Approaches to Developing Quality Skills of Systems Engineers

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Abstract

Computer systems for financial institutions and public bodies are widely used in society and errors in these systems can have a wide-spread and significant impact on various communities. In the past our own system have caused inconvenience to the general public. Given the pressing need to identify and solve these quality issues, our first step was to conduct on-site hearings to assess quality-related awareness and gain a full understanding of the situation. The results of these interviews showed that if either the customer has a high awareness relating to quality, or if the systems engineer has adequate quality skills, then it is possible to ensure quality. As a systems vendor, we recognized the necessity to ensure quality on our side, regardless of the degree of customers' awareness concerning quality issues. Given the difficulty in transforming customers' quality awareness, we (the vendor) sought to improve our organizational processes to enhance both quality awareness and quality skills. The result of these efforts was that the number of serious system failures, which had reached 13 in 2007 was reduced to 5 in 2010. Of the 5 failures there were none that were attributable to application glitches.

1. Introduction

The number of serious system failures had tended to be lower than 7 until 2006, but rapidly increased to 13 cases in 2007 (Figure 1.1). Some failures were attributable to engineers not doing what they were supposed to do, for example, "oversights in procedures when changing servers," and "failure to confirm abnormal signs when migrating databases." We recognized that this was due to insufficiencies in our quality processes and that it would be necessary to assess the situation and construct countermeasures. Accordingly, we established the "Quality Improvement Working Group" to investigate actual quality activities across the entire company and take appropriate countermeasures.

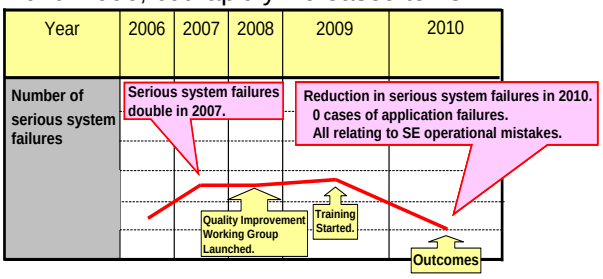

Figure 1.1 Trends in the occurrence of serious system failures

2. Investigation into status of quality-related activities

2.1 Purpose

The purpose of the investigation was to define problems clearly and to take appropriate countermeasures.

2.2 Procedures of investigation

Investigations were implemented in the following way.

(1) Quality activities investigation
(2) Interviews with systems engineers
(3) Identifying the causes of quality issues and discussing solutions
(4) Implementation of concrete solutions to address quality issues
(5) Assessment of the results of the implemented solutions

The important points are as follows:

(1) Selection of interview method
Before implementing the investigation, we first compared the methods available, considering the options of both questionnaire-based and interview-based investigation. While the questionnaire-based method is useful from the perspective of gathering statistical data and

analyzing company-wide trends, it does not reflect the direct views and backgrounds of the systems engineers themselves.
On the other hand, although an interview-based investigation would be likely to have a limited statistical usefulness, given the limitations in the number of interview samples that could be acquired, it is ideal as a means of revealing what systems engineers really think. For the purposes of this investigation it was decided to adopt the interview-based method, in the expectation that rather than statistical precision, it would provide qualitative information.

(2) Pre-interviews
To improve the accuracy of the interviews and to collect comments from as many engineers as possible, we appointed several interviewers. Before conducting the interviews, we conducted pre-interviews to avoid divergence in the quality of the information procured by each interviewer (depth and breadth). A number of representative interviewers implemented these pre-interviews as samples, from which hypotheses were formulated (Figure 2.1). Based on these hypotheses, and in order to clarify and further examine various issues and share future directions and challenges, all interviewers then implemented the main interviews.

	Hypotheses		
1	Environment	Characteristics of the project	Major differences of quality awareness depend on the different teams and projects.
2		Customers, bosses, and senior engineers	Customers and bosses will tend to have an elevated awareness of quality issues.
3	Individual's skills	Experience	Managers and team leaders have awareness of quality, but lack skills to put this awareness into practice, nurture it in others and pass it on to junior colleagues.
4		Quality management	Systems engineers lack interest in quality management. Awareness of the importance of quality management is not widespread.

Figure 2.1 Hypotheses from pre-interviews

(3) Survey
We took face-to-face interviews (duration of 30 to 60 minutes), with questions based on those listed on an interview sheet.

2.3 Content of interviews

(1) Targets
Interviews about quality awareness and knowledge were implemented with a total of 31 engineers, from various divisions and with varying degrees of experience.

(2) Content of interviews

(a) Interview format
To avoid divergence among interviewers, the same format was used for each interview (Figures 2.2 to 2.4)

	Sheet name	Purposes of interview	Figure
1	Interview sheet for quality awareness	To avoid divergence among interviewers arising from differences in interview skills.	2.3
2	Worksheet for interview analysis	To promote awareness of individual responses and to lead to hypothesis.	2.4

Figure 2.2 Interview format

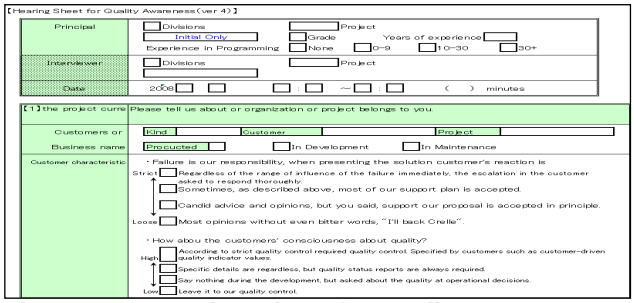

Figure 2.3 Interview sheet for quality awareness

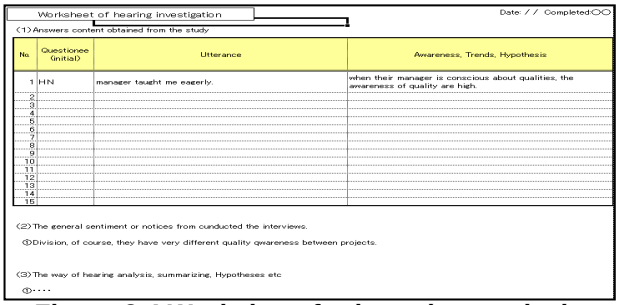

Figure 2.4 Worksheet for interview analysis

(b) Individual items in interview

The individual items included in the interview were designed to gain a comprehensive picture of whether issues concerning approaches to quality were related to a) individual engineer's skills, b) individual engineer's working environment, or c) problems with measures implemented by the company as a whole (Figure 2.5).

	Interview items	
1	Present condition of project	Information about project that interviewee is involved in: Project summary, members, role of interviewee, customer characteristics, occurrence of failures and operational errors
2	Quality awareness, recognition of issues	Priorities among cost, quality, and delivery time; issues and challenges relating to quality
3	Practice of "Quality Management System"	Understanding of "Quality Management System", and its implementation.
4	Quality control methods	Understanding of quality control methods and their implementation.
5	Organizational activities	Unique approaches to quality issues.

Figure 2.5 Individual items in interview

3. Verification (Results of interviews)

Using the hypotheses formulated in Figure 2.1 above, we placed environment quality awareness, in other words customers' awareness, on the vertical axis, and individual skills, in other words individual's quality skills, on the horizontal axis to see the correlation between the two.

3.1 Low-career engineers

Engineers with experience of less than five years were referred to as "low-career engineers". We created a matrix by taking the degree of quality awareness as the vertical axis and taking each engineers' quality skills as the horizontal axis. The positioning of each engineer in this matrix can be seen in Table 3.1. The low-career engineers are cognizant of their lack of quality skills and therefore can be found in the first or second quadrants. The results show that regardless of customer's quality awareness, the quality skills of low-career engineers remain low.

Table 3.1 Distribution of low-career engineers (Number of people)

		Engineers' quality skills	
		Low	High
Customers' quality awareness	High	①50%	③0%
	Low	②50%	④0%

3.2 Mid-career engineers

Engineers with more than five years experience were referred to as "mid-career engineers." Table 3.2 shows a matrix like that for low-career engineers in Table 3.1 In contrast to low-career engineers, mid-career engineers can be found in each of the four quadrants. In the quadrants where the customer's quality awareness is high (first and third quadrants), there are four times as many engineers with high quality skills than those with low quality skills. In the quadrants where the customer's quality awareness is low (second and fourth quadrants), there are 1.5 times as many engineers with low quality skills than those with high quality skills. A tendency can be seen where in cases in which the customer's quality awareness is high, so too are engineers' quality skills high. Conversely, where customer's quality awareness is low, engineers' quality skills are also low. In other words it can be seen that there are some factors relating to quality skills that are dependent on the working-environment.

Table 3.2 Distribution of mid-career engineers (Number of people)

		Engineers' quality skills	
		Low	High
Customers' quality awareness	High	①12%	③48%
	Low	②24%	④16%

3.3 Correlation analysis between serious system failures and working environments

We next implemented a correlation analysis between the serious system failures that occurred in 2007 and the corresponding working environments by devising a matrix that plots engineers' quality skills on the vertical axis and plots the customer's quality awareness on the horizontal axis (Table 3.3).

Table 3.3 Distribution of serious system failures in 2007 (Number of cases)

		Engineers' quality skills	
		Low	High
Customers' quality awareness	High	①23%	③ 0%
	Low	②62%	④15%

The first and third quadrants, where customers' quality awareness is high, experienced few failures, regardless of the engineers' quality skills. Similarly, in the fourth quadrant, where employee's quality skills are high, there are few serious system failures. However, the second quadrant, where both quality skills and quality awareness are low, accounted for 62% of the serious system failures. This shows clearly that when both the customers' quality awareness and the engineers' quality skills are high, quality improves accordingly. When one or other of customers' quality awareness or engineers' quality skills is high the incidence rate for serious system failures improves from 62% to 23%or 15%.

4. Solutions to issues

4.1 Improving low-career engineers' quality skills

Table 3.1 shows that low-career engineers' quality skills have a low correlation to the customers' quality awareness. However, according to the interviews, low-career engineers are highly motivated and it is therefore necessary to engage in training that will provide them with basic knowledge about quality activities.

4.2 Improving mid-career engineers' quality skills and quality awareness

From Table 3.2 it can be seen that when the customers' quality awareness is high, so too are the engineers' quality skills high, leading us to hypothesize that mid-career engineers have been taught quality skills by customers. On the other hand, it seems that when the customers' quality requirements are low, engineers tend to adjust to the lower level required of them. For mid-career engineers with low skills who were placed in the first and second quadrants in Table 3.2, we asked the following question: "What kind of quality should be offered in the services and products provided by you and your organization in the future?" The results showed that several engineers who belong in the second quadrant, where the customers' quality awareness is low, responded that "It would be acceptable to maintain current quality standards," despite the fact that their quality skills are currently low. However, many of the first quadrant engineers, where the customers' quality awareness is high, responded that "More needs to be done to improve product and service quality," and no engineers in the first quadrant responded that it would be acceptable to maintain current quality standards. This demonstrates that each engineers' quality awareness depends on the customers' quality awareness (environmental factors).
When considering the issues and challenges that face quality-related education that has been implemented to date, given the differences in education systems we decided to group mid-career engineers into two categories, those with 5 to 10 years of experience and those with more than 10 years of experience.

(1) Engineers with 5 to 10 years' experience
The engineers with 5 to 10 years of experience had engaged in training commensurate with the number of years they had been working. It has been the case that integrated and standardized training has been provided, regardless of the division in which each engineer works (development, maintenance, etc.) and regardless of the skills they already possessed. For this category it is considered a necessity to improve training content by providing training in the required areas of quality skills and at the appropriate time for each engineer.

(2) Engineers with more than 10 years' experience
For engineers with more than 10 years of experience, their lack of or possession of quality skills in the working environment was dependent on whether they had received systematic training or not. Accordingly, if the customers' quality awareness is low, this serves to keep the engineers' skills and awareness low as there is no incentive to improve.

Given the experiences of these two categories in (1) and (2) above, we considered that it would be effective to provide individual training at the required time to each engineer.

4.3 Creating an environment conducive to quality-related activities

Table 3.3 shows that when either the customers' quality awareness or employee's quality skills are high then it is the case that quality can be ensured. As the systems vendor, we need to ensure quality regardless of the customers' quality awareness. Given the difficulty in transforming customers' quality awareness, we (the vendor) sought to improve our organizational processes to enhance both quality awareness and quality skills.

4.3.1 Creating an environment for improving quality awareness through managers

If quality-related education is left to each individual workplace there is a divergence in effectiveness due to environmental factors (customer's awareness). We considered that it would be effective to develop a workplace environment that would serve to improve quality skills across the company. To create a quality-conscious workplace, we thought that it would be effective to educate management about how to focus on quality issues and increase motivation to acquire quality skills.

4.3.2 Efforts to improve quality awareness

To effectively develop quality awareness, it is essential to aim to create overall awareness by sharing information on quality-related activities implemented through various projects, and also to improve organizational management. Therefore, we decided to create a forum for sharing information across the company as a whole.

4.3.3 Creating quality guidelines

A good way to increase motivation to improve quality skills, promote independent thoughts and actions and create momentum is to compile guidelines that set out concrete actions. We therefore decided to create a tiered education system, including a management tier, and identify the various skills that each tier of the workforce should aim to acquire.

5. Implementation of concrete solutions

We created a system for quality-related education in a two-tier structure, which would provide knowledge that is easily understandable and useful in the workplace.

(1) To gain knowledge and learn about quality-related techniques we created a "technical-training" module.
(2) A "practical-training" module was also created as a means of applying the quality-related knowledge and technologies gained in the "technical-training" module. This "practical-training" includes study using actual cases where trouble has occurred based on the instructor's own experience. The purpose is to develop quality awareness through exchange of opinions among project members and enable engineers to put this "virtual" experience into practice in the workplace.

Each of these modules was implemented for the various tiers of the workforce.

5.1. Education for low-career engineers

(1) Technical-training
The purpose of technical-training is to learn basic knowledge required for quality activities (how to write a report concerning a technical failure, the methods and purposes of statistics and summation, and an overview of SDEM, etc.)
(2) Practical-training
The purpose of practical-training is to learn the importance of quality by talking about the experiences of mid-career engineers in dealing with technical failures.

5.2. Education for mid-career engineers

We classified the quality-related techniques according to their function.

(1) Technical-training
We prepared education programs according to the functions of each job, including for developers, system operators, and quality managers, etc., so that each person could improve

their quality skills at the necessary time.

(2) Practical-training
By taking the quality-related knowledge and techniques acquired according to the functions of each engineer and using them in analysis of actual examples of technical trouble that had occurred at the company, we sought to promote understanding about the use of quality analysis techniques. By actually analyzing why the technical trouble had occurred, the aim was to enable engineers to implement causal analysis in their respective work fields and acquire problem-solving skills.

5.3. Education in improving organizational qualities

5.3.1. Education for managers

(1) Technical-training
Retraining is provided for quality management, with the aim of enabling managers to become drivers for quality improvement within the company, and also learn about the ways to ensure that the knowledge and skills acquired by low-career and mid-career engineers could be put to use in the workplace.

(2) Practical-training
The purpose of practical-training is to improve organizational qualities by encouraging managers to talk about each project's quality-related activities, to reflect on their own activities and identify new directions for further improvement, sharing information and mutually raising awareness.

5.3.2. Quality symposium

A Quality Symposium had been held in the past with the purpose of improving quality awareness and quality skills by giving awards to excellent research papers in each department, providing keynote speeches from outside experts, and introducing useful reference tools. We aimed to improve the Quality Symposium in order to build awareness of issues relating to technical trouble, utilizing the knowledge of experts and introducing successful and unsuccessful case studies. The improvements made to the Quality Symposium are as follows:

(1) The theme of the symposium is based on a timely topic relating to quality that particular year.
(2) The content of the symposium covers not only unsuccessful cases, but also highlights successful cases, underlining how improvements can be made.
(3) In terms of managing the symposium, we asked some participants to ask questions in advance, thus creating an atmosphere in which it is easy to ask a question.

5.3.3. System of quality education

We created a system of quality education as described in 5.1, 5.2, 5.3.1 and 5.3.2 above for the purpose of highlighting to all employees in every tier of the workforce the sort of skills that they should aim to acquire, the importance of thinking and acting independently, and promoting quality improvement.

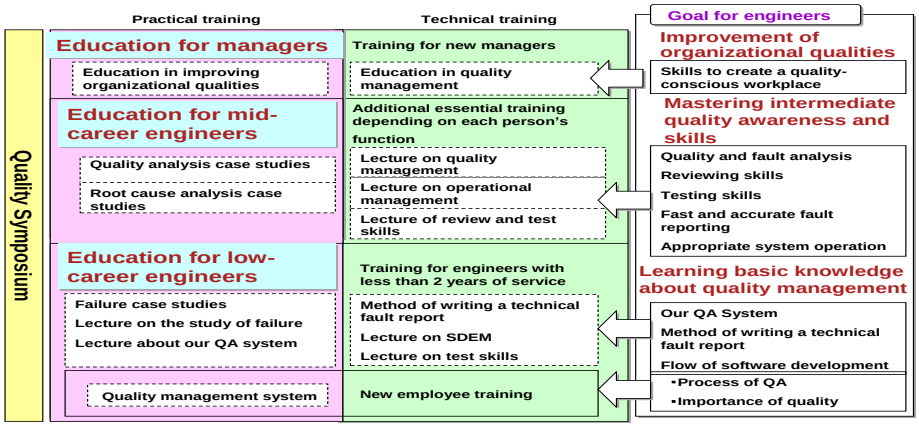

Figure 5.1 System of quality education

6. Outcomes

6.1. Reduction of failures

When education systems function properly, engineers are able to proceed with the work utilizing the basic quality-related knowledge they have gained for all processes, including process completion decisions, reviews, test techniques, and efforts to prevent recurrence through the use of report sheets on trouble and failures.
It is quality managers who control quality of entire projects by utilizing quality analysis techniques, thus the management tier works to promote the creation of an environment in which quality activities can be easily implemented.
In this way, knowledge and techniques required for quality-related activities are acquired and utilized by all tiers in the company and it is these efforts that are assumed to have led to the achievement of 0 application glitches, dropping from 5 in 2007.

6.2. Results of participant questionnaire

(1) Quality Skill Training
According to the results of questionnaire, the basic course is mostly well-received. The course for mid-career engineers is also evaluated highly, given that the average score in response to the question “was the knowledge you gained from training useful?” was 4.27-4.75 (out of a maximum of 5). All lectures in the course for managers are also well-received, with the majority responding that the training is either “extremely useful” or “useful.” Conversely, this may indicated that new managers do not have sufficient experience of quality analysis.

(2) Quality Symposium
To learn stress the importance of engineers engaging in operations in an honest and open manner, at the Quality Symposium it is always the case that a successful case study is used as an example. These reviews of successful cases always gain a good evaluation from the symposium participants, who express the opinion that successful cases provide useful reference materials and learning experiences.

6.3. Follow-up questionnaire to recipients of training

6.3.1. Result of Follow-up Questionnaire

We conducted a questionnaire during the period from September 2009 to June 2010, targeting 70 engineers who had taken the mid-career training course on practical ways to engage in quality analysis. The follow-up question was taken for the purpose of assessing the effectiveness of the training and the degree to which knowledge acquired is applied in operations.
The results showed that 80% of engineers understood quality analysis sufficiently to use it in their own projects. Actually some of the respondents had already taken action following the training, by readjusting their quality indicators, or using quality analysis techniques they learned in the course. Also, they indicated that their quality awareness had improved.
The follow-up questionnaire results show that:

(1) Courses for “quality of maintenance and operations” and “quality relating to system infrastructure” are essential
Currently the majority of courses are related to product development or quality and there are no training courses available for “quality of maintenance and operations” or “quality relating to system infrastructure.” It will therefore be necessary for the company to implement such courses, targeting system infrastructure, maintenance and operations, given the scale of our business operations.

(2) It is ideal for engineers to acquire quality awareness at an early stage of their careers
The target for providing training within a career progression framework had previous been set at around 10 years. However, based on the comments received in the follow-up questionnaire it is evident that training should be provided at an earlier stage in the careers of systems engineers. New targets are being considered as follows:
(a) Developer: Pre-training, followed by up to three years experience as systems engineer.

(b) Leader, co-leader: Experience as systems engineer of between three to six years.
(c) Quality manager: Experience as systems engineer of more than six years.

(3) Quality training is more effective when provided on repeated occasions
Comments were received that it is more effective and beneficial for training to be provided on repeated occasions, rather than as a one-off course. We therefore aim to newly develop training periods in line with the purposes and targets of the training accordingly, providing repeat courses as a means of boosting understanding.

Evaluation perspective	Result of Questionnaire	
Knowledge	Understood quality analysis well enough to use it in projects	81.4%
	Learned new quality indicators	92.9%
Action	Readjusted their quality indicators	48.6%
	Applied quality analysis techniques they learned in the training course	37.1%
Awareness	Quality awareness improved following participation in the course	64.3%

Figure 6.1 Result of Follow-up Questionnaire

6.4. Enhancement of system of quality education

Given the requests provided by respondents in (1)-(3) above, we have plans to enhance the system of quality education in the future as follows.

(1) Add a course for “quality of maintenance and operations” and “quality relating to system infrastructure”
(2) Clarify the purpose and the target of quality awareness education, so that engineers can attend quality awareness education at an early stage in their careers.
(3) Add courses for developers, leaders and co-leaders, and quality managers, so they can learn about quality in a system that provides repeated training courses at appropriate intervals.

7. Future development and challenges

(1) Approaches to eliminating operating mistakes by systems engineers
As a result of the aforementioned approaches for quality improvement implemented from 2008 to 2010, we accomplished no serious system failures caused by application glitches in this fiscal year. As we move forward, we will continue the quality skill training and we are also aiming to implement new approaches that seek to eliminate operating mistakes by systems engineers.
(2) We are committed to continuing our efforts to strengthen corporate structures for quality improvement, through quality skills education and training and the forum of our regular Quality Symposium.
(3) Given that our current understanding is not based on quantitative measurement of the relationship between quality and the persons who have received quality training, one of our future changes will be to implement more effective measurement methods.

References

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