

Six Sigma and DOE Implementation

by Kim Niles

The University of California San Diego's (UCSD) Six Sigma Black Belt Certification Program recently uncovered Design of Experiments (DOE) training statistics from a large corporation before and after its switch to Six Sigma. Two hundred engineers trained before the switch produced ZERO DOE's over the next year. After the switch they began producing numerous DOE's on almost a daily basis. This paper will attempt to explain what makes the difference.

Creating a Paradigm Shift

The real power behind DOE is not easily seen. Understanding the true power of statistics, especially DOE, requires a paradigm shift in thinking. Six Sigma initiates this shift by promoting statistical thinking and understanding of the economics of reducing variation. The use of wide-ranging and interacting data to gain comprehensive situational understanding opposes one's natural born tendency to change one factor at a time (OFAT) and "see" what happens.

A recent DOE observed by the author generated over twenty pages of plots, analysis, and predictions, and nearly solved a half-million-dollar process problem, as one might expect. However, this came after an untrained engineer had written a report one paragraph long explaining how the same experiment was a failure. The engineer had accidentally picked a 3^2 full factorial in designing his experiment and had no idea it could be analyzed in any way other than in the first order. What he saw in the data was all he thought he had. The human eye for example could not see interaction effects.

Interdependent Environmental Factors

The following environmental factors exemplify key aspects of interdependency between Six Sigma and DOE where DOE implementation would obviously be facilitated. One can also see how traditional DOE training programs might lack any or all of these factors:

- 1. Customer communication.** DOE's produce high-level situational understanding, which often promotes customer communication and customer focus.

2. **Top-down support.** Top management's support is mandatory for success. Edicts; project selection, review, and management; resource allocation; deployment plans; and incentive programs all help facilitate project and DOE implementation.
3. **Superior training.** Six Sigma provides approximately twenty times more classroom training time than traditional non-Six Sigma DOE-related training, plus hands-on projects and mentoring.
4. **Team and structure advantages.** Team synergy is critical for brainstorming, planning, collecting data, understanding and standardizing results, and communicating. Hierarchical team-oriented structures with full-time resources promote accountability and wide-ranging input. Black Belts and Master Black Belts provide technical support. Green Belts are trained and motivated to take data, learn, and see that DOE's and other related techniques are implemented successfully.
5. **Quantifying benefits.** Six Sigma and DOE both require an understanding of cost relationships. These relationships also include soft costs associated with variation reduction.

Addressing Fears

DOE's are not intuitive; experimental risks need to be assessed and managed with regard to costs and gains expected. There are many related fears that inhibit DOE implementation. Six Sigma programs naturally help remove these fears as outlined above. Most of these fears are related to:

- Cost/ROI.
- Training or experience.
- Design or center point selection.
- Control factor or factor range selection.
- Resources for analysis and data taking.
- Management buy-in or authority to perform the experiment.
- Cooperation from other key individuals.
- Understanding of how to perform software and/or hand analysis.
- Sample size selection per run.
- Losing data.
- Response factor selection.
- Noise factor allocation.
- Communicating through protocols and reports.
- Non-normal data.
- Making assumptions or managing statistical confidence.

To illustrate how complex and difficult overcoming these fears can be, let's look at the cost/ROI fear in more detail. This fear is usually the result of incorrect expectations. While some experiments may have the potential to result in costly interruptions to production or product that needs to be destructively tested (can't

be resold), it is very rare that managed costs outweigh real obtainable benefits. However, DOE's are often re-designed to minimize costs.

When cost is a concern, more clarity in the test objective, more confidence in the factors or ranges to be tested (including response factors), or more efficient test models or strategies need to be developed as follows:

- **Reaffirm test objective.** How well does the objective tie to the customer or real need? What assumptions have you made or can you make?
- **Reconsider test conditions.** Is the experimental space likely to produce acceptable or resalable product? Expectations are driven by factor and range selection in accordance with fundamental principles (hierarchical ordering, effect sparsity, effect heredity). Power and/or signal-to-noise analysis, "expert" advice, brainstorming, or other mean and dispersion (robustness) methods all help in setting test conditions. Confirm that the response factor(s) are well correlated with the control factors being changed.
- **Reconsider the model.** Different types of designs (screening, response surface, mixture, D-optimum, nested, inner and outer arrays, etc.) and resolutions (III, IV, or V best) fit different needs more efficiently. Block factors less likely to have an effect (especially noise factors). Center point use builds confidence through error estimation.
- **Reaffirm test strategy.** Some cost strategies include starting with statistically weak designs to augment later if needed, using many small DOE's vs. few large, screening to response surface progressions, wide to narrow range progressions, Taguchi's resolution III approach (dig wide, not deep; improve variation, then shift the mean), Shainin's visual methods, or using pre-existing data in virtual designs or for making assumptions.

Embracing Six Sigma and DOE

DOE implementation requires a lot more than teaching mathematical concepts and graphical plotting techniques. Author Stephen Covey outlines how change requires knowing what to do, how to do it, and having the desire to do it. Embracing Six Sigma and DOE together creates an interdependent environment that enables full coverage of these principles. When this happens, we are well on our way toward saving the billions of dollars that top Six Sigma companies are reporting.

About the Author

Kim Niles is nearly finished with his master's degree in Quality Science from California State University, Dominguez Hills, with emphasis in Six Sigma and Process Management. He received his bachelor's degree in 1984 in Applied Arts & Sciences from San Diego State University through the Industrial Technology Department. He has a wide range of experience using all types of Designed Experiments and has personally performed more than 130 experiments producing an estimated savings to several San Diego companies in excess of six million dollars.

Currently a Quality Engineer with Delta Design, Inc., Niles is an officer in three engineering societies (ASQ703, SAMPE, SDEC). He also serves on the advisory boards for UCSD's Six Sigma Black Belt Certification Program and Palomar College's Quality A.A. degree and certificate program.