.