Six Sigma Quality: Experiential Learning

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Six sigma, a management philosophy developed at Motorola by Bill Smith in 1985 (Chadwick, 2004), consists of the rigorous application of statistical tools to improve profits, reduce costs, and improve speed. As Harry and Schroeder (2000) said, "Six Sigma is about making money." The track record of major firms that first employed six sigma is impressive. General Electric in 1999 reported in its Annual Report that six sigma had increased after-tax earning by $2 billion. Larry Bossidy (CEO at Allied Signal) brought the firm back from near bankruptcy by employing six sigma. Others such as Polaroid, Asea Brown Bovari (ABB), and Ford Motor Company have reported similar results. In a careful review of annual reports, Waxer, (ND) found that savings attributed to six sigma between 1986 and 2000 ranged from 1.2% to 4.5% of annual revenue for a number of Fortune 500 firms. Bolten (2003) reported that Idaho National Engineering and Environmental Laboratory achieved six sigma savings of over $40 million in 18 months. These results reflect the differences between six sigma and total quality management (TQM) that was introduced in the United States in 1980 by W. Edwards Deming. TQM, despite considerable emphasis in firms across the industrial world, has frequently not lived up to its expectations (Repenning and Sterman, 2001).

Six sigma is a sequential process that begins by asking hard questions regarding level of defects, time required to perform operations, and customer expectations. The answers provide the "working area of operations" for six sigma projects. It is important to understand that six sigma projects are seldom, if ever, incremental ("kaizen") quality improvement that is so characteristic of TQM. Six sigma projects are all about robust change — changes that lead to 50% or more improvement in quality and speed.

Measurement and Process of Six Sigma

A classic, standard measurement in six sigma is defects per million operations (DPMO). DPMO is calculated by multiplying an error rate by one million and dividing by the number of ways an error can occur. For example, if we find that historically 10% of all students get an "F" in a particular course and if the ways they get an "F" are poor test scores, inadequate preparation, or excessive absenteeism, then we have three "opportunities" and a DPMO of 33,333. That is approximately 3.33 sigma in six sigma terminology (Six Sigma Academy, 2002). It should be noted that one can convert DPMO values to sigma by consulting a normal probability table, realizing that six sigma shifts the mean 1.5 sigma to reflect the differences in long and short run variation. The target for six sigma projects is to increase Sigma (reduce DPMO) to a level of Six Sigma – a DPMO of 4.3 or less. That, of course, is an improvement in quality of almost 8000%! As this juncture the reader might be tempted to ask, "Has anybody actually achieved quality performance at that level?" The answer is a resounding yes. Motorola, GE, ABB, Polaroid and number of smaller firms have achieved six sigma quality. The bottom-line payoff for this kind of substantial improvement is attractive. The costs of quality at three sigma are 25–40% of sales (revenue) and at six sigma are less than 1% of sales (Harry and Schroeder, 2000).

The process of six sigma begins with a specific definition of the quality or cost problem to be resolved. This definition includes measurement of the problem (DPMO) and existing costs attached to the problem. Targets are then set for improvement and the process begins. Most often six sigma initiatives in industry are managed by highly-trained practitioners called "Black Belts." These individuals — frequently engineers — have received at least 80 hours of classroom training in six sigma techniques and have participated in prior projects. Their role is to provide expertise and to function as the project manager. Black Belts are often assisted by Green Belts who have had 40 hours of training.

A six sigma project usually has five steps with an unavoidable acronym: DMAIC.

- **Define (D):** In this phase customer needs (internal or external) are identified as well as the specific process or product to be improved.
- **Measure (M):** The measure phase determines the baseline and target performance of the process, inputs and outputs, and validates the measurements to be employed.
- **Analyze (A):** Analysis identifies the root causes of the problem. One common output is a very detailed map showing all the steps in the process under study.
- **Improve (I):** This is the creative step. Ideas are developed to best resolve the targeted problem, and the ideas are tested to validate the solution.
- **Control (C):** The control phase documents the solution, assigns responsibilities for performance of the needed changes, and tracks the results over time.

Six Sigma in the Classroom

The author of this paper has been teaching quality management (MGMKT 650) at a regional university in the Midwest for 10 years. This is a senior level required course for management majors, although a number of MBAs take the course as an elective. Occasionally students from the College of Technology also take it. The author had previously been the executive responsible for the quality and manufacturing functions at three steel companies and has been a member of the American Society for Quality and the Society of Manufacturing Engineers for roughly 25 years.

For seven years the course was taught in a traditional format with lectures, homework problems, outside speakers, and case studies. Results were about what one might expect for a quantitative, required course for management majors. The author decided to change the course substantially four years ago because of the burgeoning use of six sigma in business – not just manufacturing firms, but service industry firms and health care organizations.

The course redesign included the adoption of Jay Arthur's Six Sigma Simplified workbook (Arthur, 2001) in addition to a standard quality management text and the creation of student teams to work on real quality problems in the surrounding community. The first year the author recruited all the firms for the student's projects by making speeches about the benefits of six sigma at community organizations and twisting the arms of friends and acquaintances in the local Chamber of Commerce. This approach attributes to the enormous success of similar kinds of projects by one of the author's mentors — Gene Woolsey at Colorado School of Mines. Woolsey's success with these kinds of projects has been nothing short of legendary. His teams over the years have created solutions for real problems in real organizations worth hundreds of millions of dollars (Woolsey, 2003). In the second and third year, the students were required to locate their own consulting clients. This was not a problem as most of the teams were able to secure an agreement with family businesses or organization for which the students worked.

Although some of the projects differed slightly in approach, most followed a similar sequence as described in Arthur's workbook. This sequence, of course, has its own unique acronym that differs a bit from classic six sigma: FISH (Arthur, 2001).

- **Focus (F):**
  - Use the voice of the customer, business, and employee to identify desired long and short range objectives.
  - Identify and track the indicators.
  - Set targets for improvement.
- **Improve (I):** Initiate process improvements.
- **Sustain (S):** Sustain the improvements.
- **Honor (H):**
  - Honor your progress.
  - Review and refocus objectives, teams and improvement efforts as required.

On the first day of class in MGMKT 650, students were given a quick overview of six sigma and were encouraged to think about what kind of firms and projects they'd like to work on during the semester. Students then self-selected their teams (usually 3–4 students per team). The first outside assignment (second week of the semester) was to meet with the manager of the firm and define a quality problem that the manager deemed important. At this meeting students also collected descriptive and historical information about the firm and its industry. Students presented this information in class in the third week of the term, and the instructor worked with them to refine the description of the problem and the kind of data needed to solve it. Generally, the data included the types of defects and frequency counts along with a preliminary estimate of the cost of poor quality (COPQ) (Breyfogle, 2003).

The students were then taught how to carefully define problems, using Pareto analysis, and also how to collect the data to estimate baseline DPMO. Later in the semester, students were taught how to identify *core* problems using an Ishikawa (fishbone) diagram and also how to develop solutions for the problems using the nominal group technique in conjunction with members of the client firm. Initial recommendations for solution of the quality problems were presented in class by each team, and the solutions were debriefed by the instructor and other members of the class. These tentative solutions were then discussed with the firm's management, and cost-benefit analyses were developed. Students then prepared a formal consulting report for the client. The students were required to obtain an acknowledgement of the recommendations from the client and include it in the final report given to the instructor for grading. Students who were fortunate enough to work on projects yielding more than $10,000 in annual savings for the clients and who achieved 85% of the points in the entire course were certified as "six sigma Green Belts."

Results of the first three years of operations are shown in Table 1.

The projects summarized in the table varied widely in terms of industry, size (dollar savings), and type of problem. The largest savings on an individual project was at Sherwin Williams Automotive Paint Division: $1,033,682 (nationwide). This project resolved the longstanding problem of improper mixing of specific automotive finishes (wrong color). The solution–developed by the team—was to create a Poka Yoke (foolproof) color-coding scheme for the paint formulas so that it became virtually impossible to select the wrong formula. At Pitt Plastic in the fall 2002 semester, the student teams tracked scrap rates on a number of plastic bag manufacturing lines, diagnosed the reasons for scrap, and eventually developed a new maintenance schedule for the bag-making lines so that savings of $140,000 per year were achieved. The Mount Carmel Hospital project in spring 2003, which yielded an estimated savings of $124,904, was to create a simple personnel scheduling algorithm for the emergency room

Table 1. Student Project Results

Semester	Name of Firm	Type of Firm	Estimated Annual Savings
Fall 01	Digital Lighthouse	Call Center	$7,200 (1)
	Freeman Hospital	Hospital	$4,055
	Depco	Educ. Products	$11,185
	PSU	Financial Aid Office	$16,706
	True Value	Hardware Store	$25,000
Fall 02	Names/Numbers	Publisher	$24,511
	Pitt Plastic	Manufacturer	$140,000
	Data Technique	Consulting	$20,304
	Pitsco	Educ. Products	$1,360
	Class Limited	Social Service	$2,000
Sp. 03	Mount Carmel	Hospital	- NA -
	Mount Carmel	Hospital	$124,904
	Control Vision	Manufacturer	$6,032
	Class Limited	Social Service	$2,272
Fall 03	Sherwin Williams	Manufacturer	$1,033, 682
	Cessna	Manufacturer	(2)

(1) Estimated annual cost savings to one of the *customers* of the client firm was more than $2,000,000.

(2) Estimated annual cost saving to Cessna was unknown, but the DPMO was reduced (improved) by a factor of 2:1.

based on historical patient demand so that unnecessary personnel were not scheduled.

Conclusions

The results of this four-year experiment have been successful from the viewpoint of the client firms. Total estimated annual savings were more than $1,400,000. The author believes that this kind of learning (experiential) can be a direct benefit to the larger society outside the ivy walls of academe, and, thus, probably meets the test of applied research described by Ernest L. Boyer in *Scholarship Reconsidered.* (Boyer, 1990). Accolades from the community have been substantial, and other courses in six sigma have been developed under the sponsorship of the Mid-America Manufacturing and Technology Center for area businesses (Box, 2003).

From a student perspective, the results have been mixed. Many students – particularly those who earned Green Belt certification – said it was the "best course I have ever had at Pittsburg State University." Others, constrained by family and work responsibilities, found the work load somewhat overwhelming. Students have estimated that the six sigma projects have generally required about 40–50 extra hours of work during the semester above and beyond normal classroom demands.

As the instructor, the author has mixed emotions about this kind of course. First and most important, this course is an opportunity to give back to the community while teaching students a set of skills that can be employed in virtually any kind of organization after graduation. Second, this is a labor-intensive course for an instructor because of the community interactions required and onsite supervision of student teams. This kind of experiential class raises two important considerations. First, is it reasonable to offer this kind of opportunity to students who are constrained by family and job demands? Many of our full-time students work 20–30 hours per week, and about 40% of them are married with children. Second, how does spending the substantial extra time required to teach this kind of course tie in to the instructor's annual performance report? This is a service activity and, at least in our university, teaching and research are valued highly while service activities receive little recognition.

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