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SIX SIGMA

The Science In Six Sigma

by **Jeroen de Mast and Søren Bisgaard**

Contrary to popular perception, some of the less important aspects of Six Sigma are the much heralded Six Sigma concept itself—the conformance quality target of 3.4 defects per million opportunities—and the sigma scale of quality. One of the more important contributions of Six Sigma is the structure it provides for managing an organization's improvement initiatives. It also prescribes a method to guide project leaders and offers an array of analysis tools.

In 50 Words Or Less

- **The structure Six Sigma provides for improvement projects is more important than the ultimate goal of 3.4 defects per million opportunities.**
- **Many parallels can be drawn between Six Sigma's innovative and experimental characteristics and the scientific method.**
- **Project leaders should have good research skills to develop causal explanations.**

When Six Sigma was introduced by Motorola in the 1980s, it was not a completely new approach. It built on field tested and proven principles that were developed in quality engineering, management and industrial statistics throughout the 20th century. Six Sigma's methods are based soundly in science, making a case for Six Sigma based on its core principles rather than its rhetoric.

Six Sigma elevates problem solving and quality improvement to a professional level by training Black Belts (BBs) and Green Belts (GBs) in an attitude that can be described as scientific.[1] Improvement actions are not based on perception or anecdotal evidence. Nor are they based on the notion of an omniscient engineer sitting behind a desk and deriving a remedy from clever deductions based on his or her technical knowledge.

The attitude Six Sigma endorses is an open-minded eagerness to study a process and learn from it and a willingness to correct one's misconceptions on the basis of experimental results and empirical feedback. This iterative inductive-deductive behavior is, in a nutshell, the tenor of Six Sigma's methodology, and it emphasizes the project leader's need for good research skills.

Table 1 gives an overview of Six Sigma's define, measure, analyze, improve and control (DMAIC) roadmap, a step-by-step procedure for improvement projects. The roadmap provides BBs and GBs with a checklist that helps them ask the right questions and deploy appropriate tools. It also helps structure progress reports and facilitates project tracking.

In addition to DMAIC, Six Sigma offers an extensive collection of tools and techniques—some statistical and others nonstatistical—BBs and GBs use to attain intermediate results during DMAIC deployment.

Causal Modeling, Discovery And Justification

Central to a scientific attitude toward process improvement is the idea that to control a system we need to understand how it works. Without understanding the mechanics of a problem, we likely are just fighting symptoms or instituting makeshift solutions. To understand a system means to have a theory that relates the system's behavior to its causal factors. In Six Sigma jargon this is expressed symbolically as:

$$y = f\,(x1, x2, \ldots, xn)$$

In this equation, y is the system's behavior and typically is a project's critical to quality (CTQ) characteristic. To control the CTQ we need to understand the factors that affect the process—the causes of its behavior. Those are the x's.

Understanding the causal factors provides us an explanation of the problem. Discovering and quantifying causal relationships as a means to explain, predict and control occurrences generally is seen as the main purpose of empirical inquiry. Thus, Six Sigma improvement projects and empirical science share the same objective: developing causal explanations.

Where causal explanation is the intended result of scientific inquiry, the philosophy of science sees its process as a repeated alternation of discovery and justification. Figure 1 is an adaptation of George Box's sawtooth model, a visual representation of this process.[2]

Learning is viewed as an interaction between observations and theories developed to explain them. Theories (hypotheses, ideas, conjectures) are inspired by observations. In the sawtooth model, this is called discovery.

TABLE 1 Six Sigma's Define, Measure, Analyze, Improve and Control Method

Define	Select problem and perform cost-benefit analysis.
Measure	Translate the problem into a measurable form, gather data and assess the current situation.
Analyze	Identify influence factors and causes that determine the critical to quality (CTQ) charactersitic's behavior.
Improve	Design and implement modifications to the process to improve the performance of the CTQs.
Control	Adjust the process management and control system to ensure improvements are sustainable.

One of the qualities that makes a theory scientific is that it is not unquestionably accepted but is put to a test. Implications are derived from it and compared with observations. In the sawtooth model, this process is called justification.

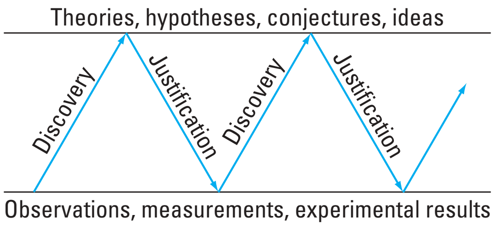
The same elements form the basis of Six Sigma's DMAIC method.[3] In Six Sigma projects, discovery is facilitated by tools such as brainstorming, exploratory data analysis, multi-vari studies, and product and process examination, but there are more approaches that can be used for hypothesis generation in improvement projects.[4] Experimentation, regression analysis and other procedures for confirmatory data analysis are Six Sigma's techniques for justification.

Core Elements Of Sound Method

Several additional elements of Six Sigma represent its sound base in scientific method:

- Precise, operational problem definitions.
- Emphasis on quantification.

FIGURE 1 Sawtooth Model of Inquiry



- Data based diagnosis.
- Daring and imaginative generation of new ideas.
- An emphasis on data based testing.

Precise, operational problem definitions. Often, targets and strategic goals are formulated in abstract terminology: "customer satisfaction," "operational excellence," "become an empowered organization," "have best in class performance." Such objectives state intention but are too vague to be acted on. Goals must be translated into specific and tangible terms—for example, in the form of CTQs or performance indicators.

Six Sigma insists on precise, operational problem definitions developed before attempting to solve a problem. It has borrowed this practice from science. An objective is operationally defined if it is so tangible people know precisely what to do and measure to establish whether the objective is met. In Six Sigma projects, operational definitions relate a CTQ to a procedure used to measure it. They also provide definitions of the experimental unit and what constitutes a defect.

Emphasis on quantification. Most interesting problems are trade-off problems—customer satisfaction vs. production costs, security vs. efficiency or customer intimacy vs. efficiency. With most of these, the answer isn't a matter of either/or—it's a matter of how much of one and how much of the other. If problems are not quantified, the trade-off nature is obscured and people tend to treat them as either/or problems and frequently politicize them.

Data based diagnosis. After a precise problem definition, preferably in quantitative terms, it is still too early to develop solutions to the problem. As John Dewey stated, "The essence of critical thinking is suspended judgment; and the essence of this suspense is inquiry to determine the nature of the problem before proceeding to attempts at its solution."[5]

Six Sigma prescribes a data based diagnosis before trying to solve a problem. The diagnosis, often in the form of a baseline study or process capability analysis, shows the nature of the problem and guides the search for solutions. It also helps with prioritizing. The proverbial "every little bit helps" does not apply in business. With limited time and resources, people must prioritize and focus on the strategically important issues. In Six Sigma terminology: Each minute spent on the trivial many issues is a waste; it is the vital few issues that determine the success of a project.

Daring and imaginative generation of new ideas. It is true that doing things right the first time is one of Six Sigma's goals, but this adage concerns routine activities. For a nonroutine activity, such as an improvement project, the pursuit of doing things right the first time is inappropriate. This attitude assumes perfect and complete knowledge.

Many of the decisions BBs or GBs make are intelligent guesses at best. That is why inquiry should not be conceived as purely vertical thinking, in a straight line from problem to solution. Instead, it is a cycle of forming tentative ideas (discovery) and their experimental verification (justification).

The generation of new ideas should be experimental, inventive and speculative. Too much emphasis on objectivity and certainty results in a bias toward conservatism and reuse of earlier tried and safe ideas, not breakthroughs. Objectivity and correctness are guaranteed by the way ideas are tested and justified, not by the way they are generated and discovered.

An emphasis on data based testing. Improvement plans, strategies and business models are based on many untested hypotheses and assumptions. No one is likely to have sufficient knowledge to be consistently right the first time, and testing and feedback are crucial.

We should verify our ideas through experiements for two reasons: first, to eliminate misconceptions, misjudgments and myths; second, to fine-tune a roughly developed idea to the specifics and complications of the real-life situation. Ideas that are not tested before they are implemented often are misconceived, appear to be based on a wrong notion of proportions and priorities, or fail because of ignored contingencies.

Experimental, Not Deductive, Problem Solving

Six Sigma prescribes a disciplined, scientific attitude toward problem solving. Such an approach costs time and effort, and less disciplined individuals often resort to quick and dirty procedures and jumping to conclusions.

Quickly jumping to conclusions appears to work when people don't bother to collect feedback about the effectiveness of their solution. Close examina-

tion reveals many supposedly successful projects in fact either solve the wrong problem or tackle the right problem with a solution that only works in theory or a solution that is not sufficiently refined based on feedback.

On the other hand, many problem solvers are too rigid. Among these are deductive theoreticians. They solve problems by gathering knowledge and deriving solutions via analytical thinking and mathematical derivations. After careful consideration, they come up with a detailed solution.

This deductive approach can be successful only if the solution is indeed implied by the knowledge at hand. Such situations are rare; existing knowledge almost always captures only part of a system's aspects, ignoring numerous specifics. Not until the final stage do theoreticians test their ideas and give reality a chance to correct misconceptions. Theoreticians aim for "first time right" solutions. They avoid confronting their ideas with reality, preventing themselves from gaining new insights and learning. Their beautiful theories often are killed by ugly facts.

A variant of the deductive theoretician is the idealist. Idealists develop solutions based on ideologies, dogmas or moral principles. If their improvement plans fail, they tend to blame it on people or the system—customers are stupid and people should not behave the way they do. They rarely conclude their ideas might have been flawed.

Another variant of the deductive theoretician is the meeting addict. Meeting addicts make decisions by conferring with others, collecting different opinions and carrying out long discussions and negotiations about which opinion is the best. While BBs or GBs might seek input from experts, they will eventually test their proposed solutions against reality, try various ideas and learn which has the most value. Meeting addicts, however, deceive themselves by believing discussion alone can single out good ideas from less valuable ones.

TABLE 2 Seven Core Principles Of the Six Sigma Method

1.	Improvement actions are based on causal modeling.
2.	Inquiry alternates between discovery and justification.
3.	Problems are defined in precise operational terms.
4.	Problems are quantified if possible.
5.	A data based diagnosis precedes attempts at solving the problem.
6.	Idea generation is daring and imaginative.
7.	Hypotheses must be tested against empirical data.

The approach these deductive theoreticians follow goes back to Plato. It has appealed to philosophers and others for centuries, probably because of its apparent rigor and elegance. It is effective when applied to reasonably simple systems in which the mechanism is completely known and the response to stimuli is predictable. This characteristic makes the deductive approach reasonably successful in mechanical physics, which has tempted many to apply this mind-set to more complex, less known or less predictable systems. To deal with complex, reasonably unpredictable systems, both analysis (deduction) and synthesis (induction) are needed.

Six Sigma: Democratization Of the Scientific Method

The principles in Table 2 are embedded in the DMAIC structure and supported by many of the tools and techniques Six Sigma offers.[6] These principles make Six Sigma more important than the attainment of 3.4 defects per million opportunities or quality improvement in general.

Six Sigma embodies skills that are imperative requirements of modern professionals. Data based decision making, sound inquiry and the ability to formulate a precise problem definition are among the skills knowledge workers—engineers, managers, marketers and salespersons—must have. As George Box aptly said, the proliferation of Six Sigma amounts to a "democratization of scientific method."[7]

Organizations that use Six Sigma invest resources and effort to continually improve operations such as manufacturing, transactions, healthcare processes, and even sales and accounting processes. These organizations employ people trained to have an innovative mind-set and professional problem solving and quality improvement skills.

In a global economy in which innovative capabilities and continual improvement are ever more important drivers of a company's competitiveness, such skills are strategically vital.

REFERENCES

1. Karen H. Wruck and Michael C. Jensen, "Science, Specific Knowledge and Total Quality Management," *Journal*

of *Accounting and Economics*, Vol. 18, 1994, pp. 247-287.

2. George P. Box, “Statistics as a Catalyst to Learning by Scientific Method Part II—A Discussion,” *Journal of Quality Technology*, Vol. 31, No. 1, 1999, pp. 16-29.

3. Jeroen de Mast, “Quality Improvement From the Viewpoint of Statistical Method,” *Quality and Reliability Engineering International*, Vol. 19, No. 4, 2003, pp. 255-264.

4. Jeroen de Mast and Marcus Bergman, “Hypothesis Generation in Quality Improvement Projects: Approaches for Exploratory Studies,” *Quality and Reliability Engineering International*, Vol. 22, No. 7, 2006, pp. 839-850.

5. John Dewey, *How We Think*, Health & Co., 1910, reprinted by Dover, 1997.

6. Henk De Koning and Jeroen de Mast, “A Rational Reconstruction of Six Sigma’s Breakthrough Cookbook,” *International Journal of Quality and Reliability Management*, Vol. 23, No. 5, 2006.

7. George P. Box, “Scientific Method: The Generation of Knowledge and Quality,” *Quality Progress*, January 1997.

ADDITIONAL READING

Bisgaard, Søren, and Jeroen de Mast, “After Six Sigma—What’s Next?” *Quality Progress*, January 2006.

Box, George P., and Soren Bisgaard, “The Scientific Context of Quality Improvement,” *Quality Progress*, June 1987.

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