

# Assessing Engineering Education: an Industrial Analogy\*

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*Embedding quality improvement methods into the teaching of engineering processes is not new to engineering education. Engineering graduates are expected to be able to develop and design products and processes that meet the needs of customers within given constraints and follow known procedures to ensure quality results. Quality function deployment (QFD) is an internationally accepted planning technique that is used to ensure that quality is designed into a product by incorporating customers' needs. The QFD matrices depict the components of this process for determining engineering characteristics, parts characteristics, key process characteristics, and production requirements. The QFD process will be used as a tool for understanding the assessment of academic programs and meeting the continuous improvement requirements embedded in Engineering Criteria 2000 [1]. The author compares the QFD process with the development of an assessment planning process and outlines considerations needed in developing an assessment tool (both content and process).*

## INTRODUCTION

THE AUTHOR uses Quality Function Deployment (QFD) to develop a step-by-step assessment process. QFD is a process familiar to many engineers. Using the steps of QFD to develop an educational assessment plan provides engineering faculty with a foundation for understanding quality assessment. It also encourages engineering faculty to expect the same positive benefits from quality assessment as seen with QFD—greater customer satisfaction and shorter development times.

This approach details the components of quality assessment and contrasts these components with the development of QFD:

QFD focuses on designing quality into a product or process. In quality assessment, the focus is on assuring quality in the educational process.

- QFD stresses knowing your customers and meeting their needs. Quality assessment stresses meeting the information needs of all constituents to provide continuous improvement.
- QFD emphasizes the enterprise functioning as a whole. Quality assessment emphasizes all aspects of the educational environment.
- QFD requires multidisciplinary teams. Quality assessment requires engagement of all members of the academic community.

Both approaches stress defining the situation and developing strategies for improvement.

QFD is an internationally accepted planning technique that is used to determine engineering characteristics, parts characteristics, key process characteristics, and production requirements. Although QFD was conceived in Japan in the late 1960s, it was not implemented in the USA until the 1980s [2]. QFD emerged as Japan transitioned from its post-World War II mode of product development through imitation to product development based on quality. QFD was used extensively in 1972 at Mitsubishi's Kobe shipyard site and was introduced in the US at Ford in 1984 [3]. Since that time, QFD has found widespread acceptance in the US at companies as diverse as Milliken, Xerox, and GE [4, 5].

QFD is a concurrent rather than a sequential approach to product development that uses cross-functional teams, improves communication between areas, identifies potential problems sooner, and documents the team's activities and findings in the House of Quality (HoQ) matrices. The cross-functional team is paramount to the success of QFD. Getting design engineers, materials engineers, tool designers, and manufacturing people immediately involved can cut development time and improve quality. 'In one instance, a wheelchair designer specified spin welding to join two asymmetrical parts' [6]. Because of the diversity and early involvement of the team, a manufacturing engineer saw a problem and suggested adhesive bonding as an alternative. This suggestion eliminated a problem that would have delayed full production. Xerox, who has won the Deming Award, the European Quality Award, and the Malcolm Baldrige Award, stresses the importance of the commitment of the team to the quality

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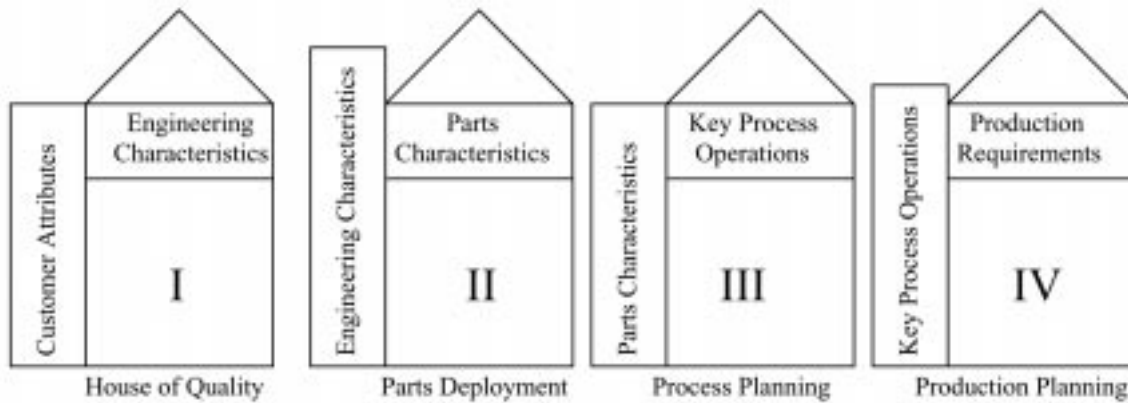


Fig. 1. Linked houses conveying the customer's voice through to manufacturing; redrawn from Hauser and Clausing 1988.

of the project. Their employees learn what quality means, how to implement it, and to develop new ways of working together [4]. A cross-functional team with a commitment to quality can insure continuous improvement.

The backbone of QFD consists of four 'houses' suggested to insure that the customer's wishes are carried all the way to manufacturing. These houses are shown in Fig. 1.

The first house is concerned with translating the wishes of the customer into engineering characteristics (ECs). Customer desires are gathered and compiled. A customer desire for a car door might be 'easy to close' [3]. ECs are a list of technical descriptors that characterize the product or process. The energy required to close the door expressed in ft-lbs is a possible EC for 'easy to close'. Developing the first HoQ identifies the key design specifications that will most please the customer. The HoQ team then selects target values for these ECs. In the case of the car door example, the team might select a target value of 7.5 ft-lbs of energy for the closing force.

These ECs become the input to the second house. The development of the second house determines the key part characteristics necessary to meet the target values for the ECs. Using the car door analogy, the closing energy of 7.5 ft-lbs becomes the 'what' and the hinge properties or thickness of the weather stripping becomes the part characteristic or 'how'. These part characteristics, such as thickness of the weather stripping become the input to the third house, which determines the key process operations necessary to insure that the key part characteristics are met. For example, the key process operation to insure the appropriate thickness of the weather stripping might be the rpm of the extruder that produces the weather stripping. Finally, the key process operations lead to the development of production requirements as shown in the fourth house. The required rpm of the extruder (key process operation) can be translated to knob controls and operator training (production requirements) [3]. Following the houses, the production requirements support the customer's desire for 'easy to close'.

## DEVELOPMENT OF ASSESSMENT QFD

The HoQ identifies customer requirements drawn from market evaluations and through benchmarking against competitors. The customer must be defined and understood. Case Corporation's Agricultural Products Division in Racine, Wisconsin, stresses the importance of considering all customers. 'We once looked at the tractor dealer as our customer. Now, we pay more attention to the person who actually writes the check for the product' [7]. Xerox spent six months determining the voice of the customer during the development of their Document Center 265 Digital Copier. They held focus groups, telephone interviews, collected surveys, and visited customers at all levels who used their products [4].

Customers for the assessment process must also be defined. What information does a given customer want to learn from the assessment process? A simplified HoQ for an assessment process at Rose-Hulman is shown in Fig. 2. For this HoQ the customers consisted of recruiters, alumni, industrial advisors, faculty, students, and administrative staff who are key stakeholders in the educational experience at Rose-Hulman Institute of Technology. Customers want students who are effective team members. This desire links closely to ABET Criterion 3 which requires that students demonstrate an ability to function in multidisciplinary teams [8]. The customer attributes in the HoQ are the WHATs that the customer wants. In this case, the WHAT is an effective team member. The HOWs or ECs are specific measurable performance criteria—metrics by which success can be evaluated. In this case, a cross-functional team identified six metrics for determining if a student is an effective team member. An effective team member must share responsibilities and duties, take on different roles when applicable, analyze ideas objectively, discern feasible solutions, develop a strategy for action, and arrive at a consensus.

In the next stage, the parts deployment house is formed as shown in Fig. 3. The ECs are the driving force that determine the parts characteristics. In

|   |   |                                   |   |                           |                            |                               |                       |  |
|---|---|-----------------------------------|---|---------------------------|----------------------------|-------------------------------|-----------------------|--|
| <b>HOWs</b><br>(measurable criteria by which success may be judged) | <b>WHATs</b>                                | Share responsibilities and duties | Take on different roles when applicable | Analyze ideas objectively | Discern feasible solutions | Develop a strategy for action | Arrive at a consensus |  |
|   |   | Effective Team Member             |   |                           |                            |                               |                       |  |
|   | Other desired attributes of a Rose graduate |                                   |   |                           |                            |                               |                       |  |
|   |   |                                   |   |                           |                            |                               |                       |  |

Fig. 2. Partial HoQ for Rose-Hulman assessment process.

the assessment example, the question becomes, ‘What are the “parts” of sharing responsibilities and duties?’ Team training is a ‘part’ that can be used to define roles and explain the assignment of duties. The ‘parts’ that support ‘Analyze Ideas Objectively’ might be decision matrices and/or the Pugh concept selection technique. Discerning feasible solutions requires that students have the

necessary technical background. The students must also have the ability to make decisions as a group. Listing pro’s and con’s or voting are strategies that groups can use to make collective decisions. A Gantt chart is helpful in developing a strategy for action. This requires that students be able to define all activities for a project and estimate the amount of time that each activity

|             |   |                               |                   |                        |              |  |
|-------------|---|-------------------------------|-------------------|------------------------|--------------|--|
| <b>HOWs</b> | <b>WHATs</b>                            | Team training                 | Decision matrices | Pugh concept selection | Gantt charts |  |
|             |   | Develop a strategy for action |                   |                        |              |  |
|             | Arrive at a consensus                   |                               |                   |                        |              |  |
|             | Discern feasible solutions              |                               |                   |                        |              |  |
|             | Analyze ideas objectively               |                               |                   |                        |              |  |
|             | Take on different roles when applicable |                               |                   |                        |              |  |
|             | Share responsibilities and duties       |                               |                   |                        |              |  |
|             |   |                               |                   |                        |              |  |

Fig. 3. Partial parts deployment house.

|                        |                |                       |                 |                 |           |  |
|------------------------|----------------|-----------------------|-----------------|-----------------|-----------|--|
| <b>HOWs</b>            |                |                       |                 |                 |           |  |
| <b>WHATs</b>           | Design Reports | Engineering Log Books | Peer Assessment | Self Assessment | Portfolio |  |
| Team training          |                |                       |                 |                 |           |  |
| Decision matrices      |                |                       |                 |                 |           |  |
| Pugh concept selection |                |                       |                 |                 |           |  |
| Gantt charts           |                |                       |                 |                 |           |  |
|                        |                |                       |                 |                 |           |  |

Fig. 4. Partial process planning house.

will need. The parts identified must be formed into a cohesive pattern. This involves identifying where in the curriculum students are getting an opportunity to gain the knowledge, skills and other attributes necessary to meet performance criteria.

The third house, the process planning house, identifies the key process operations for determining whether or not a criteria has been achieved. The process planning house is shown in Fig. 4. The parts characteristics identified in the parts deployment house must be tied to key process operations. The key process operations are the instruments that will be used for assessment. For example, a design report might contain a Pugh concept

selection chart that illustrates a team’s ability to analyze ideas objectively. An engineering logbook could contain minutes from group meetings that indicate the roles assumed by the student. Peer assessment can contain a listing of the contributions of the team member to the project and an indication of the quality of the member’s effort. Self-assessment can be the student’s description of their contributions to the team effort. A portfolio can contain evidence that the student has met the desired criteria.

Students need a variety of methods and opportunities for demonstrating that they have met the teaming performance criteria. The teaming

|                       |   |                 |                          |                     |  |
|-----------------------|---|-----------------|--------------------------|---------------------|--|
| <b>HOWs</b>           |   |                 |                          |                     |  |
| <b>WHATs</b>          | Individual Grades throughout the course | Course Averages | Institutional Assessment | External Evaluation |  |
| Design Reports        |   |                 |                          |                     |  |
| Engineering Log Books |   |                 |                          |                     |  |
| Peer Evaluation       |   |                 |                          |                     |  |
| Portfolio             |   |                 |                          |                     |  |
| Self Assessment       |   |                 |                          |                     |  |
|                       |   |                 |                          |                     |  |
|                       |   |                 |                          |                     |  |

Fig. 5. Partial production planning house.

'thread' must be clearly defined in the curriculum and feedback on the students' performances is necessary to monitor the effectiveness of the curriculum.

After students have completed documenting their attainment of the performance criteria, there must be a mechanism for evaluating individual students, individual departments, and the institution as a whole. This mechanism is detailed in the fourth house which is shown in Fig. 5. The production planning house relates key process operations to production requirements. Figure 5 indicates that assessment is both formative and summative. Individual grades and feedback during a course allows an individual student to improve his or her performance. Course averages allow a professor to look at the performance of the class as a whole and identify areas for improvement in future offerings of the course. Institutional assessment and program assessment are both utilized. Program assessment determines if the students are meeting the goals of the particular discipline and institutional assessment is used to determine progress toward institutional goals. In both institutional and program assessment, feedback affects the development of the entire curriculum—not just an individual course. The production planning house allows strengths and weaknesses to be identified for individuals, courses, and programs. Assessment results are evaluated and reported to constituents thus closing the continuous improvement loop. At each stage in the process the customer desire for an effective team member drives the tools and processes utilized.

The QFD technique parallels the requirements for developing an educational assessment program:

In QFD, customer attributes are used to identify ECs; in quality assessment, performance criteria are developed to meet the customers' objectives.

- In QFD, the ECs drive the development of parts characteristics. In quality assessment, strategies are identified to achieve the desired performance.
- In QFD, the parts characteristics determine the key process operators. In quality assessment the strategies identified determine the curriculum.
- In QFD, the key process operations lead to

production requirements. In quality assessment the curriculum is evaluated thus leading to feedback and improvement.

The development of both a quality assessment process and QFD involve teamwork, ambiguity, iteration and integration. The team must represent a microcosm of the organization. Expertise, experience and varying perspectives are vital. The team grows, changes and must be nurtured. The core membership remains the same, but size and representation change as it moves through development, production, and continuous improvement. The team must be able to deal with ambiguity. There are usually several 'good' answers. Not all answers are equally good—some are definitely wrong. The team must be capable of compromise and evaluation of possibilities. The process is not a linear one. It is characterized by a series of loops where what is learned in one step of the process is used to improve the next. Components must be integrated in the best possible way. Multiple processes are utilized but they are all interrelated to demonstrating the performance criteria.

## SUMMARY

A wise man once said, 'All models are wrong, but some are useful'. The Quality Function Deployment model provides a useful tool for understanding the processes required to meet the letter and the spirit of Engineering Criteria 2000. As engineering faculty work to develop continuous improvement processes related to engineering program outcomes, they are encouraged to look at quality models that have been developed, tested and implemented successfully in the business setting and are presented to students in the engineering curricula. A cross-functional team which is committed to understanding the voice of the customer works to improve the quality of the product. Use of this analogy provides faculty with a familiar language and framework for assessment planning and 'demystifies' the assessment process. It also motivates us to embrace assessment for we can expect to see the increase in customer satisfaction and decrease in development time that has long been lauded by proponents of QFD.

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