Quality Function Deployment for Engineering Curriculum Redesign

So Young Sohn, Angela Kim
Dept of Industrial Engineering, Yonsei University, Seoul, Korea

Abstract: *Since the creation of ABET's EC 2000, many countries have adopted outcome-based assessment for engineering education accreditation. In order to meet with expected outcomes, changes are necessary in engineering curricula. In this study, we apply Quality Function Deployment to revamp existing industrial engineering curriculum by reassessing it with outcome-based accreditation. We suggest a systematic way of utilizing a roof matrix in the House of Quality to identify the overlapping and prerequisite relations among courses. This results in enhanced specific tracks of revised curriculum by removing overlapping courses and identifying newly required courses. This approach is expected to contribute to general management areas as well.*

Introduction

Today's employers and corporate leaders expect engineering graduates to perform competently in the work force both at national and international levels (Koehn 1997; Anderson *et al.* 2007). Thus, considerable efforts are being directed toward preparing engineers who possess technical skills as well as the ability to function in a global environment (Swearengen *et al.* 2002). In this regard, in addition to the approach of a performance assessment at university (Johnes, 1996), engineering education at university level is required to provide qualified courses to keep up with the trend (Lee et al., 2007).

Also, the accreditation and assessment of courses has become mandatory and dynamic for quality assurance of higher engineering education (Patil *et al.* 2004) , and is a powerful tool for making it "easily noticeable and comparable" especially in the labor market (Augusti, 2005) . This is the main reason that engineering accreditation systems have been actively developed and invigorated to satisfy essential needs on a global scale. For instance, the most widely accepted accreditation system, ABET, is the agency responsible for accreditation of engineering degree programs in the United States (Koehn, 1997). For Korea, the Accreditation Board for Engineering Education of Korea (ABEEK) was instituted recently and many Korean universities are trying to adopt the accreditation system that ABEEK requires. Engineering accreditation is generally an outcome-based assessment that is presented in EC 2000 with 11 outcomes. To improve the accreditation process, the ABET Board of Directors proposed a new set of criteria, ABET Engineering Criteria 2000 (Koehn, 1997) , which has been running since 2000. Recently, its impacts on engineering education were analyzed (Soundarajan, 1999) .

Central to the overall philosophy of EC 2000 is the assumption that educational outcomes can be measured (Stephan, 2002). Student learning outcomes comprise a major portion of engineering accreditation (Bender *et al.*, 2006).

As the importance of engineering accreditation increases, colleges and universities interact with multiple constituents or quality monitoring groups that require the assessment of student learning (Kim, 2003; Bender *et al.*, 2006) . Thus, a new system is installed in each university, and engineering curriculum content in particular is revised to meet the standards of accreditation (Kim, 2003). Although there were efforts for curriculum redesign, a systematic approach that connects student learning outcome-based accreditation criteria with curriculum design has not been suggested.

The main purpose of this paper is to suggest a systematic approach for curriculum redesign reflecting outcome-based criteria for an engineering education. We propose Quality Function Deployment (QFD) (Chen *et al*, 2006; Akao *et al.*, 2003 Lowe *et al.*, 2000 Lai *et al.*, 2007; Chakraborty *et al.*, 2007, Sohn *et al.*, 2001) to present the curriculum design methods, which can fulfill requirements in 'Program Outcomes and Assessment' criteria.

QFD for Curriculum Redesign

In this section, we propose a curriculum redesign process via QFD methodology. We considered an industrial engineering program at A University in Korea, which is undergoing curriculum revision to prepare for accreditation.

HOQ Design

In general, HOQ is a matrix that displays the Whats, the Hows, the interrelations between them, and the criteria for deciding which of the Hows will best satisfy customer needs. The roof of the house, which is particularly important in our study, identifies the correlation between the Hows. The basic structure and explanation of HOQ is presented in both Figure 1 and Table 2. They show how QFD constituents are allocated in the house of quality.

Table 1. Program outcomes and assessment in KEC2005

Index	Attributes
	Engineering programs must demonstrate that their graduates have:
A	an ability to apply knowledge of mathematics, science, and engineering
B	an ability to design and conduct experiments, as well as to analyze and interpret data
C	an ability to design a system, component, or process to meet desired needs
D	an ability to function on multi-disciplinary teams
E	an ability to identify, formulate, and solve engineering problems
F	an understanding of professional and ethical responsibilities
G	an ability to communicate effectively
H	the broad education necessary to understand the impact of engineering solutions in a societal context
I	a recognition of the need for, and an ability to engage in, life-long learning
J	a knowledge of contemporary issues
K	an ability to comprehend global culture and international cooperation
L	an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Table 2. HOQ structure

Composition	Detail
1. Customer Needs (What)	Program Outcomes
2. Technical Requirement (How)	Curriculum (Course)
3. Technical Requirement Correlation Matrix	Interrelationship between two courses
4. Interrelationship Matrix	Relation between 1 and 2
5. Customer Preference	Priority of individual program outcome
6. Weight	Weight of individual course

First, region 1 is the Whats criterion, including items related to customer's needs. As our customer's needs indicate the requirements in engineering accreditation criteria and our targeted case of a university is in Korea, we put 12 program outcomes of KEC 2005 in ABEEK. These program outcomes are similar to those in EC2000. A noticeable difference in KEC2005 is that the H criteria in EC2000 is subdivided and specified into H and K criteria to emphasize its global aspect. Program outcomes are presented in Table 1.

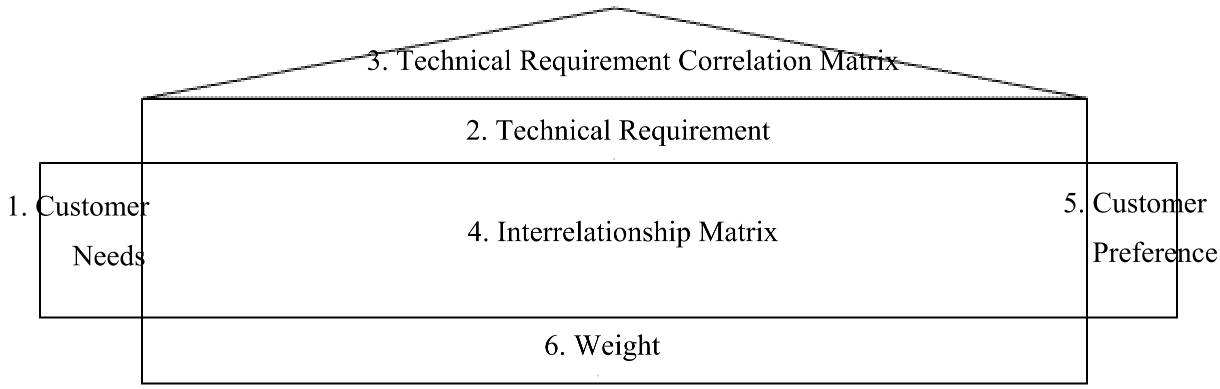

Figure 1. HOQ structure

Next, the Hows are the technical requirements, which are methods for accomplishing the outcomes in region 1. The course curriculum in region 2 was selected to be the Hows in our study. The Hows include not only the course curriculum of a corresponding university but also that of a benchmarking university for the potential adoption of those in a new, revised curriculum design. More specifically, the curriculum refers to all the mandatory courses of cultural studies such as English Reading and major-related courses. Also, we add extracurricular programs, such as an internship, to verify the necessity of internships to the Whats by using QFD.

The roof of the HOQ, called region 3, is a correlation matrix that displays the interrelationship between the Hows in region 2. In this study, we propose a special utilizing method for the roof in the context of curriculum design. Briefly, we subdivided and presented the interrelationship between the courses into prerequisite and overlapping relations. Then, several equations are suggested for making a decision about removing or merging courses in a new curriculum design. The detailed process for utilizing the roof will be explained.

In region 4, the interrelationship matrix displayed the relationship between customers' requirements and technical design items. The relationships between each of the 12 program outcomes and individual courses are presented in our study. Each matrix cell will be filled up with numerical values in a certain scale. Filling the interrelationship matrix involves discussions and consensus building within the QFD team (Chakraborty *et al.*, 2007).

Region 5 is the part for calculating the weight of each customer need, which represents the importance of each program outcome in our analysis. Weights were computed based on both survey data from respondents who were constituents of an engineering education at the corresponding university, and the evaluation scores of those at a competitive university.

Before standardizing the sum of weights as 1, we computed the *absolute weight* of program outcomes, which is the product of 3 independent values:

$$\textit{Absolute Weight} = \textit{Priority} \times \textit{Level up Ratio} \times \textit{Sales point} \qquad \textbf{(1)}$$

where priority was the average of the importance of each outcome obtained from the respondents on a 7-point scale, and the Level-up Ratio was the ratio of the target score to the current evaluation score of the corresponding university's IE curriculum assessed with respect to each program outcome. The evaluation score is computed based on the survey data, while the target score is decided by comparison to the competitor's program (Koksal and Egitman, 1998; Pitman *et al.*, 1996). Lastly, the

Sales-point is the marketing point of program outcomes given in Table 1. This can be obtained from IE students' discussion.

Lastly, region 6 showed the final weight of each course by multiplying the values in region 4 and the absolute weights obtained from equation (1) in region 5. We computed the final weight of an individual course curriculum as follows:

$$Weight_j = \sum_i Absolute\ Weight_i \times Interrelation_{ij} \quad \textbf{(2)}$$

where i is the index of outcome and j is the index of course. $Interrelation_{ij}$ indicates the value representing the relationship between outcome i and course j in region 4.

Utilization of the Roof

Although the basic role of the roof was to display interrelations among individual courses in region 2, we suggest special utilization methods for the roof by taking two steps. The first step was to divide the interrelations among courses into overlapping and prerequisite relation. The next step was to modify the curriculum by removing or merging the overlapped courses based on the results from the former step.

To show the prerequisite relation, we relied on two assumptions. First, the course with a higher prerequisite score is located relatively on the left-hand side. This was to make the QFD simple by showing the prerequisite relation with the relative location of the course on the roof. Since the score on the matrix did not indicate which course was a prerequisite for another, we tried to show this relation by their relative locations. Next, we assumed that the prerequisite relation between courses was consistent.

For the first step, since we needed to show both the overlapping and prerequisite relationship in one roof, we divide each intersected cell of the roof into two parts as shown in Figure 2. We put the degree of prerequisite relation on the upper part while putting that of overlapping relation on the lower part. Empty cells represent the fact that no known correlation existed in the pair. The degrees of relation were set up as a 1, 3, 5 scale in Table 3 with higher numbers representing higher degrees of correlation.

Next, we utilize the prerequisite, overlap, and relation scores to modify the curriculum. First, the *prerequisite score* of course j was computed using the following equation:

$$\text{Total prerequisite score}_j = \sum_{k=1}^{n} \text{prerequisite}_{jk} \quad \textbf{(3)}$$

where j, k is the index of courses and n is the total number of courses. According to this equation, courses with a higher prerequisite score were more likely to be basic courses.

Second, the *overlapping relation* of course j was computed as:

$$\text{Total overlap score}_j = \sum_{k=1}^{n} \text{overlap}_{jk}\ . \quad \textbf{(4)}$$

The overlap score indicates the degree of similarity between two courses j & k. This can be used for decisions about removing overlapped courses.

Table 3. Relation degrees of the roof

Degree	Prerequisite	Overlap
1	Rarely	Rarely
3	Partially	Partially
5	Mostly	Mostly

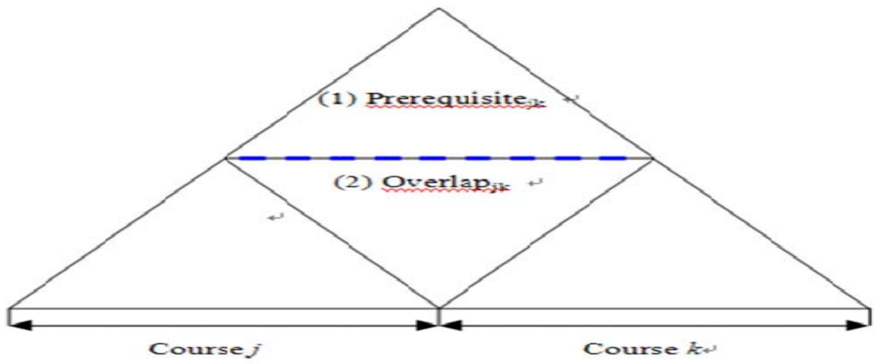

Figure 2. Structure of intersected cell in roof

We used both overlap and prerequisite scores to redesign the current curriculum at the corresponding university. After computing each score, we chose courses with high overlap scores. If those courses also had high prerequisite scores indicating that they were necessities for other courses, we needed to keep those in the curriculum. However, if some courses had relatively low prerequisite scores, then we needed to modify those courses either by simply removing them or merging them with other courses.

To merge one course with another, the relation score should be considered:

$$\text{Relation score}_{jk} = \text{prerequisite}_{jk} + \text{overlap}_{jk}\,. \quad \textbf{(5)}$$

This was suggested to complement the decision for removing or merging courses. That is, two courses with a high relation score should be merged into one course.

RCM Application

Once all the information was in place to make a decision about removing or merging courses, we reorganized the curriculum by dividing the courses into several tracks based on their relation. In this paper, we suggest a new clustering method using the relation score. We call it RCM (Relation Clustering Method). Details of the proposed methodology follow.

$$Maximize\ \ Total\ \ \mathrm{Re}lation\ \ Score = \sum_{c} \text{Relation Score}_{c} \quad \textbf{(6)}$$

$$\text{where Relation Score}_{c} = \sum \mathrm{R}elation\ \ Score_{ij} \quad \textbf{(7)}$$

For all *ij*, course $i \in$ cluster c and course $j \in c$

Using (6) & (7), one can find clustered tracks of courses. Since we already eliminated unnecessary courses from the curriculum, a high total relation score indicates a close relatedness among courses in the cluster. That is, close relatedness can indicate that courses in that cluster share similar contents or objectives.

Conclusion

We proposed a methodology based on QFD to revise the curriculum using ABEEK accreditation criteria, which are globally verified ways to enhance the quality of education. QFD analysis can be used to develop a systematic way to build new curricula, which consider objectives, the degree of importance for each course, sequential relations, overlapping relations among courses, and the specific track of the curriculum. Furthermore, this methodology is expected to be extensively utilized for other curriculum redesigns according to ABEEK accreditation criteria.

Acknowledgment

Gyeong Mu Kim, Il Seo Son, Chang Wei Noh, Chi Ho Song participated in data collection and analysis.

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