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TEACHING QUALITY IN HIGHER EDUCATION

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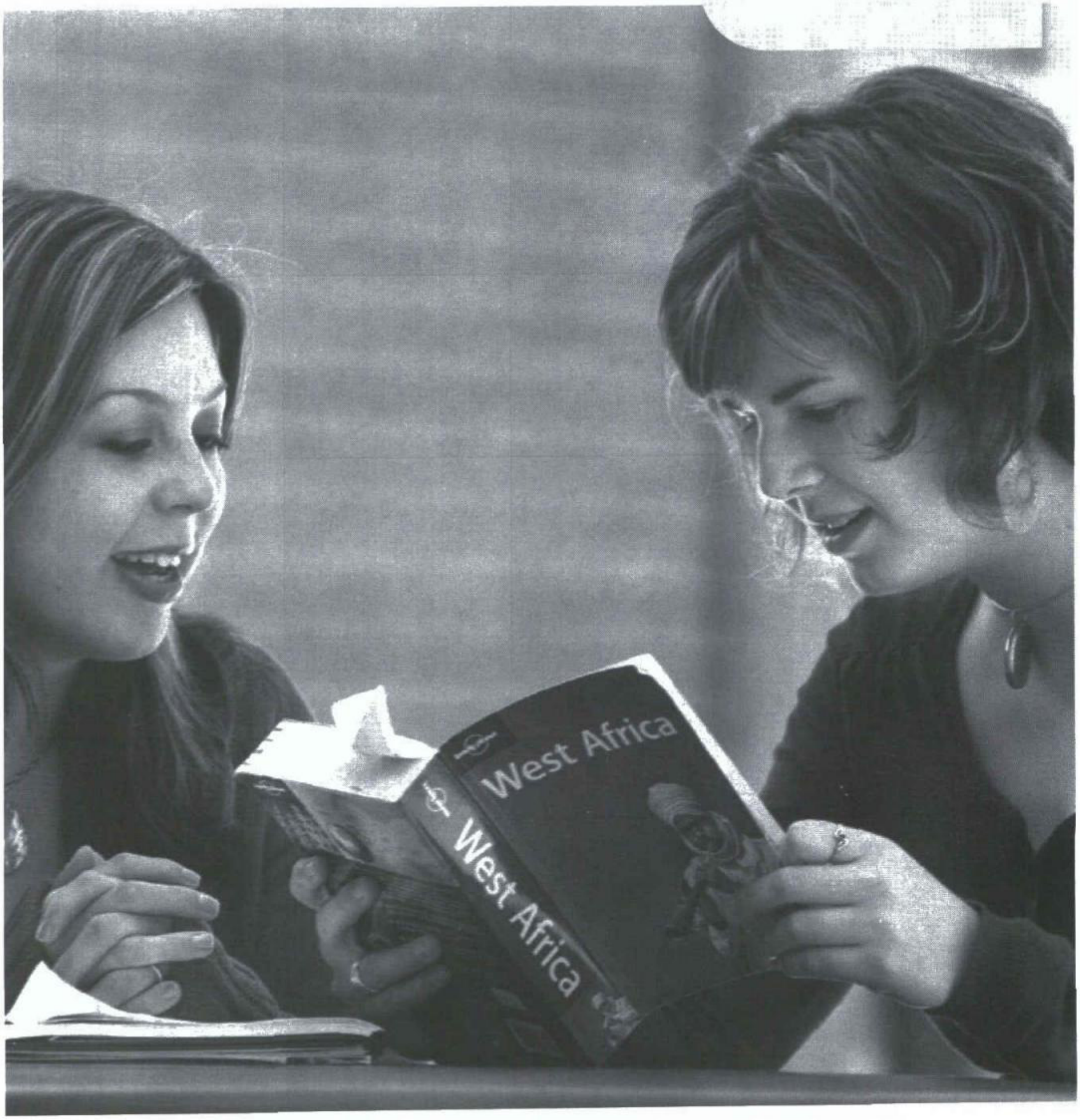


INTRODUCTION

The Quality Assurance is an engineering discipline which governs the quality, safety, economy, serviceability, maintainability and reliability of products and services (1). The term Quality Engineering signifies body of knowledge comprising the theory and application of both statistical and management methods employed in creating quality in goods and services (2). Both disciplines overlap and share common building blocks. The Quality education in four-year universities generally focuses on quality engineering topics in the industrial/manufacturing engineering field. On the other hand, a few number of two-year colleges adapted teaching at the Quality Technician level. BCC is one of the few community colleges that offer both a terminal Quality Assurance (ITQA) degree and a transferable Quality Engineering (ESQA) degree by using most of the same quality topics and courses. In recent years, some universities and colleges along with professional organizations have been offering the same quality tools packaged with Six-Sigma, or Lean Six-Sigma concepts. In this paper, BCC course offerings related to quality concepts are given in special boxes to help the reader to link the quality concepts to the courses in the ITQA and ESQA programs.

QUALITY SYSTEM

Figure 1 illustrates a general body of knowledge for quality. The Quality Management Concepts are the foundation of quality. They are also referred as Total Quality Management (TQM) philosophy which includes contributions from quality gurus such as Deming, Juran, Crosby, and Taguchi. TQM also includes newer concepts such as Quality Circles, Teamwork, and Motivation.

Along with the TQM, Quality Engineering Techniques and Quality Improvement System make the Total Quality System which is responsible of making services and products to meet the needs of customers.

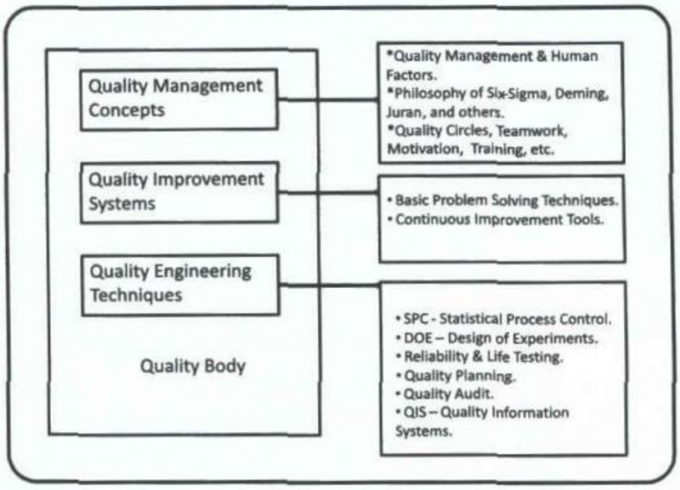


Figure 1. Body of knowledge of Quality.

A Quality Improvement System (QIS) consists of the core concepts, the cycle of quality improvement, and the managing elements to carry out the continuous improvements and changes necessary in today's competitive environment. The main goal of quality improvement is the reduction of variability in products and processes (4). The core concepts which should be placed at the center of quality improvement cycle are (3):

> Most of these concepts are suitable to teach in small projects and group activities format. Quality Assurance, Quality Management related topics are bundled in the SENIOR PRACTICUM course and the SIX-SIGMA TOPICS course. These two courses are core courses in the ITQA program.

- Definition of quality: meeting the requirements
- Customer impact: cost of ownership
- Operating impact: the cost of quality
- Improvement process: defect prevention
- Responsibility: each employee
- Performance standard: zero defect
- Environmental impact: the cost to society.

In recent years, a structured five-step problem solving procedure is introduced in conjunction with the six-sigma philosophy. DMAIC process is an acronym for the five steps, Define, Measure, Analyze, Improve, and Control. DMAIC can also be used in all aspect of quality improvement activities (5).

The Quality Engineering Techniques are the major tools needed for quality practitioners and managers. Most of the college level courses cover these techniques and many great textbooks are available (8).

QUALITY ENGINEERING TECHNIQUES

The term Quality Engineering refers to the discipline that compromises the mathematical methods, management and costing approaches, statistical problem-solving tools, computer information systems and all related sciences behind them that are needed in designing, producing, delivering, servicing, and recycling products and services (2). Traditionally, the primary objective of quality engineering efforts has been the systematic reduction of variability in the key quality characteristics of the products and services. Lately more emphasis has been given to the environmental considerations and sustainability (7).

SPC : Statistical Process Control employs basic probability laws and statistical methods to control and improve the overall product and service quality by controlling key manufacturing processes or services.

Some important components of SPC are:

- PACT: Process Analysis and Control Technique is an analytical technique for determining the key elements of a manufacturing process to control. It can be followed by screening experiments.

- Short production run SPCs which includes individual X and moving range charts especially useful in service industries to identify trends.

- Real-Time SPC uses on-line data collecting and analyzing tools on key manufacturing processes or operations.

- Process Capability studies measures the inherent variability of the process so that performance potential can be determined.

- Metrology studies repeatability and reproducibility of instruments and operators.

METROLOGY is offered as a stand-alone core course in the ITQA and as a technical elective in the ESQA program, while the SPC is offered as a core course in the ITQA and the ESQA program.

DOE: Design of Experiments is an off-line quality improvement technique that can be used to study the effects of input variables, called factors, on a response. It is very useful to identify the interrelationships between variables, and key variables to optimize and control the processes (8). The effective use of DOE methodology can lead to products that are easier to manufacture with higher reliability, have more robust production and field usage characteristics. Some important components of DOE are:

- Classical methods include the randomized block designs, factorial, fractional factorial designs, response surfaces, and regression analysis as described in classical DOE books.

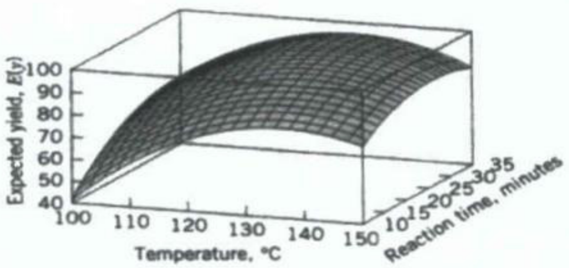
- Taguchi methods use loss functions and orthogonal arrays based on conventional experimental designs to design robust products insensitive to noise.

- EVOP: Evolutionary Process Operation is an on-line technique used to improve the processes while they are running.

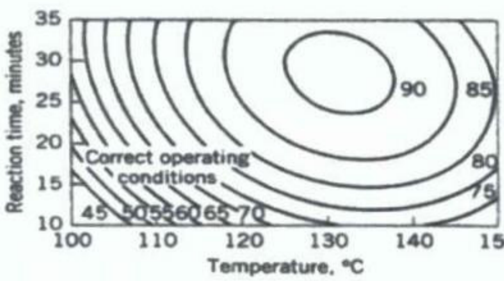
- Other methods, such as Shainin methods, Stochastic Analysis, and Forecasting are also important in industrial/manufacturing engineering field. They are more likely to be covered in those engineering fields then quality.

DESIGN of EXPERIMENTS is a core course for both degree programs and has prerequisites of STATISTICS. Taguchi methods and EVOP are presented in the SIX-SIGMA TOPICS course due to time limitations of the DOE course.

The effective use of DOE includes a series of screening experiments in terms of fractional factorial designs to identify the key influential factors, and the direction of optimum conditions. More elaborate Response Surface designs can be used to reduce variation, to find optimum conditions, to achieve robustness in products and processes. Figure 2 illustrates a contour and a response surface plot of an example take from a textbook (4). Since response surfaces are generated by higher-order polynomial functions, they are subject to goodness of their fit and assumptions of multiple linear regression analysis. When DOE and Regression Analysis are carefully conducted, they provide the most return on any kind of investment an organization can make.



■ FIGURE 14.1 A three-dimensional response surface showing the expected yield as a function of reaction temperature and reaction time.



■ FIGURE 14.2 A contour plot of the yield response surface in Fig. 14.1.

Figure 2. Response surface and contour plots of temperature and reaction time on yield.

RELIABILITY: The reliability engineering approach uses models, probability theory, and life data analysis. Maintainability, Availability, and Preventive Maintenance are also considered under reliability.

- Reliability Prediction Models of serial and parallel systems, individual component reliability, reliability testing, and important design parameter determinations such as hazard rate and mean-time to failure, are important aspects of classical reliability theory.

- FMEA. Failure Mode Effect Analysis attempts to identify possible effects caused by the failure of a component.

- FTA. Fault tree analysis starts with failure and backtracks to the possible cause of that failure.

RELIABILITY and ACCEPTANCE SAMPLING are combined and offered as a core course for the ITQA and the ESQA program. FMEA and FTA are offered in the SENIOR PRACTICUM course.

QUALITY PLANNING: is a strategic activity for an organization's long term survival, and is an important as the product development plan, the financial plan or the marketing plan among others.

- PERT: Program Evaluation Review Technique and Gantt charts are primary tools used in project planning and control for many years.

- QFD: Quality Function Deployment converts customer needs and voices into product process specifications and several levels of technical requirements.

- Quality Costs are an important financial control tools in business management. Table 1 provides basic categories of quality cost. Figure 3 illustrates a classical model for optimum quality cost (6).

Quality Costs

Prevention Costs	**Internal Failure Costs**
Quality planning and engineering	Scrap
New products review	Rework
Product/process design	Retest
Process control	Failure analysis
Burn-in	Downtime
Training	Yield losses
Quality data acquisition and analysis	Downgrading (off-specing)
Appraisal Costs	**External Failure Costs**
Inspection and test of incoming material	Complaint adjustment
Product inspection and test	Returned product/material
Materials and services consumed	Warranty charges
Maintaining accuracy of test equipment	Liability costs
	Indirect costs

Table 1. Decomposition of Quality Costs.

The project planning and control tools, QFD, and quality cost topics are covered in the SENIOR PRACTICUM course and the SIX-SIGMA TOPICS course.

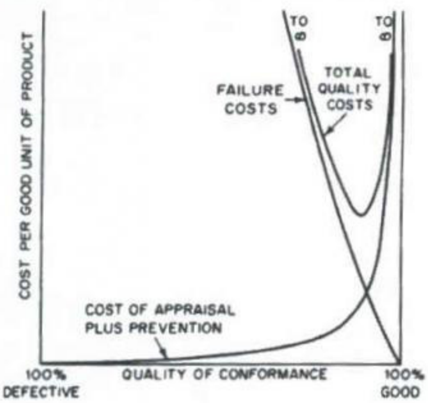


Figure 3. An Optimum Quality Cost Model.

The effect of globalization by using cheap-almost-everything is resulted a shift in the optimum point of total quality cost function. The shifting of the TQC function to the right makes poor quality more cost effective which is a contradiction to the spirit of quality. This prompted to rethink the cost structure of quality especially true cost to environment and customer (7).

QUALITY AUDIT: is an independent, methodical, examination of quality actions with the intent to verify conformance to a performance standard and to report observations for assurance of corrective action.

- Evaluation audits include quality systems survey and quality program assessments.
- Compliance audits include in-line and end-item product audits, process audits, systems and special audits such as software auditing.

Since these audits can be organization specific, BCC does not provide any formal training. However, the ITQA and ESQA programs are subject to periodical reviews.

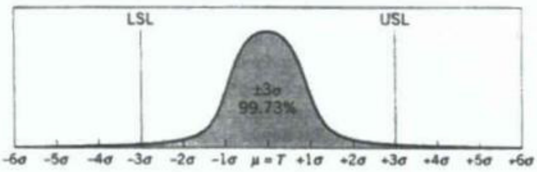
QUALITY INFORMATION SYSTEM: consists of collecting, organizing, analyzing, and reporting information on quality to assist decision making at all levels. Many database programs exist to support such system.

- Supplier Rating System includes evaluations and ratings of suppliers.
- Quality Deficiency Reporting System includes in-process rejection, scrap, returned goods, and corrective action information (3).

A special attention should be given in report writing to insure the compliance with ISO-9000 and related standards. This is one of the learning objectives of the SENIOR PRACTICUM course at BCC. ISO-9000 and related certifications also provide quality improvement opportunities.

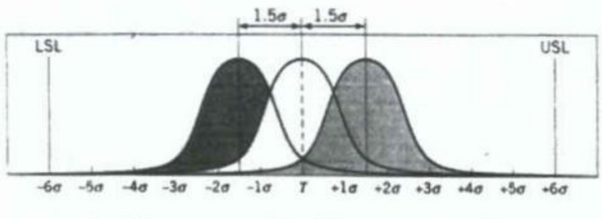
SIX-SIGMA

Six-Sigma is developed by MOTOROLA in the late 1990s, and it quickly gained widespread acceptance. The main idea is to reduce the variability in the key product quality characteristics to the level at which the failures or defects are extremely unlikely, namely 2 per billion defective. Figure 4 shows a normal probability distribution as a model for the mean on target and shifted by $\pm1.5\sigma$ from the target with the specification limits are at 3σ on each side of the mean (4).



Spec. Limit	Percent Inside Specs	ppm Defective
±1 Sigma	68.27	317300
±2 Sigma	95.45	45500
±3 Sigma	99.73	2700
±4 Sigma	99.9937	63
±5 Sigma	99.999943	0.57
±6 Sigma	99.9999998	0.002

(a) Normal distribution centered at the target (T)



Spec. Limit	Percent inside specs	ppm Defective
±1 Sigma	30.23	697700
±2 Sigma	69.13	608700
±3 Sigma	93.32	66810
±4 Sigma	99.3790	6210
±5 Sigma	99.97670	233
±6 Sigma	99.999660	3.4

(b) Normal distribution with the mean shifted by $\pm1.5\sigma$ from the target

Figure 4. The Six-Sigma concept.

The body of knowledge for Six-Sigma as required for a Black Belt certification is very comprehensive (5). Many of the topics are covered by individual courses offered in the both ITQA and ESQA program. The missing pieces are collectively covered in the SIX-SIGMA TOPICS course.

SIX-SIGMA TOPICS is a core course for the ITQA and a technical elective for the ESQA program. It is recommended for the students pursuing green belt or black belt certification from ASQ.

In recent years, two other tools sets, lean systems and design for six-sigma (DFSS) have become identifies with six-sigma. While a lean system focuses on elimination of waste, and cycle-time improvement, DFSS is a structured methodology for the commercialization of products from design to servicing phase. These techniques generally employ basic tools and principles of Industrial Engineering.

COOPERATIONS with ORGANIZATIONS

Higher education institutions have social responsibilities in their communities. They have to consider the needs of local communities in one hand, and on the other hand they have to be aware of the national/international trends. One effective way of getting inputs from local community and organizations is to conduct surveys. BCC has made considerable changes to its ITQA program with the help of such survey. A copy of this survey is given in Appendix A.

Another great way of having continuous cooperation with local community and industries is to establish Advisory Boards for degree programs. This avenue is currently used many colleges and universities in USA.

Organizing events in conjunction with professional organizations and their local chapters such as ASQ, and keeping faculty up-to-date in their field is also critical for long term success of any viable program.

FUTURE DIRECTIONS

Quality field and education in general are subject to constant changes. We have to rethink the effects and true cost of non-conformal products and services. The recent trends of "being green", "social Responsibilities", "sustainability of resources" are all closely related to quality and performance excellence (7). The quality education is more important than ever for the survival of an organization, a community, and even for the planet.

On-line course development and distance learning are here to stay and should be an integral part of any quality curriculum. More interactive tools and statistical software tools should be provided to the students in order to make them life time learners. The future will belong to those who employ continuous improvement principles in every aspect of life.

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