AC 2011-807: INTEGRATING INTERNAL AND EXTERNAL CUSTOMER VOICES TO IMPROVE MANUFACTURING ENGINEERING UNDERGRADUATE CURRICULUM USING QFD

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Integrating Internal and External Customer Voices to Improve Manufacturing Engineering Undergraduate Curriculum Using QFD

Abstract

Quality Function Deployment (QFD) has been widely used in a variety of industry with the goal to achieve quality improvement and cost reduction. QFD is one of the tools to identify the strategy of taking into account the voices from customers and prioritize the efforts and/or recourses in building customers' needs into product designs. This paper discussed the implementation of QFD in an educational scenario, where the principles of QFD are applied to systematically improve the design of Manufacturing Engineering curriculum in a Midwest private institution. The incorporation of QFD is aimed at integrating the voices of various stake holders into curriculum development; the voices of academicians, students and companies that hire students are recognized and reflected in the curriculum quality improvement process. Fifty companies, current students, alumni, and all departmental faculty members become customers in the construction of QFD house. The outcome and process roadmap of this QFD-based curriculum improvement project may serve as an example for other academic institutions with the commitment of developing an effective and efficient curriculum to continuously meet the expectations of all constituencies.

1. Introduction

The changing economic condition and the present economic crisis have impacts to not only the economic world but also to academic institutions. Under this present condition, satisfying the customers would be one of the most important tasks for academic institutions as well. Delivering high quality education to students and preparing them to be more competitive in their job markets become a significant contributing factor to the sustainability of universities in the present competitive global market [10].

Globalization and liberalization have intensified the competition in various sectors such as industry, agriculture and service. However in educational sector whose major task is to develop human resources for other sectors, not every institution has realized the significance of the impact from market force. Among different types of schools, technical institutions are expected to set an example in propagating quality consciousness, teamwork, and production optimization, managing resources in the competitive environment and encouraging team spirit among all concerned parties [8].

In order to stay alive in the competitive world, many institutions are striving to provide their best programs [10]. All these institutions are continuously renovating their curriculum by offering good quality education, environment, facilities and teaching methods. Instructors at these academic institutions play a major role in designing curriculum for students. The process of curriculum design typically involves three different entities—academic institutional instructors or faculty, students and employers [3]. From the point of view of universities, there are generally two types of customers serviced by the

curriculum being designed: students and employers. Students are internal customers who directly receive the knowledge and skills imparted by the curriculum. Employers are referred as external customers. Employers provide employment to students, benefit from students' command of skills and concepts imparted by the curriculum. The lack of voices in terms of demands and expectations from both students and employers makes the curriculum less effective in meeting the needs of all customers. Given that both internal and external customers have voices that speak out their needs and expectations, the curriculum can be considered as a product of the university that needs to satisfy the expectations of both the internal and external customers. In such cases, an instructor's subjective opinion could significantly hinder the curriculum development. Therefore, there is a need to consider the question that how customer needs are transferred systematically into the desired products and that what kind of method should be used? For this reason, a systematic approach is needed to carry all the customer voices effectively and transfer them into the desired product features.

"Quality function" is defined as the collection of activities through which one achieves fitness for use. "Deployment" is the Japanese word, which refers to an extension or broadening of activities. Thus "Quality Function Deployment" means responsibilities for producing a quality item. The American Supplier Institute Inc [1] defined Quality Function Deployment (QFD) as a system for translating consumer requirements into appropriate company requirements at every stage, from research through product design and development, to manufacture, distribution, installation and marketing, sales and service. QFD is a systematic and organized approach of taking customer needs and demand into consideration while designing new products or services or while improving them. It focuses on customer expectations or requirements, often referred as the voice of the customer. It is a team based management tool in which customer expectations are used to drive the product development process. By implementing QFD, an organization is guaranteed to implement voice of customer in the final product. This paper intends to use QFD method to systematically translate the customer voices into an effective curriculum. A systematical QFD approach is implemented to assist in renovating an undergraduate manufacturing engineering program in a Midwestern university in United States, where QFD forms the crux of the curriculum design methodology.

2. Overview of QFD

QFD method was documented in Japan in the mid 1970's and was first introduced to the United States in 1983 by Professor Yoji Akao. Since then, remarkable development and implementation of QFD for curriculum design and improvement have been observed world-wide [5]. QFD method is a technique linking customer demands and product development. Ranking system in QFD method helps to identify and prioritize customer's voice clearly.

One of the main principles used in QFD is to determine directly from customers what they expect in a particular product or service viz., quality of curriculum in the instant case. This is called Voice of Customer in parlance of QFD. There are different approaches to achieve this goal. They are:

- One to one customer interviews.
- Focus groups.
- In context customer visits.

Interviews are useful because they allow probing customer voice effectively. Focus groups are also productive because they promote the development of creative ideas by allowing participants to build on view points. In context customer visits allow to actually observe how existing status can be improved after understanding the needs from customers. All the data reflecting customer voice can be captured through a structured statement on customers' needs. The requirements are then prioritized based on the level of importance the customer assigns to each requirement. Sometimes gap analysis is done to evaluate the importance and related data is prepared with reference to

- Importance to the customer
- Level of customer satisfaction

2.1 Basic Concept of QFD

QFD, while highly customized, usually includes a "relationship matrix" with a number of attached analysis sections [4]. Each row describes a requirement, or what Dr. Yoji Akao, co-founder of QFD, called "demanded quality." This is the voice of a relevant customer. Each column describes a measurable "response" to the demanded quality – something that the solution provider would propose to drive and measure in order to satisfy requirements. This is the voice of a "provider", who will endeavor to address the requirements. Each cell asks a team to evaluate a relationship between the intersecting row and column. Depending on the objective of a particular QFD and its place in the development cycle, the sense of this evaluation can be quite different.

Figure 1 shows the structure of a QFD model where it has a front door showing WHATS (requirements) of both internal and external customer's voices with an importance scale. The roof of the House of Quality (HOQ) is occupied by the HOWS which determines the technical attributes to achieve customers' WHATS. The triangular portion above the roof represents the Correlation Matrix between conflicting HOWS. The body of the house comprises of the ranking system between WHATS and HOWS known as the Relationship Matrix followed by prioritizing the results.

Subsequent sections of the paper describe a detailed systematic approach in transferring the customer voices into the desired product features by developing a House of Quality satisfying the needs of all the customers.

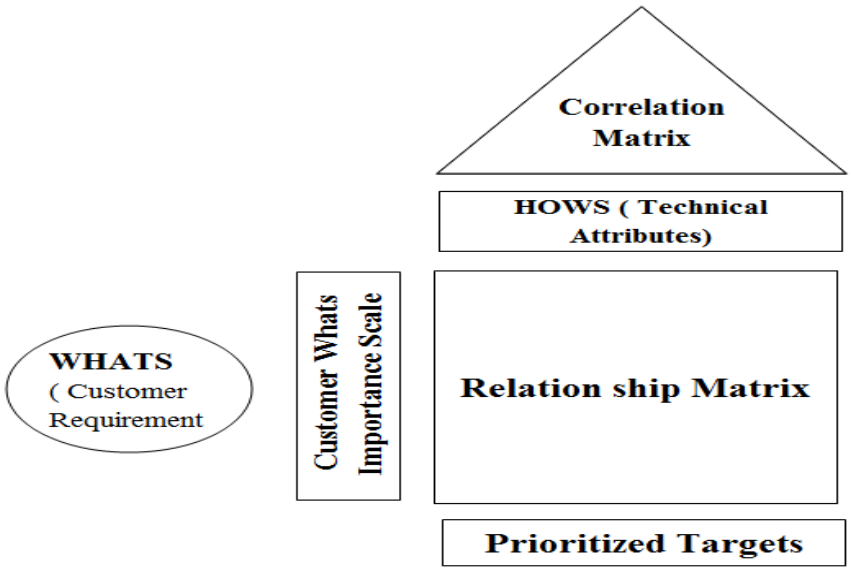

Figure 1 QFD Structure

2.2 Procedures to Transfer Customer Requirements into Desired Product Features - Initializing the QFD process

Step 1: Identifying the Product and Customers

The process of QFD is initiated by identifying the product and customers. There is always a need to understand who are our customers, what are their requirements, and what is their product and what are customers looking for in the product.

Step 2: Determining the Voice of Customer (Customer Needs)

Customer demands are collected through surveys and these requirements serve as Voice of Customer to initiate the QFD process. These voices serve as the WHATS in the House of Quality. This step initializes the developments of the HOQ.

Step-3: Developing the House of Quality

Developing the HOQ consists of six stages; a detailed explanation of each stage is described in the following steps.

stage1: Consolidating customer requirements (WHATS) into the HOQ

The customer voices are important in developing a HOQ which are known as WHATS and serve as the front door of the QFD matrix as shown in Figure 1.

stage2: Identifying importance scale for customer WHATS

The important scale is ranked by the customers. The scale indicates how important the needs are to the customers.

stage3: Determining the technical portion of QFD matrix (HOWS).

Once the customer needs (WHATS) are identified, then appropriate design requirements which are known as HOWS are determined.

stage4: Relationship between WHATS and HOWS

This is the main body of the QFD matrix, as it indicates how much each design requirements affects each customer need. Inter relationships for customer needs and design requirements are established, which are placed in the middle of the technical portion of the QFD matrix.

stage5: Correlation matrix

The objective of this stage is to highlight any requirements that are in conflict with others. If action on one item will harm another item, then this negative effect needs to be resolved. The triangular portion accommodates these relations, which gives the overall QFD matrix the appearance of a roof top.

stage6: Prioritizing targets

Column weights can be calculated, by using the customers' importance level in conjunction with weights assigned to the relationship symbols. The resultant number provides a method of judging the relative importance of each of the design requirements. Column weights can serve as an index for highlighting those design requirements that have the largest relative effect on the product. These column weights are entered at the bottom of the technical portion of the QFD matrix.

3. Construction of House of Quality

Two houses are constructed in this research, one for external customer and the other for internal customer. The procedures discussed in the above section are applied and are explained step by step in this section.

Step 1: Identifying the product and customers

The product considered in this study is the curriculum offered for an undergraduate manufacturing engineering and technology program in a Midwest educational institution in the United States. Students and employers are considered as customers for this study. Potential employers in the field of manufacturing engineering are considered as the external customers. Internal customers are further classified into two types - alumni and current students.

Step 2: Identifying the voice of customers and documenting their requirements

QFD begins with collecting the customer voices and incorporating them into the HOQ. An extensive online search for jobs related to manufacturing engineering were collected using websites such as yahoojobs.com, monster.com, careerbuilder.com. Thus obtained job descriptions were classified into knowledge, skills and working ethics as shown in Table 1. The data collected from these websites served as the base for external customers' voice which helped to initiate the HOQ for external customers.

Table1. External Customer's voices

Requirements	Manufacturing Engineering	Relative Frequency
Knowledge's	Production and process Development	22
	CAD and 3d modeling	19
	Lean and its concepts	18
	Tool design	18
	Manufacturing Quality	18
	CAM & CNC machining	15
	Six Sigma	7
Skills	Computer skills	35
	Communication skills	24
	Problem solving skills	18
	Documentation Skills	10
	Team building skills	9
Work ethics	Positive attitude	18
	Leadership qualities	14

The job descriptions were collected from 50 companies and were used not only for obtaining external customer voice but also served as a base for internal customer voice. Using the job descriptions from Table 1 a survey was designed for a total of 11 internal customers (alumni and current students) to collect their voices. Table 2 shows the customer voice for internal customers.

Step3- Developing House of Quality

House of Quality for External Customers

Stage 1: Consolidating external customer requirements (WHATS):

Data from Table 1 has been used as the external customer voice (WHATS) and are incorporated into the HOQ. Figure 2 shows the HOQ with WHATS of external customers. The requirements thus obtained were given a relative importance scale based on customer frequencies.

Table 2. Internal Customers

Requirements	Relative Frequency
Production & Process development	8
CAD&3D Modeling	8
Lean and its concepts	7
Communication skills	7
Problem solving skills	5
Computer skills	4
Better and fast computers	4
Lab accessibility to students	3
Less lecture hours with more practical Knowledge	2
CAM& CNC Machining	2
Manufacturing Quality Control	1
Tool Design	1
Six Sigma	1
Team building skills	1

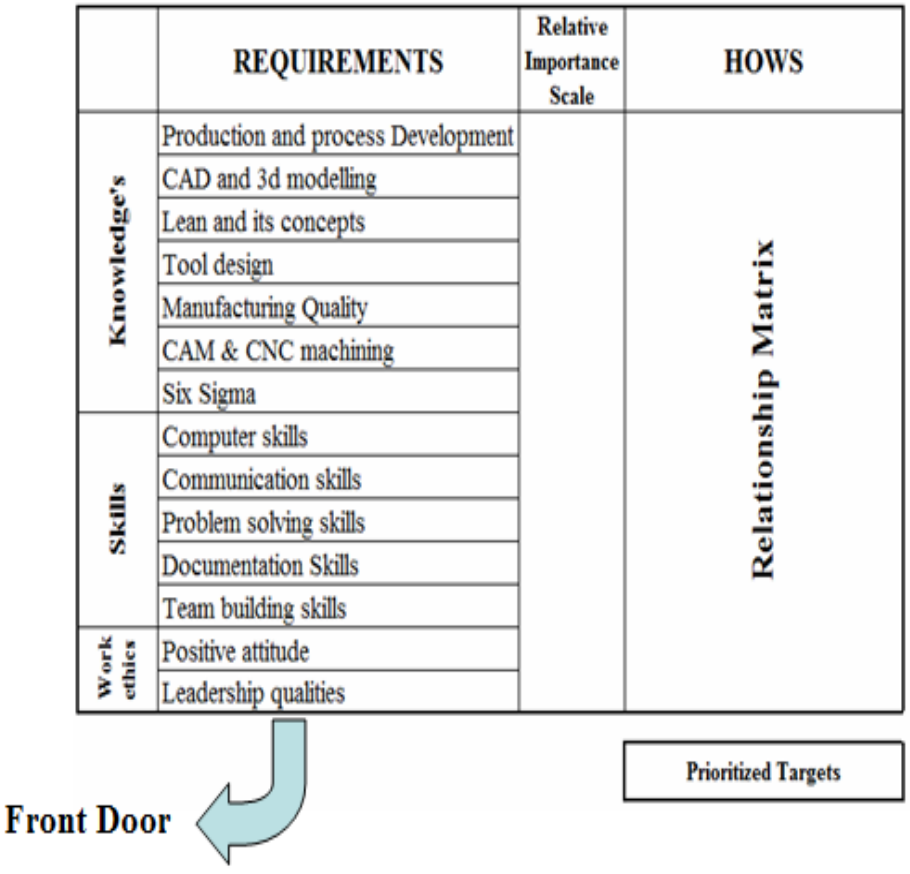

Figure2. Front door of external customers in HOQ

Stage 2: Identifying importance scale of customer WHATS

The importance scale for external customers WHATS depends on the frequency and relative percentage range. An importance scale of 1–5 has been chosen accordingly depending on the relative percentages calculated as shown in the following example, where 5 denotes the most important and 1 being the least.
For example: As shown in Table 1 for Production & Process development of external customers had a frequency of 22 out of 50 companies. The relative percentage is calculated as (22/50)*100 = 44%. The range for relative importance scale for external customers is given as 0%-9% as 1 (least significant), 10%-19% as 2, 20%-29% as 3, 30%-39% as 4, 40% and above as 5. Table 3 shows the frequency, relative percentages and importance scale for external customers.

Table3. Frequency, Relative %, Importance Scale for External

REQUIREMENTS		**Relative Frequency**	**Relative Percentages**	**Importance Scale**
Knowledge's	Production and process Development	22	44%	5
	CAD and 3d modeling	19	37%	4
	Lean and its concepts	18	35%	4
	Tool design	18	35%	4
	Manufacturing Quality	18	35%	4
	CAM & CNC machining	15	21%	3
	Six Sigma	7	14%	2
Skills	Computer skills	35	70%	5
	Communication skills	24	48%	5
	Problem solving skills	18	36%	4
	Documentation Skills	10	20%	3
	Team building skills	9	18%	2
Work ethics	Positive attitude	18	35%	4
	Leadership qualities	14	27%	3

Stage 3: Determining the technical portion of QFD matrix (HOWS)

In order to meet the customer requirements the necessary actions in the form of suggestions are needed. Suggestions (HOWS) were provided with the help of the faculty to meet the voices of external customers. These HOWS were incorporated in the top portion of HOQ. Figure 3 gives a clear idea of QFD matrix with customer WHATS, relative importance scale and HOWS.

				HOWS							
				RELATIVE IMPORTANCE SCALE	More case and mini projects related to real world problems	Having more team projects in the class	Using consistent softwares between classes	More hands-on lab work with increased equipment utilization in course work	Course related seminars by specialist's	More Real world experience for the faculty	Modifying curriculum with lean and sizsigma concepts
WHATS		REQUIREMENTS									
	Knowledge's	Production and process Developme		5							
		CAD and 3d modelling		4							
		Lean and its concepts		4							
		Tool design		4							
		Manufacturing Quality		4							
		CAM & CNC machining		3							
		Six Sigma		2							
	Skills	Computer skills		5							
		Communication skills		5							
		Problem solving skills		4							
		Documentation Skills		3							
		Team building skills		2							
	Work ethic s	Positive attitude		4							
		Leadership qualities		3							
					Relationship between WHATS and HOWS						
					Prioritized targets						

Figure 3. QFD structure for external customers with WHATS , HOWS and relative importance scale

Stage 4: Relationship between What's and How's

To rank the relationship between WHATS and HOWS the research group collectively brainstormed with the faculty. During the session each how was ranked on a scale of 1-9

with 9 being the high significant effect on the corresponding WHAT and 1 being the lowest significant effect on its corresponding WHAT. Here in this relationship some of them are not ranked as they are neglible. The process could be better explained by considering the following example. More hands on lab work with increased utilization usage have a highly significant effect (ranked 9) in gaining knowledge in production and process development.

Stage 5: Correlation Matrix

The correlations are important and will help to identify impacts and tradeoffs, since desirable change in one could have a negative effect on another. But this research doesn't have any conflicts between the suggestions and hence this step was eliminated.

Stage 6: Prioritizing the Targets

In this step, column weights can be calculated, by using the customer WHATS importance level in conjunction with weights assigned to the relationship symbols and then adding all cell numbers. Once the column weights are obtained they can serve as an index for highlighting the suggestions (HOWS) in QFD matrix that have the largest relative effect on the customer WHATS.

Sample calculation for prioritized target:

In the case of external customers HOQ the final prioritized weights are calculated as 50% of knowledge's sub-prioritized targets + 25% Skills sub-prioritized targets + 25% Work Ethics sub-prioritized targets. For example in Figure 3, sub-prioritized target for knowledge's was done as (5*7+4*3+4*7+4*5+4*7+3*7+2*7) and the final prioritized target value 116 was obtained as (50%*158+25%*115+25%*33)

The top 7 prioritized targets for external customers are:

- Modifying curriculum with lean and six-sigma concepts.
- More case studies and projects related to real-world.
- Having more team projects in the class.
- More real world experience for faculty.
- More hands on lab work with increased utilization of equipment in course work.
- Course related seminars by specialists.
- Using consistent softwares between courses.

House of quality for Internal Customers:

Similarly the same procedure is applied to construct the HOQ for internal customers

Stage 1: Consolidating external customer requirements (WHATS)

To establish customer requirements in the front door of QFD house, the voices of internal customers listed in table 2 will be incorporated. Figure 5 shows the HOQ for internal customers with customer WHATS in front door.

External Customers	WHATS				HOWS						
				Relative Important Scale	More case and mini projects related to real world problems	Having more team projects in the class	Using consistent softwares between classes	More hands-on lab work with increased equipment utilization in course work	Course related seminars by specialist's	More Real world experience for the faculty	Modifying curriculum with lean and sixsigma concepts
		Requirements									
		Knowledge's	Production and process Development	5	7	5	7	9	3	7	7
			CAD and 3d modelling	4	3	3	9	7	3	3	5
			Lean and its concepts	4	7	9		5	7	9	9
			Tool design	4	5	5	5	9	5	7	7
			Manufacturing Quality	4	7	7		3	7	7	7
			CAM & CNC machining	3	7	3	7	9	5	7	3
			Six Sigma	2	7	5		3	5	7	9
			SUB-PRIORITIZED TARGETS		158	140	112	174	128	174	174
		Skills	Computer skills	5	5	7					9
			Communication skills	5	5	7			1	5	7
			Problem solving skills	4	9	9		7	3	9	9
			Documentation Skills	3	5	3				5	7
			Team building skills	2	7	7		1	3		9
			SUB-PRIORITIZED TARGETS		115	129		30	23	76	155
		Work ethics	Positive attitude	4	3	7			5	7	7
			Leadership qualities	3	7	7			1		7
			SUB-PRIORITIZED TARGETS		33	49			23	28	49
			PRIORITIZED TARGETS=(50%Knowledges+25%skills+25%work ethics)		116	114.5	56	94.5	75.5	113	138
			RANKING		2	3	7	5	6	4	1

Figure 4. Prioritized targets of External Customers

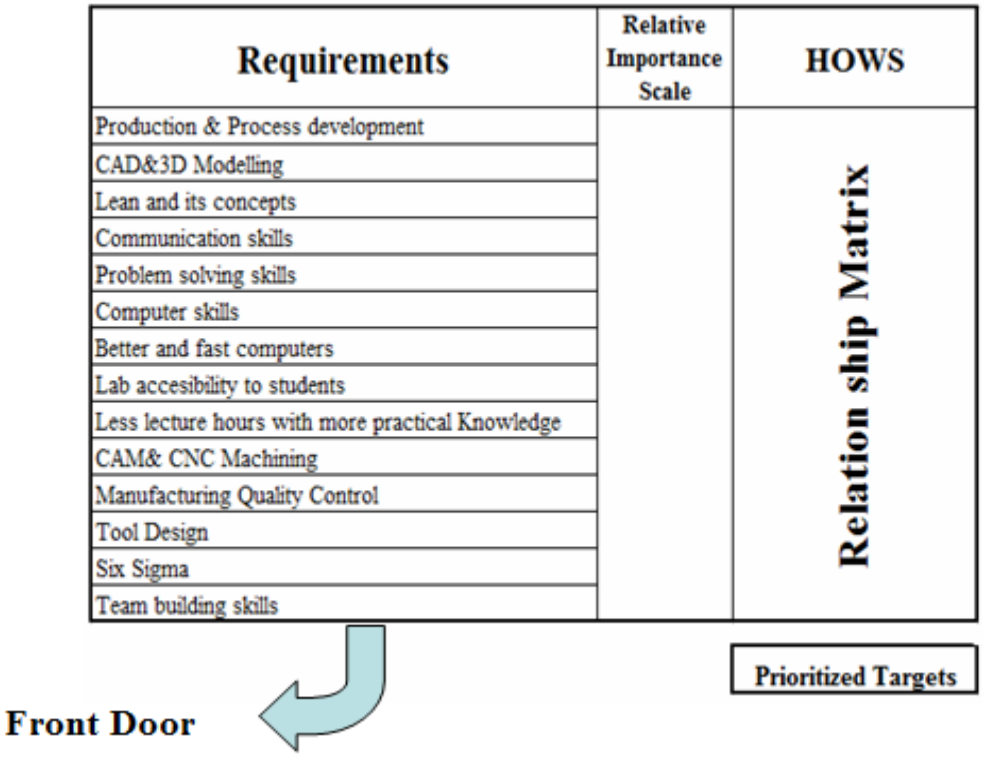

Figure5. Front door of internal customers in HOQ

Stage 2: Identifying importance scale of WHATS

Importance scale for internal customers was given in a similar way as it was done for external customers. Data obtained from the surveys were converted into relative percentages depending on the frequency count of every customer requirement. An importance scale from 1–5 was chosen depending on the range of relative percentages, where 5 denotes the most important and 1 the least . The entire process of identifying the importance scale is better understood considering the following numerical example. For example: As shown in Table 2 for Production & Process development of internal customers, the frequency count was noted to be 8 out of 11 responses. The relative percentage is therefore calculated as (8/11)*100 = 72.7%. The range for relative importance scale for internal customers is given as 0%-15% as 1, 15%-30% as 2, 30%-45% as 3, 45%-60% as 4, and 60%-75% as 5. Table 4 shows the frequency, relative percentages and importance scale for internal customers.

Table 4. Frequency, Relative %, Importance Scale for Internal Customers

Requirements	**Frequency**	**Relative Percentages**	**Importance scale**
Production & Process development	8	72.7	5
CAD&3D Modeling	8	72.7	5
Lean and its concepts	7	63.6	5
Communication skills	7	63.6	5
Problem solving skills	5	45.5	4
Computer skills	4	36.4	3
Better and fast computers	4	36.4	3
Lab accessibility to students	3	27.3	2
Less lecture hours with more practical Knowledge	2	18.2	2
CAM& CNC Machining	2	18.2	2
Manufacturing Quality Control	1	9.1	1
Tool Design	1	9.1	1
Six Sigma	1	9.1	2
Team building skills	1	9.1	1

Stage-3: Determining the technical portion of QFD matrix (HOWS)

Online survey was conducted for alumni and in-class survey was conducted for current students to gather the necessary critical elements in meeting the customer requirements. The data obtained from the surveys provided the research group with some suggestions for their effects in meeting the requirements. Considering the result of the surveys, the research group generated best suggestions by brainstorming and HOWS were included into the top portion of the HOQ for internal customers. A group of 3 senior undergraduate manufacturing students participated in the brainstorming sessions and provided their valuable suggestions. Figure 6 gives a clear idea of QFD matrix of internal customers with WHATS, relative importance scale and HOWS.

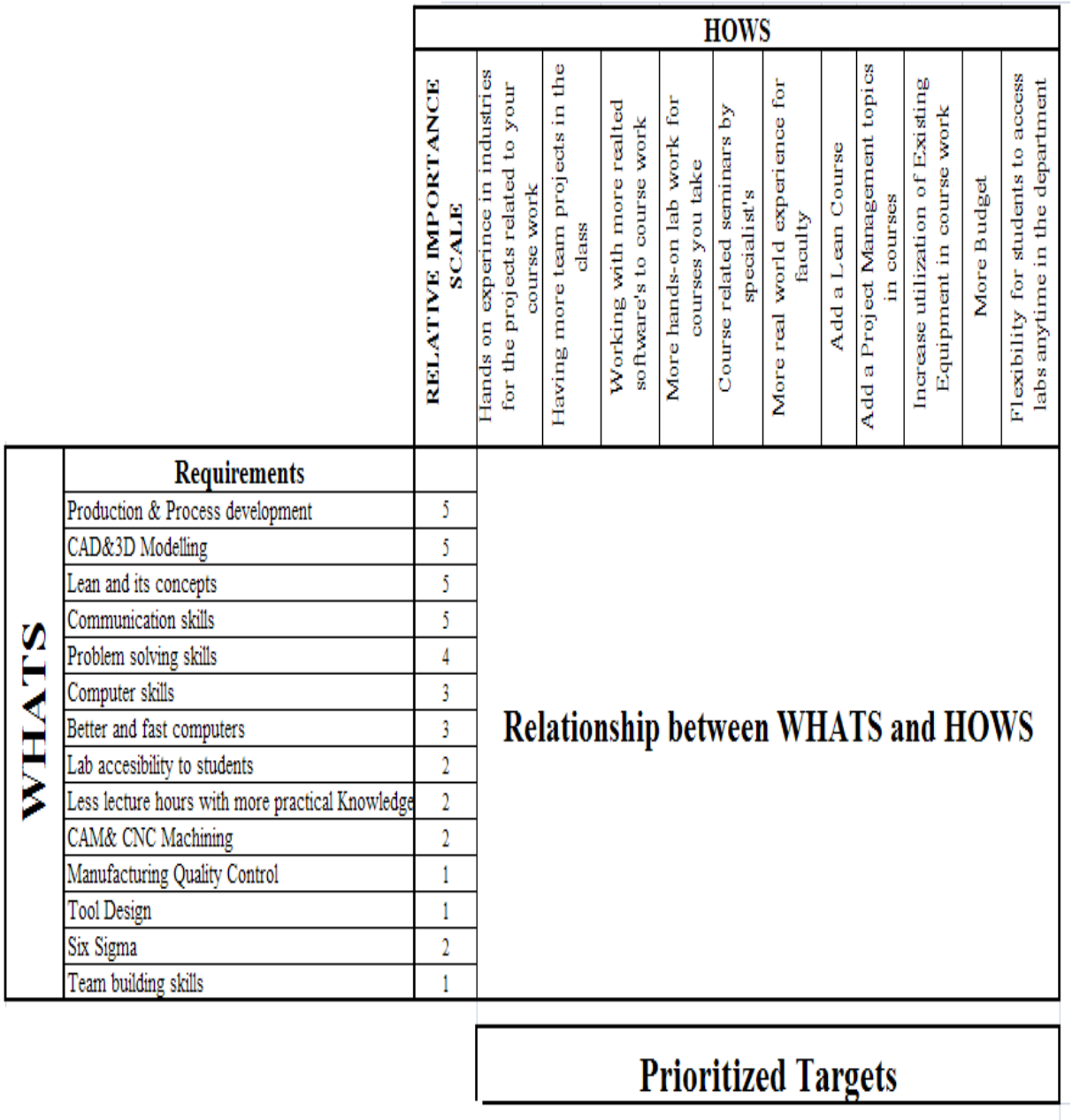

Figure 6. QFD structure for internal customers with WHATS, Relative importance scale and HOWS.

Stage 4: Relative ranking between WHATS and HOWS

A similar procedure was followed to rank the relationship between the WHATS and HOWS as was done for the external customers.

Stage 5: Correlation Matrix

Again this research doesn't have any conflicts between the suggestions and hence this step was eliminated.

Stage 6: Prioritizing the Targets

Prioritizing is done in a similar way as it was done for external customers. As an example, the calculation to obtain a prioritized target 250 is done as (5*7+5*7+5*9+5*5+4*9+3*3+2*9+2*7+1*7+1*7+2*7+1*5)

			HOWS											
INTERNAL CUSTOMERS	What's	Requirements	Relative importance scale	Hands on experince in industries for the projects related to your course work	Having more team projects in the class	Working with more realted software's to course work	More hands-on lab work for courses you take	Course related seminars by specialist's	More real world experience for faculty	Add a Lean Course	Add a Project Management topics in courses	Increase utilization of Existing Equipment in course work	More Budget	Flexibility for students to access labs anytime in the department
		Production & Process development	5	7	7	5	7	5	7	9	5	7	7	7
		CAD&3D Modelling	5	7	3	5	7	5	5	3	5	3	5	9
		Lean and its concepts	5	9	7	3	9	5	9	9	5		5	5
		Communication skills	5	5	7			3	5	5				
		Problem solving skills	4	9	7		7	5	7	7	5	5		
		Computer skills	3	3	5	5	7		7	7	3	5		7
		Better and fast computers	3										9	
		Lab accesibility to students	2				7					9	5	9
		CAM& CNC Machining	2	9	3	7	9	3	7	5	3	9	7	7
		Less lecture hours with more practical Knowledge	2	7	7	3	7		7	7		7	7	
		Manufacturing Quality Control	1	7	5	3	5	7	7	5	7		3	
		Tool Design	1	7	5	5	7	3	7	7	3	9	5	7
		Six Sigma	2	7	7	3	5	3	5	5	5	3	5	
		Team building skills	1	5	9			3	5	7	9			
		PRIORATIZED TARGETS		250	216	114	232	135	236	232	139	150	168	165
		RANKING		1	5	11	3	10	2	3	9	8	6	7

Figure7. Prioritized targets for internal customers

As a result, the top 7 prioritized targets for internal customers are:

- Hands on experience in industries for the projects related to course work.
- More real world experience for faculty.
- Add a lean course.
- More hands-on lab work for courses taken
- Having more team projects in the class.
- More budget.
- Flexibility for students to access labs anytime in department.

4. Educational Impact

Based on the result of the QFD analysis, the Manufacturing Engineering curriculum was improved and implemented in the Midwest private institution. With the voice of customers built into the curriculum, the following outcomes have been obtained

- The improved curriculum is well received by students. Students enjoy the learning environment as the curriculum is becoming more student-centered. In particular, project-based courses give students a balanced education by integrating theory and application.
- The improved curriculum is positively commented by industry advisory board.
- The job placement rate achieves 100% upon graduation.

Such a result is a reflection of effectiveness of QFD method applied in improving educational programs. The QFD process will be continuously repeated in the future in order to drive the improvement to embrace the ever-changing customer needs.

5. Conclusions

In today's competitive world, customer satisfaction is a vital goal to be accomplished at an affordable cost. One important factor in customer satisfaction is the effective identification of customer expectations. In this paper the implementation of QFD is discussed in an educational scenario, where the principles of QFD are applied to systematically improve the Manufacturing Engineering curriculum in a Midwest private institution. The method of QFD is able to integrate the voices of various stake holders into curriculum development. The voices of academicians, students and companies that hire students are recognized and reflected in the curriculum quality improvement process. Fifty companies, current students, alumni, and all departmental faculty members become customers in the construction of QFD houses. Through using QFD to improve the curriculum, the research group expects the new curriculum to reduce the potential training costs for companies and reduces the gap between academia and industry.

This research revealed that the curriculum shall reckon the following important aspects:

- The students need to have hands on experience from industry, so that the future employer would get a qualified engineer who could easily dovetail into the practical scenario prevailing on the shop floor.

- The courses being designed need to be effective and efficient so that students will be enriched with enough knowledge and skills in both depth and scope before they land a job in industry.

- The university is expected to provide state of art lab facility, and increase the level of lab accessibility for students.

- Concept and practice of Lean, Six Sigma, TQM etc. should be built up in every stage of the curriculum, as it is strongly demanded in industry.

With the outcomes produced by this research, academic institutions' decision makers can now have a better basis on which to make their decisions as the areas designated as highly important for performance improvements can easily be pinpointed and addressed. While this study demonstrates the effectiveness of QFD in improving Manufacturing Engineering curriculum, the authors believe that the same method can be expanded to improve the curriculums in other majors and programs.

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