Batanero, C. (Ed.), Training Researchers in the Use of Statistics, 53-63.

Printed in Granada, Spain

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STATISTICAL TRAINING OF RESEARCHERS IN TOTAL QUALITY MANAGEMENT: THE JAPANESE EXPERIENCE

A training system for statistical methods in Total Quality Control or Total Quality Management is discussed and we suggest what and how to teach. It is stated that we have no department of statistics in the universities in Japan and stressed that applied statistics is most efficiently taught to those who have their own problems and motivations to apply these statistical methods. It is then essential for a company to have their own training systems for the TQM researchers although some extra company training courses may also be efficiently utilised. As an example we introduce in some detail the seminars provided by JUSE as well as in-company training systems of Toyota Motor Corporation and Takenaka Corporation.

1. INTRODUCTION

In this paper we consider a training system for statistical methods in TQC (Total Quality Control) or TQM (Total Quality Management). Two important aspects of the system are what and how to teach. The success of quality control in Japan is due to the company-wide activities, which involve all the staff and departments in a company and do not just depend on a few experts. It is also due to the natural tendency of the Japanese to be very diligent, generally clever and willing to devote themselves to the company.

Each company has a statistics section as a part of the QM promotion section. Ideally a company should have a TQM promotion team involving several advisors and trainers who are expert in the area and can teach these statistical methods. However, some elementary courses may be more efficiently taught in Japan by an external institution such as JSA (Japanese Standards Association) or JUSE (Japanese Union of Scientists and Engineers). Such institutions are particularly useful in Japan since there is no department of statistics in the universities and statistical methods are very poorly taught.

Now I describe five courses to learn the statistical methods that are most useful in practice:

1. *Elementary statistics:* Basic idea of variations in data, statistical estimation and tests, concept of TQM, basic tools such as QC seven tools and control charts;
2. *Design of Experiments:* One- and two-way layouts, split plot design, hierarchical design, orthogonal array, analysis of variance (ANOVA), reliability analysis;
3. *Multivariate Analysis*: Regression analysis, discriminant analysis, principal component analysis, correspondence analysis, cluster analysis, contingency tables;
4. *Advanced:* Beyond ANOVA techniques, graphical modelling, GLM, GAM, Multiple correspondence analysis, Taguchi method;
5. *Applications*: Problem solving by integrated use of various statistical methods.

The first three courses might be taught by some external institution, but the last two should be taught within the company and should be based on the researcher's own problems. It is then desirable to have convenient tailor-made software for statistical analysis and the database of the company's past achievements. It should be stressed here that the CWQC (Company-Wide Quality Control) in Japan has been successfully developed by all the people within a company, by applying statistical methods to his or her own problem even though the methods used might be very elementary. It should also be noted that a recent trend is to apply statistical approaches not only to the manufacturing processes but also to the planning, marketing and management processes of the company. It is also essential to have the hierarchical education system in a company for maintaining its statistical activities. One of the most successful examples in Japan is the Toyota System.

Finally an annual company-wide conference is very useful to give people in the company an opportunity to present their statistical activities to the top management of the company and to promote their statistical activities. A presidential award might be given to the best achievement.

2. GENERAL STATISTICAL BACKGROUND IN JAPAN

We will begin by describing the general background of statistics education in Japan. One of the most prominent characteristics is that there is no department of statistics at Japanese universities and that statisticians are scattered around various faculties forming very small research teams.

There was a very hot discussion on this subject a long time ago, when it was decided to distribute the statistics offices (called koza in Japan) over the various faculties requiring the study of statistics within their own field, instead of having a concentrated statistical department. A koza has been composed of one professor, one associate professor and two research associates.

To give an example, at the University of Tokyo about 15 professors and associate professors of statistics are working in the Faculties of Economics, Engineering, Medicine, Agriculture, Education, Mathematics, and Culture. In my experience as a Professor of the Department of Mathematical Engineering at the University of Tokyo, I took charge of a laboratory composed of one associate professor, one research associate and about ten doctoral and master students including a few from companies. There is only one statistics laboratory among more than two hundred laboratories in the Faculty of Engineering at the University of Tokyo. It may be surprising that we have only one professor and one associate professor among approximately 400 faculty members in the very big Faculty of Engineering. We have, however, several additional statistics laboratories in the Faculties of Economics, Medicine, Science, Agriculture, Education and Culture and we organise an inter-faculty statistics meeting once a week and collaborate to educate graduate students. In this sense the University of Tokyo is rather favoured and I am afraid that the case will not be the same for other many universities.

Professional statisticians are usually brought up in the statistics laboratories scattered in various faculties in the universities as in the example of the University of Tokyo. The number and the range of lectures are usually not enough and students read books themselves or in small groups, attend seminars and discuss their notes with their supervisors. There is no particular external consulting service for researchers in the universities. Of course we give advice on their request, though this is not often needed since, at least in the Faculty of Engineering, researchers are usually capable enough to

solve their statistical problems by themselves with the aid of some statistical package.

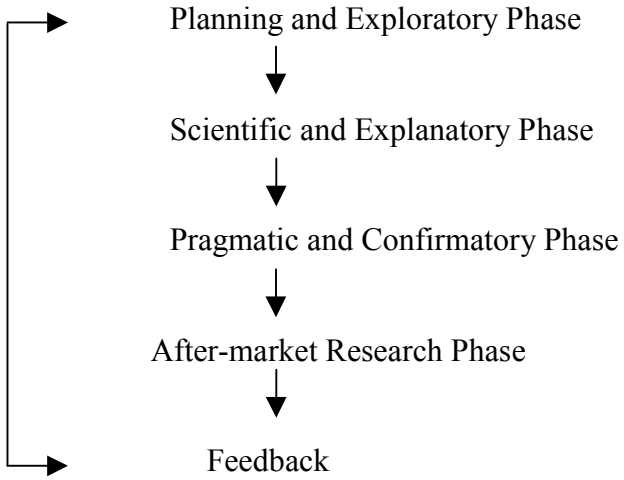
Therefore, we think it is important to have a weekly inter-faculty statistics seminar for graduate students. We have many opportunities to present our respective problems and ideas to our colleagues and obtain suggestions from them, and sometimes this naturally leads to collaborative work. Those opportunities include seminars and symposiums.

Most undergraduate students, however, take only an elementary statistics course during their studies except those students who belong to particular departments where there is statistics staff. They only have a poor concept of variations in data and an elementary knowledge of statistical tests and estimation. The general backgrounds of the researchers who perform the Total Quality Management in the company in Japan will be mechanical, civil and electronical engineering, chemistry, architecture and so on. Even when I give advice to graduate students from other departments on their requests this is far from sufficient. It is thus essential to have the statistical training courses outside universities for researchers in companies who did not receive any proper statistics courses in universities.

However, this is not a major defect in Japan since applied statistics can be most efficiently taught when students have their own problems and motivations. In my experience, for example, it is much more difficult to teach the idea of multiple comparisons procedure to students in a classroom than to explain those ideas to researchers in pharmaceutical companies who are dealing with various types of multiplicity problems in their ordinary research work, such as multiple endpoints, subgroup analyses and interim analyses.

It is therefore possible for a researcher to learn statistics methods after he or she has been involved in some department of a company and has realised the problems to be solved there. We also note that the Deming Prize Application has been useful in Japan to motivate people in companies to learn statistics (see the special issue: The Deming Prize edited by Okuno, 1990-1991).

Fig.1 The Four Phases of R & D Activities



One thing I should stress here is that a researcher in a company should not be an individual data analyst, but should relate his or her research to preceding and succeeding works. Any research and development (R&D) activity has four steps of exploration, explanation, confirmation and after-market research, and thus the information obtained by the after-market research should give feedback promptly to the first step of planning,

as it is shown in Figure1.

In each phase the type of data might be different and even with the same data the approach to the data and the decision based on the data might be different (Hirotsu, 1992). An example of this could be the difference between Phase II and Phase III of clinical trials in the stream of new drug development, which are sometimes referred to as explanatory and pragmatic phases. To perform his or her role appropriately, it is therefore essential for a researcher to be aware of the stage he or she is in the stream of R & D. This implies the necessity of an in-company training course at least in the final stage of education of applied statistics, and also suggests a need for a general manager to supervise the whole process of R & D.

Now under the circumstances of Japan and the characteristics of applied statistics, the need of some extensive training system for people to perform TQM in companies is obvious.

3. TQM EDUCATION COURSES HELD OUTSIDE COMPANIES

In Japan we have many TQM education courses outside companies. Typical and extensive examples are the courses provided by JUSE and JSA (see Ishikawa, 1969 and Mizuno & Kume, 1978). There have been, however, several changes since these papers and the current status of JUSE is described in some detail below.

A variety of systems of education courses exist, such as post-oriented, division-oriented, theme-oriented, methodology-oriented courses, statistical software courses and a correspondence course. There are also various levels from elementary to advanced, which include also rather philosophical seminars to introduce the concept of TQM as well as more technical statistical seminars. Since it is important to maintain the training system successfully in a company, top management of the company should be aware of the relevance of applying statistics fully in the R & D activities. It should also be noted that there are courses provided not only for the manufacturing processes but also for the planning, marketing and management processes.

3.1. POST ORIENTED COURSES

1. *Top Management Course* (intensive, 9 hrs.×4 days): Introducing the managing director to management and TQM for the promotion of company-wide quality management activities.

2. *Executive Management Course* (intensive, 9 hrs.×4 days): Introducing the general manager to planning and implementing TQM.

3. *Senior Management Course* (6 hrs.×3 days): Introductory course for senior managers to the basic principles of TQM and TQC.

4. *Middle Management Course* (6 hrs.×9 days): Practical course for middle managers to promote TQM in their respective departments.

5. *Chief Basic Course* (6 hrs.×6 days): Role of chief staff in the ordinary quality control activities.

3.2. DIVISION ORIENTED COURSES

1. *TQM Instructor courses* (6 hrs.×6 days): Methods of introduction and promotion of TQM for TQM instructors with basic knowledge of TQM and TQC.

2. *Procurement Department Course* (6 hrs.×4 days): Purchasing and logistics service control for value engineering and cost reduction.

3. *Elementary Course for Sales Department* (6 hrs.×4 days): Concept of TQM and QA (Quality Assurance) in sales department.

4. *Advanced Course for Sales Department* (6 hrs.×8 days): Roles of sales department for TQM and the current method of QA for customer satisfaction.

5. *QC Seminar for Good Manufacturing Practice* (6 hrs.×3 days): Necessary knowledge of GMP (Good Manufacturing Practice) to promote TQM and QA in manufacturing and selling foods and drugs.

3.3. THEME ORIENTED COURSES

1. *Policy and Planning Seminar* (6 hrs.×3 days): Method and organisation for determining the management, quality and quality control policies of the company and for transmitting them throughout all the company sectors.

2. *Introductory Course for TQM* (6 hrs.×3 days): Basic concept of TQM, quality and control; Method of problem solving and approaching a project.

3. *Cost Down Seminar* (6 hrs.×6 days): Basic concept, promotion and method of cost down in manufacturing planning and purchase departments.

4. *QC Story Seminar for Achieving a Management Project:* An approach and know-how for innovating the business based on the company top management policy.

5. *Introductory Course for Product Liability* (6 hrs. ×3 days): Current status of the law and system for product liability; Experiences and measures to solve the product liability problems.

6. *Advanced Course for Product Safety:*
   A. Product Safety Technology Course (6 hrs.×2 days): Guidelines of product liability for engineers in planning, design, research and development, quality assurance and quality control.
   B. Product Safety Co-ordinator Course (6 hrs.×2 days): Roles of the product safety co-ordinator in product safety; Designing the product safety review system and the document safety system.

7. *R & D Management Seminar:* Management of research and development; Method of new product development, market research and new product planning.

3.4. METHODOLOGY ORIENTED COURSES (ELEMENTARY)

1. *QC Seminar Basic Course* (6 hrs.×30 days): Seminar of quality control concepts and theory and application of statistics for engineers and staff with at least 3 years business experience; Lectures, practice with personal computer and QC games for basics statistics methods, statistical test and estimation, design of experiments, regression analysis, reliability engineering, sensory test, feeling evaluation and so on.

2. *QC Seminar Elementary Course* (6 hrs.×8 days): Basic concept of quality control and elementary statistics methods including QC seven tools, collecting and summarising data, test and estimation, analysis of variance and correlation and regression analyses.

3. *QC New Seven tools* (6 hrs.×3 days): Affinity chart method, relation chart method, system chart method, arrow diagram method, process decision program chart (PDPC), matrix chart and matrix data analysis.

4. *Seminar for Computer Application for Problem Solving* (6 hrs.×2 days): Problem solving, decision making and information system.

5. *Quality Function Deployment (QFD) Seminar*
   5.1. *QFD Practice Course* (6 hrs.×2 days): Practice of QFD application, making two-way tables and problem solving.
   5.2. *QFD Introductory Course* (6 hrs.×4 days): Outline and utility of QFD.

6. *Strategy Planning Seminar for Policy Management* (6 hrs.×2 days): Framework of planning strategy, environmental analysis, product analysis, market analysis, allocating resources, analysis of strategy factors; case studies.

7. *Product Planning Seven Tools*
   7.1. *Introductory Course* (6 hrs.×4 days): Seven tools for producing hit product; Group interview, questionnaires, positioning analysis, imaginary method, joint analysis, product planning based on marketing; case studies.
   7.2. *Quick Course* (6 hrs.×1 days): Outline of seven tools for product planning.

3.5. METHODOLOGY ORIENTED COURSE (ADVANCED)

1. *Design of Experiment Seminar* (1) (7 hrs.×8 days): Role experimental design, mean and variance, test and estimation, 1-way layout, 2-way layout, split plot design, orthogonal array, theory of ANOVA, correlation analysis, simple regression analysis.

2. *Design of Experiment Seminar* (2) (7 hrs.×12 days, 4 days per a month): Multi-way layout, advanced orthogonal array, non orthogonal experiment, sequential experiment, mixed experiment, random effects model, optimisation of multiple-end variables, Taguchi method, multiple regression analysis, analysis of proportions.

3. *Multivariate Analysis* (1) (7.5 hrs.×4 days): Introduction to multivariate analysis, principal component analysis, variable selection in regression analysis, logistic

regression analysis.

4. *Multivariate Analysis* (2) (7.5 hrs.×4 days): Latent structure analysis of categorical data, graphical modelling, canonical correlation analysis, covariance structure analysis integrating regression analysis and factor analysis, data mining.

5. *Statistical Methods for Clinical Trials Seminar* (1) (6 hrs.×7 days): Introduction to clinical trials, planning, designing, elementary statistical methods including non-parametric method and cross-over design.

6. *Statistical Method for Clinical Trials Seminar* (2) (6 hrs.×24 days, 2 days per month): Introduction to statistical inference, regression analysis, ANOVA, analysis of categorical data, analysis of survival data, dose-response analysis, sample size determination, meta-analysis, statistical guideline for regulation.

7. *Data Management in Clinical Trials Seminar* (camping system, 6 hrs.×5 days): Outline of data management in clinical trial.

3.6. STATISTICAL ANALYSIS SOFTWARE SEMINARS BASED ON JUSE-QCAS OR JUSE-MA

1. *QC Practice Seminar* (6 hrs.×3 days): Process analysis, problem solving, QC seven tools, and regression analysis.

2. *Design of Experiment Seminar* (6 hrs.×3 days): Factorial experiments, orthogonal array, QC game.

3. *Multivariate Analysis Seminar* (6 hrs.×3 days): Principal component analysis, multiple regression analysis, and correspondence analysis.

4. *Reliability Analysis Seminar* (6 hrs.×2 days): Analysis of reliability data and field data.

5. *Seminar for Questionnaire Planning and Its Analysis by Personal Computer* (6 hrs.×2 days): Application of multivariate analysis to the analysis of questionnaires.

3.7. CORRESPONDENCE COURSE (6 MONTHS)

This course is based on two textbooks, one for methods and the other for practice of quality control.

Similarly the Japanese Standards Association (JSA) provides some standard courses, in particular, ISO 9000 and ISO 14000 seminars.

4. IN-COMPANY TQM EDUCATION AND TRAINING

Although these external seminars provide a very good opportunity for TQM education and training the internal education of people in a company is even more important for practising these methods and techniques in their ordinary activities.

Most companies, if not all, arrange education and training courses in TQM for their

employees. Ideally for in-company education a company should be equipped with:

1. A hierarchical education system;
2. Tutors with various achievement levels;
3. Taylor-made software for statistical analysis;
4. Database of company's past projects and case studies;
5. Annual company-wide conference for statistical activities.

In this section we describe two characteristic cases of in-company education system.

4.1. THE CASE OF TAKENAKA CORPORATION

The Takenaka Corporation was the winner of the first Deming Prize in the construction sector and should be regarded as the leader of the sector. Its education schedule has been introduced by Jido (1990-91), from which we reproduce his Table 3.2 (Table 1 here).

We can see from Table 1 that the Takenaka Corporation is giving in-company seminars by in-company instructors and extra professionals for its employees to learn the TQC (TQM) concepts and statistical methods as well as using extra seminars provided by JUSE and JSA. It should be noted that a hierarchical system is taken so that senior instructors who have finished an advanced course can teach the elementary course. It is essential for the staff and foremen to learn statistical methods based on their own problems. A more recent example of this approach is seen at the Toyota Motor Corporation.

4.2 CASE OF TOYOTA MOTOR CORPORATION

According to the highly stable condition of manufacturing processes in Japan a recent tendency of TQM is changing from statistical approaches to a more philosophical (or conceptual) approach with slogans such as customer's satisfaction, market in (rather than product out), source control and so on. It is, however, obvious that the philosophy of TQM can only be carried out with the scientific approach. Furthermore the recent development of statistical methods has enabled us to handle new types of problems and data coming out of off-line as well as on-line processes. It is therefore very inappropriate to adhere to the classical SQC (Statistical Quality Control) approach and it is strongly recommended to go beyond it. Under these circumstances Toyota's approach is remarkable in that it is convinced of the necessity of the new scientific SQC method and it is practising it. We will briefly introduce the system here and refer to Amasaka and Osaki (1999) as well as to Amasaka et al. (1999) for details.

First, Toyota has developed its own methodology called 'SQC Technical Methods' integrating statistical methods such as Seven New Tools and other basic SQC methods, multivariate analysis and design of experiments with engineering technology, which can be used efficiently and appropriately at each step of problem solving in the course of research, development, manufacturing and marketing. This is carried out by assessing a one shot analysed with a ready made statistical method. They call it mountain climbing for problem solving by use of 'SQC Technical Methods'.

To support the efficient utilisation of the 'SQC Technical Methods' the integrated SQC network TTIS (Toyota SQC Technical Intelligence System) has also been developed. It is composed of TSIS (Toyota SQC Intelligence System), TPOS (Toyota TQM Promotional SQC Original Soft), TSML (Toyota SQC Manual Library) and TIRS

(Toyota Information Retrieval System).

Table 1. QC Education Schedule in Takenaka Corporation (Table 3.2 of Jido, 1990-1991)

HIERARCHY	PURPOSE	IMPLEMENTATION PROCEDURE	
		Seminar	Follow-up
Directors	To acquire knowledge to evaluate TQC activities as top management	Director Special Course (JUSE)	To enhance knowledge through attending President Diagnoses & Consultations.
General managers	To acquire fundamental knowledge and concept of TQC, as "upper" middle management.	Executive Course (JUSE)	To hold Branch General Manager's QC Diagnoses and Consultation
Senior managers	To acquire principal knowledge and basic statistical methods of TQC as middle management.	Manager Course (JUSE & JSA)	To participate in various QC Diagnoses and Consultations.
Managers		In-house TQC Manager Seminar (5 days)	
QC Specialists	To acquire the TQC concept, statistical methods and other professional knowledge becoming QC promoter in his department.	Various outside seminars (JUSE & JSA)	To present the outcome of TQC activities at in-house gatherings and conventions.
Engineers	To acquire the TQC concept and statistical methods.	In-house TQC Basic Course (B) 15 days	To present QC activities at various gatherings and conventions.
Administrators	To acquire the TQC concept and basic statistical methods.	In-house TQC Basic Course (A) 10 days	
Staff members	To acquire the TQC concept and often-used QC techniques	In-house TQC Elementary Course 3 days	
Clerical workers	To acquire the TQC concept and knowledge required for QC circle activities	Seminars and lectures conducted by in-house instructors	QC circle gatherings and conventions.
New recruits	To acquire basic TQC concept	In-house TQC Orientation Course 1 day	

JUSE: Union of Japanese Scientist & Engineers, JSA: Japanese Standards Association

TPOS is the friendly tailor-made software of Toyota and it is composed of TPOS-PM (Multivariate Analysis), TPOS-PS (General SQC Methods), TPOS-PO (design of experiment), TPOS-PK (sensitivity analysis) and TPOS-PR (reliability analysis). Multivariate analysis, for example, contains discriminant analysis, multiple regression analysis (1), (2) and principal component analysis. One can refer to various successful applications in real business through TSIS and also find past successful examples of problem solving in Toyota by TIRS. To sum up TTIS is, as stated in Amasaka and Osaki (1999), the intelligent system for SQC applications consisting of four main systems synthesised to grow while supplementing one another. TTIS has been very efficiently used in in-company education and training of SQC in Toyota.

Toyota also employs the hierarchical system of education and training. It is intended, in addition to educate beginners, to train the in-company SQC special staff and advisors who can act as SQC promotion leaders of workshops of 200 departments and also to be engaged in the SQC seminars as trainers.

Now the Toyota education system is planned and implemented in six ranks: Beginner (100%), business (100%), intermediate (60%), lower advanced (15%), upper advanced (5%) SQC classes and SQC special advisor class (2%). The ratios of participants to the total of twelve thousand employees are given in the parentheses so that 100% of employees are, for example, expected to attend the beginners and business classes.

The beginners and business classes are designed to cover the daily works while at the two middle class courses participants will learn and practice the new SQC methods. The two highest classes are aimed at training the trainers and leaders of respective workshops and for extra professional purposes advanced lectures are also given. Qualifications for SQC special staff and SQC special advisors are determined and the respective titles are given to successful candidates. According to Amasaka and Osaki (1999) eight hundred special staff and advisors who have successfully completed the six steps are now actively engaged in their respective works.

Three courses for the beginner personnel are prepared in more detail: technician, sales and clerical courses. Typical curricula of the technician course (3 days, 21 hrs.), which are composed of twelve lectures, are given in Amasaka and Osaki. It should be noted that in the second lecture they learn how to integrate various statistical methods to solve real problems using the Toyota Technical Methods. The TPOS is fully utilised throughout the twelve lectures so that each trainee can take the TPOS back to his or her own workshop for practical use.

5. TQM SYMPOSIUMS AND CONFERENCES

JUSE and JSA have been promoting many conferences and symposiums on various topics and at a variety of levels. It is important to attend those meetings to present their own activities and to learn of achievement by others. An annual Conference on Science SQC is being held within the Toyota Group inviting top management and external professionals to attend and it is a very good incentive for employees to present their achievement to the heads of the company.

Of course the Annual Conference and Symposium of the Japanese Association of Quality Control are also giving a very good opportunity for researchers of TQM to present their achievements as well as to learn from others.

6. CONCLUDING REMARKS

As stressed in the text the most important thing for training researchers in the company is that trainees themselves have their own motivations. Then it is essential to teach statistical methods based on the real problems they are confronted with. When they have their own motivations and related data, it is very easy to teach them statistical ideas. It does not depend on the particular field where they are working. It inevitably suggests to them not to work alone when analysing their data, but to be aware of the phase of R & D activities he or she is, and to include manufacturing, marketing and after market research.

I also suggested that statistics training is most efficiently done by in-company trainers with some appropriate software and database of the company's past achievements. Then an in-company hierarchical education system of special SQC advisors and staff is essential for discovering skills and also for maintaining the system itself. However, if the in-company education system is not matured enough the courses outside the company may also be efficiently utilised.

In Japan, JUSE, JSA and other Institutions are providing a sufficient variety of courses, philosophical as well as technical, for TQM training. Researchers can also consult with the experts in the universities. Those experts have usually some connection with JUSE or JSA and they can introduce appropriate tutors for the companies. It should be noted that even the most prominent companies such as Toyota Motor Corporation and Takenaka Corporation are utilising the courses of JUSE introduced in § 3.

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