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Selection of Curricular Topics Using Framework for Enhanced Quality Function Deployment

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Based on the fact that products and services require an interdisciplinary approach, there is a growing conviction that engineering disciplines are converging rather than diverging. The curricula must, therefore, be designed to ensure that a student will posses all the qualities of a generalist and all the competence of a specialist with a capacity for life long learning. Decision science can be an effective tool for enhancing organizational participation during strategic and complex decision making. The challenge was to develop a set of curricular topics that not only directly contributed to the identified goals but that did so proportionately to the respective importance level of each goal.

This paper describes an application of Quality Function Deployment (QFD) to define curricular topics that meet program objectives. The inputs for the QFD's were obtained through several brainstorming sessions of students, faculty members, administrators, and business people. Based on the ability of QFD to establish relationships, the model identifies the most important topics and quantifies their impact on meeting program goals. The model was developed to support restructuring of a masters of technology programme. It provides a framework using enhanced quality function deployment for selection of curricular topics.

The model provided a practical methodology for developing faculty consensus in the selection of curricular topics with a strategic focus. The decision problem is structured for assessment of impact of curricular topics on the program goals keeping checks on consistencies.

Keywords: Quality Function Deployment (QFD), Analytical Hierarchy Process (AHP), House of Quality (HOQ), Programs goals (PG), curricular topics (CT).

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1. INTRODUCTION

The Department of Engineering Management at Azad Institute of engineering and technology offers a Masters of Technology (M Tech) degree in Advanced Computer aided design (ACAD). The faculty recognized that the M Tech programme curriculum should be examined and selected based on relevance to existing conditions. Based on changes in the Industrial requirements, faculty personnel turnover, administrative pressures to increase enrollment, and other environmental changes indicated the need to critically examine the M Tech curriculum. The diverse nature of requirements of stakeholders that include management, enrolled and prospective students, faculty, surrounding industries, etc in a Technical Education System (TES) makes it extremely difficult to decide on what constitutes quality. QFD is a proven tool in ascertaining customer desires, prioritizing them, and directing organizational resources towards customer satisfaction (Akao 1990). QFD principles have been applied to product development, realization of physical goods, intangible services, software, systems and strategy, educational improvement, etc (Hunt and Killen 2004, Soota et al 2008a). QFD has been used along with analytical hierarchy process (Dweiri and Kablan 2005, Soota et al 2008b), along with neural network (Mahapatra and Khan 2007), fuzzy logic (Chin Hung Liu 2008, Chin Hung Liu and Hsin Hung Wu 2008)

Some of the applications relating to quality improvement in curriculum have been mentioned. Mazur (1996) used application of QFD to design a course of Total Quality Management (TQM) at the University of Michigan College of engineering, resulting in growth of student–teacher ratio and need to increase the number of sections from one to three. Clayton (1995) reported the use of QFD to build a degree program in the department of Vision sciences at Aston University in the United Kingdom. Nilsson et al (1995) reported on the use of QFD to develop a Mechanical engineering program more responsive to the needs of changing industries in Swedan. In Japan Akao, Nagai and Maki (1996) have systemized a process for identifying and analyzing both the internal and external evaluators of higher education and using QFD to identify and improve critical and conflicting needs. Seow and Moody (1996) used it to design a MSc degree in quality management at University of Portsmouth in U.K. Pitmanet al (1996) showed QFD application in an educational setting.

Suliman (2006) demonstrated the use of QFD in review of curriculum. Mahapatra and Khan (2007) have done a empirical study using Neural network approach for assessing technical education. Mahapatra and Khan (2007b) have developed a method to provide guidelines for administrators of the institutions to prioritize improvement policies needs to be implemented.

2. PROGRAM OBJECTIVES AND GOALS

The curriculum redesign effort adopted a methodology based on which the curricular topics (CTs) were to be directly linked to desired outcomes i.e. program goals (PGs). The process of data collection employs adaptation of vocalyst process for extracting information from the data which was qualitative as well as quantitative. There were a series of brainstorming sessions and meetings between the faculty and management to develop program objectives and associated goals. Various program objectives and goals are identified based on factor analysis on cross-sectional questionnaire survey and interviews.

These are summarized below as program objectives and goals.

2.1. Program Objectives

1. Provide skills, knowledge and attitudes to manage the computer aided technology based enterprise.
2. Develop ability to choose and apply appropriate approaches to computer aided design and management problems.
3. Foster outstanding technology leadership skills.

2.2. Program Goals (PGs)

1. Develop and implement projects
2. System based problem solving
3. Leadership qualities to make a difference
4. Design and special skills
5. Teamwork and communication
6. Quantitative and analytical skills

However it was observed that the program goals were not equally important, the identity and character of the program is highly dependent the emphasis placed on specific program goals. A framework for linking customer requirements to product characteristics is provided by quality function deployment (QFD). The methodology used serves as a mechanism for developing curricular topics in a disciplined and well-structured format. The next section describes the modeling structure and its application within an academic context.

3. PORTFOLIO MODEL FOR QFD

Basic approach to quality function deployment (QFD) involves translation of desires of customers into product design or engineering characteristics and subsequently into parts characteristics, process plans and production requirements. Each translation uses a matrix called House of Quality (HOQ) for identifying customers needs (CNs) and establishing priorities of engineering characteristics (ECs) or design requirements to satisfy the customers needs (Griffin and Houser 1993, Soota et al 2008a). These strengths indicated QFD would be an attractive alternative for analyzing the problem of selecting curricular topics. The specific information presented in this paper generally reflects the methods applied but the details have been modified for brevity while demonstrating basic model concepts.

The program goals are evaluated using pairwise comparisons to find their priority weights. Pairwise comparison matrix to find the e-vector is shown in table 1. Analytical hierarchy process or eigen vector method is used to find the degree of importance. A short computational procedure to get e-vector is to raise pairwise comparison matrix to powers that are successfully squared each time. The process of squaring stops when there is no significant change between all the elements of the pairwise comparison matrix in two successive steps of squaring. After that the row sums are calculated and normalized to get e-vectors. The consistency ratio (CR) is evaluated to check for inconsistency of judgments, such that the values of ratio exceeding 0.1 are indicative for the need to revise judgments of comparison matrices (Satty and Kearns 1985, Shin et al 2002).

Table 1. Pairwise comparison matrix

Goals	Develop/Implemt	System based soln	Leadership	Special skills	Written/oral skills	Quantitative	*e-vector*
Develop/Implemt	1	2	2	3	3	2	*0.298*
System based soln		1	0.5	1	1.5	1	*0.131*
Leadership			1	1.5	2	1.5	*0.201*
Special skills				1	1.5	1	*0.138*
Written/oral skills					1	1	*0.101*
Quantitative						1	*0.130*

CR is less than 0. 1, hence acceptable

3.1 Correlations and Interactions

Relationship rating between PGs and CTs is developed using very strong, strong, medium, weak, very weak, no relationship method of eliciting contribution of CTs to the satisfaction of PGs as shown in table 2. The curricular topics (CTs) identified were scored based on the direct impact using a traditional (5, 4, 3, 2, 1, 0) scoring method: five indicates very high impact of a topic on an objective, four indicates high impact, three indicates moderate, two indicated small impact, one indicated negligible impact and zero indicates no impact. Detailed information for scoring methods can be obtained from Armacost et al (1994).

Table 2. Correlation among curricular topics and program objectives

Curricular topics / Goals	Wts	Advn Maths	Info sys CAD	Geomt modelling	Finite Element Method	Adv Mechanics of solids	Robotics	Optimization	Simulation	ICG and Design
Develop/Implem	0.3	3	5	2	1	3	4	3	3	2
System based soln	0.13	3	4	1	1	1	2	3	3	3
Leadership	0.2	1	4	1	1	2	2	3	1	1
Special skills	0.14	1	2	5	5	1	3	3	5	3
Written/oral skills	0.1	0	5	1	0	0	1	1	1	1
Quantitative	0.13	5	1	1	4	1	3	5	3	3

In Table 3 the strength of reinforcement between ECs is evaluated. The interaction between a pair of ECs is a fractional value between +/-1. Using the relation rating scale of (5, 4, 3, 2, 1, 0) a parallel set of interaction score are defined. Very high interaction between two ECs is assigned a score of [5/ (5+4+3+2+1)] =0.333, high interaction a score of [4/15] =0.266, moderate interaction is assigned a score of [3/15]=0.2, small interaction a score of [2/15]=0.133, negligible interaction scored as [1/15] =0.066 and no interaction results in zero score. Consistent with the concept of correlation, the matrix assumes that the interaction of ECs is mutually equivalent.

Table 3. Interaction among curricular topics

Goals	Advn Maths	Info sys CAD	Geomt modelling	Finite Element Method	Adv Mechanics of solids	Robotics	Optimization	Simulation	ICG and Design
Advn Maths	1	0.066	0.133	0.2	0.066	0.066	0.333	0.2	0.066
Info sys CAD	0.066	1	0.133	0	0	0.2	0.066	0.066	0.333
Geomt modelling	0.133	0.133	1	0.2	0.2	0.333	0.2	0.133	0.266
Finite Element Method	0.2	0	0.2	1	0.066	0.133	0.066	0.066	0.066
Adv Mechanics of solids	0.066	0	0.2	0.066	1	0.066	0.066	0	0
Robotics	0.066	0.2	0.333	0.133	0.066	1	0.133	0.266	0.2
Optimization	0.333	0.066	0.2	0.066	0.066	0.133	1	0.2	0.066
Simulation	0.2	0.066	0.133	0.066	0	0.266	0.2	1	0.133
ICG and Design	0.066	0.333	0.266	0.066	0	0.2	0.066	0.133	1

4. INTEGRATED RELATIONSHIP MATRIX

Let us denote Table 2 as matrix **A** of m rows representing CTs and n columns representing PGs. The elements of this matrix may be described as a_{ij} (i = 1, 2,…, m and j = 1, 2,…,n). Similarly, the interaction data in Table 3 denoted as n x n matrix **B** with elements b_{ij} (i, j = 1,2,…, n). The combined impact of Curricular topics (CTs) on Program goals(PGs) may be defined by the m x n matrix **C,** the result of the matrix product (**A x B** = **C**) as shown in Table 4. The elements of matrix demonstrate the complete impact of CTs on PGs including direct and interaction impact. The elements of **C** (cij) describe the complete impact of CTs on PGs

Table 4. Matrix for modified HOQ

Goals	Wts	Advn Maths	Info sys CAD	Geomt modelling	Finite Element Method	Adv Mechanics of solids	Robotics	Optimization	Simulation	ICG and Design	Row totals	Relative wts
Develop/Implem	0.3	5.989	7.326	6.727	3.258	4.126	7.792	6.257	6.192	5.858	53.825	0.2033
System based soln	0.13	5.592	6.126	4.794	2.726	1.794	5.327	5.659	5.594	5.859	43.601	0.1647
Leadership	0.2	3.126	5.196	3.93	2.128	2.662	4.329	4.527	2.928	3.461	32.487	0.1227
Special skills	0.14	5.258	4.858	9.661	7.391	2.792	8.191	6.458	8.124	6.855	59.728	0.2256
Written/oral skills	0.1	1.128	5.798	2.597	0.531	0.332	2.932	1.929	2.062	3.33	20.739	0.0783
Quantitative	0.13	8.726	3.59	5.994	6.391	2.322	6.524	8.458	6.66	5.522	54.317	0.2052
											264.697	

$$C_{ik} = \sum_{j=1}^{n} a_{ij} b_{jk} \quad \text{--- (1)}$$

In case of ‘geometric modelling' impact on ‘system based solution’

C_{32}= 3*0.133+4*0.133+….3*0.133+3*0.266 = 4.794 ---- (2)

The total of the row elements are defined by the sum of the row impact values. The case of row total for ‘system based solution’ is illustrated below.

$$\sum_{j=1}^{n} C_{ij} = 5.592+6.126+4.794+\ldots\ldots+5.594+5.859 = 43.601 \qquad \text{---- (3)}$$

This is used to evaluate the weighted priority, for example for ‘system based solution’ relative importance weight is 0.1647 as given below.
C_{ij}^{N} =Relative weight of i_{th} row

$$C_{ij}^{N} = \frac{\sum_{j=1}^{n} C_{ij}}{\sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij}} = 43.601/264.697=0.1647 \qquad \text{---- (4)}$$

The modified HOQ is normalized to get Table 5. The column totals are obtained from product of importance rating and normalized values, which are then converted to percentages

$$\sum_{i=1}^{m} w_i C_{ij} = 0.1113*0.3+0.1283*0.13+\ldots+0.1606*0.13 = 0.1079 \qquad \text{---- (5)}$$

w_i= Weights of the criteria
C_{ij}= Normalised values of the matrix shown in table 5

Table 5. Normalised matrix for modified HOQ

Goals	Wts	Advn Maths	Info sys CAD	Geomt modelling	Finite Element Method	Adv Mechanics of solids	Robotics	Optimization	Simulation	ICG and Design
Develop/Implem	0.3	0.1113	0.1361	0.1250	0.0605	0.0767	0.1448	0.1162	0.1150	0.1088
System based soln	0.13	0.1283	0.1405	0.1100	0.0625	0.0411	0.1222	0.1298	0.1283	0.1344
Leadership	0.2	0.0962	0.1599	0.1210	0.0655	0.0819	0.1333	0.1393	0.0901	0.1065
Special skills	0.14	0.0880	0.0813	0.1617	0.1237	0.0467	0.1371	0.1081	0.1360	0.1148
Written/oral skills	0.1	0.0544	0.2796	0.1252	0.0256	0.0160	0.1414	0.0930	0.0994	0.1606
Quantitative	0.13	0.1606	0.0661	0.1104	0.1177	0.0427	0.1201	0.1557	0.1226	0.1017
		0.1079	0.1390	0.1255	0.0746	0.0584	0.1349	0.1243	0.1141	0.1168
		10.8%	14.0%	12.6%	7.5%	5.9%	13.6%	12.5%	11.5%	11.7%

5. RESULTS OBTAINED

It is possible to evaluate the disproportionate allocation of weights to curricular topics and how to restructure them. For example 'development and implementation' has a weightage of 0.30 but it receives only weightage of 0.2033 as shown in table 4. From the table 5 it can be seen that Geometric modeling contributes weight of 0.11 on 'system based solution' and 0.126 weight to overall objective. Normalized weights for curricular topics are listed in the table shown below.

Table 6. Normalized weights for curricular topics

Curricular Topics	Weight Vector
Advanced mathematics	0.1079
Information System for CAD	0.1390
Geometric Modeling	0.1255
Finite Element Method	0.0746
Advanced Mechanics of solids	0.0584
Robotics	0.135
Optimization	0.125
Simulation	0.115
ICG and Design	0.117

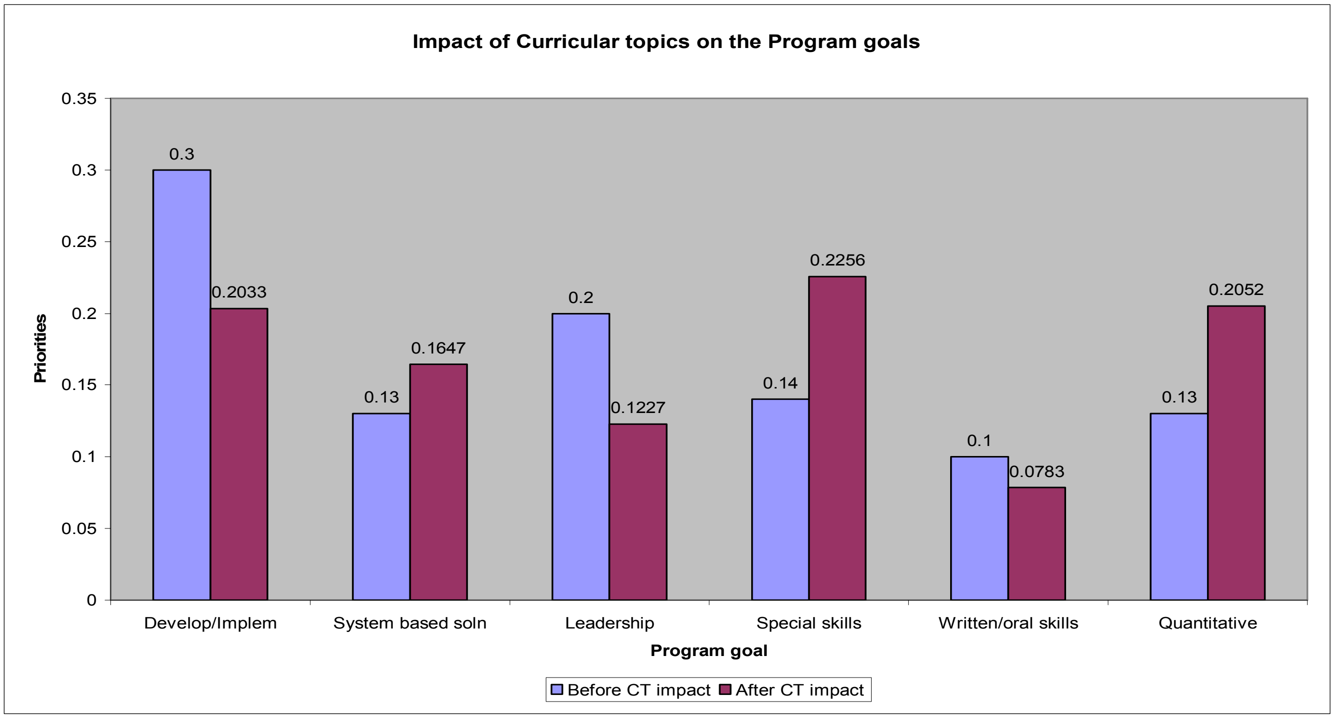

Figure 1. Impact of Curricular topics on the program goals

6. CONCLUSION

The selection and prioritization of the required curricular content to support program goals and objectives is the basic objective of any educational setup. It was desired to develop a set of curricular topics that not only directly contributed to the identified goals but that did so proportionately to the respective importance level of each goal. This research works on for developing a methodology for selection of curricula for an educational programme, by prioritizing the content in accordance to the objectives.

It evaluates the weights for goals and objectives, finds the correlation between the goals and the curricular content, finds the impact of curricular topics on the programme objectives, evaluate the disproportionate allocation of weights to curricular topics and suggests how to restructure content. To identify the components of such curricula, Quality Function Deployment (QFD) is used for determining and assessing the relationships between industry requirements, curriculum areas of study and specialization, contents and instruction methods and styles. This research enables us to identify and prioritize the objectives, goals of an educational programme, for finding the important curricular topics by quantifying their impact on meeting programme goals

It can be observed that 'development and implementation' has a weightage of 0.30 but it receives only weightage of 0.2033. It can be seen that Geometric modeling contributes weight of 0.11 on 'system based solution' and 0.126 weight to overall objective. The preliminary results of the pilot field test show that it is a useful tool in ascertaining customer desires, prioritizing them, and directing organizational resources towards customer satisfaction. The methodology can be used to explore the tradeoffs associated with the scope of engineering courses in terms of breadth and depth of coverage of the subjects.

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BIOGRAPHICAL SKETCH

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