Using the Integration of QFD and IDEF Techniques for Mobile Wireless Classroom Process Improvement

Rungchat Chompu-inwai, Toni L. Doolen

**Department of Industrial and Manufacturing Engineering
Oregon State University
Corvallis, Oregon, 97331-2407
Phone: 1.541.737.2365 Fax: 1.541.737.5241
E-mail address: toni.doolen@orst.edu.**

Introduction

ABET 2004-2005 criteria for accrediting engineering programs require that institutions assure quality and foster the systematic pursuit of improvement in the quality of engineering education, satisfying the needs of constituencies in a dynamic and competitive environment¹. Each engineering program seeking accreditation must have in place a process based on the needs of the program's various constituencies in which the objectives are determined and evaluated¹. For this purpose, a systematic approach for educational process improvement and reengineering is needed.

Quality Function Deployment (QFD) is a quality improvement tool for determining customer requirements and translating them into product or service specifications. QFD has been applied for extracting customer requirements, as well as for designing elements based on those requirements in both university settings and other educational institutions in previous studies^{2,3,4,5}. However, only the question of what is needed to achieve the requirements is answered. The question of how the design elements or requirements can be achieved is unanswered. Integrated Definition Language 0 (IDEF₀) functional modeling is a structured approach for system design and analysis and can be used to answer these questions. With the use of IDEF₀, functions, inputs, as well as mechanisms that are required to get the desired outputs under specific constraints can be identified.

This paper explores the complementary use of two different engineering modeling tools in describing educational processes associated with mobile wireless technology (MWT) classrooms. QFD and IDEF₀ are integrated to determine the requirements and to specify the processes of the mobile wireless classroom. For this study, mobile wireless classrooms are defined as classrooms where MWT (e.g. personal digital assistants (PDA's), laptops and other customized devices with wireless capabilities) have been used with the goal of improving teaching processes and learning. The methodology presented in this paper provides a comprehensive framework for process improvement and reengineering. A specific application of this methodology was used to compare MWT classrooms in Industrial and Manufacturing Engineering (IME) at Oregon State University (OSU) with non-MWT classrooms. This was completed to illustrate how the methodology could be applied.

QFD Overview

QFD is a quality improvement system for designing a product and its necessary corresponding system design elements based on customers' needs and expectations (voice of customer). It increases the focus on understanding customers' requirements, including identifying and ranking the relative importance of customer requirements. Furthermore, results of a QFD analysis can be used to prioritize the most important system design elements, enabling efforts and resources to be concentrated on improving those design elements that most effectively meet customers' needs.

Laying out customer requirements and design specifications in a matrix enables each customer requirement to be compared with each of the design specifications. Figure 1 illustrates a QFD house of quality. In the body of the matrix, symbols are entered representing the strength of the relationship between the two lists. At the roof of the house is where some of the design specifications are interrelated with each other, in terms of a positive or negative relationship. The left hand side of the matrix is where the customer requirements and the importance rating are listed. The right hand side is where the competitive analysis is listed. From this information the prioritization of each item that has the greatest potential for success will be developed and used in planning. The bottom part of the matrix shows the prioritized design specifications and how difficult it will be to achieve these successfully⁶. Other information that can be placed in QFD is product benchmarking data and target values.

At any stage, QFD describes the matrix of what the customer wants versus how the supplier will supply it. The first QFD matrix is used to translate customer wants (requirements of the actual end-customer) into product characteristics (broad details of how the requirements will be met). The product characteristics are then translated through another QFD matrix into part characteristics. Part characteristics are translated into process characteristics. Finally, process characteristics are translated into production controls. For the purpose of this study, the QFD process was only concerned with the development of the first two matrices.

Figure 1. QFD house of quality

Figure 2. General elements in IDEF₀ modeling approach

IDEF₀ Overview

IDEF₀ is a functional modeling technique. The principle goal of IDEF₀ is to provide a structured approach for breaking a complex system into more elemental components that are

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simpler to deal with⁷. Each function within a system can be thought of as a process in which mechanisms transform the system from an initial state to a transformed state subject to certain controls. Each function is defined in terms of a set of inputs, outputs, mechanisms, and controls. Boxes are used to represent activities, actions, processes, functions, tasks and operations. Arrows indicate relationships or information flow among the functions. The arrows entering and leaving the boxes on the left and right represent “inputs” and “outputs” respectively. An input is something that is changed by the process. Outputs are what the inputs are transformed to. Functions transform inputs into outputs. Arrows entering from the top of the boxes are “controls” and arrows entering from the bottom are “mechanisms”. Controls restrict or guide the way transformation occurs. Mechanisms are actors (humans, machines) that perform the function. Figure 2 shows general elements in an IDEF₀ model.

An IDEF₀ model consists of an integrated set of diagrams. Each diagram contains more detail about a function and is linked to more general diagrams. The process of describing a function in more detail is called decomposing a function. The more general diagram is called the parent of the detailed diagram. IDEF₀ models are read in a top-down manner. The top level diagram or the A-0 diagram summarizes the overall function of the system, which is represented by a single box⁸.

QFD and IDEF₀ Models Development Process

Based on previous research, QFD and IDEF₀ were used in combination⁸. The major steps in the QFD and IDEF₀ models development process are (1) the development of the first QFD matrix (2) the development of the IDEF₀ models based on the information from the first step, and (3) the development of the second QFD matrix using the functions or activities defined in the IDEF₀ models in step 2.

(1) The development of the first QFD matrix

The goal of this step is to elicit the requirements of the customers (WHATs) and the design elements (HOWs) through the QFD process.

Identifying potential stakeholders is the first and the most important step of the QFD process. At any point during the process a customer and supplier can be defined. The customer is the person receiving an input, which is the output of the supplier. The customer/supplier chain links all the way through the process from inception to launch and beyond⁶. Educational institutions often involve many stakeholders. Different classifications exist in literature. Customer does not mean only the student or the parents. These stakeholders could be internal customers, i.e. students, faculty, administrators, as well as external customers, such as community, perspective employers, other universities, accrediting agents, alumni, and donors. Each institution must determine (based on its own circumstances) how many of these are part of its customer base. For this study, customers of IME at OSU are defined as (1) internal customers who are students and faculty, and (2) external customers who are accrediting agents and perspective employers (industry).

Each group of customers has its own definition of satisfaction and each definition must be known and addressed. Various methods, e.g. interviewing, questionnaire process, brainstorming, focus group discussions, etc. can be used to determine customer requirements. Customers are asked to rate the importance of each requirement (for example on a scale 1 to 5, where 1 represents the least importance and 5 represents the most

importance). These values are then averaged for each WHAT to give an overall rating. For this study, the example of the first QFD matrix for the external customers was developed (see Figure 3). The external customer requirements are defined based on three groups of external customers (1) ABET Requirements (2) Manufacturing Program Criteria, and (3) Industrial Engineering Program Criteria. A small team of external customers assign the importance values for the requirements. Figure 3 shows the QFD matrix for external customers. A QFD matrix for the internal customers can be constructed similarly.

One of the significant aspects of the QFD system is using cross-functional teams. This team is composed of students, faculty members, and potential employers. After the WHATs are found, the design requirements (HOWs) that would satisfy the WHATs must be determined by the cross-functional team. It is necessary for the cross-functional teams to also prioritize and decide which HOWs should be selected to implement. Relationships between WHATs and HOWs are determined. A correlation scale of strong (weight 5), medium (weight 3), and weak (weight 1) is used to describe the relationship between each design element as it intersects with each customer requirement. The prioritization of the design elements can be seen from their absolute and relative value shown in the QFD matrix.

The design element absolute value is calculated by summing the products of the importance value of each requirement and the correlation value at the intersection between that requirement and that design element. For example, in the first QFD matrix, for the design element of “Institution-industry and institution-community relationships”, the absolute value was found by multiplying the importance value for the requirement of “Understanding of professional and ethical responsibility” (3) by the strong correlation value (5) to get 15. This value was then added to the value of 3, which results from multiplying the importance value for “Board education necessary to understand the impact of engineering solutions in a global and societal context” (3) by the weak relationship value (1), the value of 2 resulted from multiplying the importance value for “Recognition of the need for, and an ability to engage in life-long learning” (2) by the weak relationship value (1), and the value of 2 resulted from multiplying the importance value for “Manufacturing competitiveness” (2) by the weak relationship value (1). The absolute result were $(3 \times 5) + (3 \times 1) + (2 \times 1) + (2 \times 1) = 22$. The total absolute values were then converted to the relative rankings given in the last row of the matrix.

From the relative ranking, the top eight quality characteristics or the design elements were identified as teaching methods, students, instructor qualifications, facilities, technology and equipment, physical learning environment, curriculum design, material and institution policies, respectively.

External Customer Requirements	Design Requirements		Importance (1-5)	Students	Instructor qualifications	Faculty-student interaction	Teaching methods	Material	Evaluation and assessment	Physical learning environment	Curriculum design	Extra activities (e.g. industry tour, practical training and internship program etc.)	Facilities, technology and equipment	Institution policies (e.g. academic honesty, class length, etc.)	Institution-industry and institution-community relationships
	Relationships														
	Strong	● 5													
	Medium	□ 3													
	Weak	○ 1													
1. ABET Requirements															
- Ability to apply mathematics, science, and engineering.			4	□	○		●				○		□		
- Ability to design and conduct experiments, as well as to analyze and interpret data.			5	□	□	○	□	□	○	□			○		
- Ability to design a system, component, or process to meet desired needs			5	□	□	□	●	○		○	○		□		
- Ability to function on multidisciplinary teams.			3	○		○	●		□	○	○	□	○	○	
- Ability to identify, formulate, and solves engineering problems.			5	□	□		●	○		○			○		
- Understanding of professional and ethical responsibility.			3	○			○					○			●
- Ability to communicate effectively.			4	●	○		○			□					
- Board education necessary to understand the impact of engineering solutions in a global and societal context.			3				○	○				□			○
- Recognition of the need for, and an ability to engage in life-long learning.			2	○			○				○				○
- Knowledge of contemporary issues.			1				○				○				
- Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.			4		○		□			○	○	○	●		
2. Manufacturing Program Criteria															
- Material and manufacturing processes.			3				○			○	○				
- Process, assembly and product engineering.			3				○								
- Manufacturing competitiveness.			2								○				○
- Manufacturing system design.			4	□			●				○				
- Laboratory experience.			2				□			●				○	
3. Industrial Engineering Program Criteria															
- Ability to design, develop, implement and improve integrated systems that include people, materials, information, equipment, and people.			4	□	○		●	○			○			□	
- Integration of systems using appropriate analytical, computational and experimental practices.			4	□	○		●				○			□	
External customer important ranking			Absolute	121	65	23	197	32	14	57	36	25	60	29	22
			Relative	2	3	10	1	7	12	5	6	9	4	8	11

Figure 3. First QFD matrix for external customers
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(2) The development of the IDEF₀ models

From the first QFD matrix, the top eight quality characteristics or the design elements were identified as teaching methods, students, instructor qualifications, facilities, technology and equipment, physical learning environment, curriculum design, material and institution policies respectively. The results from QFD process can be used to prioritize the most important system design elements, enabling efforts and resources to be concentrated on improving these elements. These eight quality characteristics were then used to develop an IDEF₀ A-0 diagram of the instructional processes context to see the relationship among them.

In the MWT classroom instructional process, inputs are students with existing abilities, knowledge, attitudes, and technology experiences. Controls are MWT availability, usability, curriculum, other requirements and regulations (e.g. ABET criteria), institution policies (e.g. academic honesty, class length, class size, etc.), and classroom policies (syllabus, learning objectives, curriculum). Mechanisms are the physical learning environment (building, and classroom configuration), material, equipment, technology (both hardware and software), instructors, as well as other students. Students have important roles in MWT instructional processes. They are both inputs which are changed by the processes and mechanisms which perform the functions. Outputs are observable changes in abilities, knowledge, attitudes, and technology experiences in students. Figure 4 illustrates the IDEF₀ A-0 (context) node of the instructional process. In the MWT classroom instructional process, students with existing abilities, knowledge, attitudes, and technology experiences enter the system, then are transformed by the instructional process, and leave the processes with observable changes in abilities, knowledge, attitudes, and technology experiences.

Figure 4. IDEF₀ A-0 diagram of the instructional processes context
(From Chompu-inwai and Doolen, 2004)⁹

The instructional process was decomposed using the IDEF technique. The results at the A0 level are shown in Figure 5. There are five major interrelated functions at the A0 level: Plan for Instruction (A1), Perform Instruction (A2), Assess Student Performance and Achievement (A3), Evaluate Course (A4), and Determine Future Improvements (A5). There

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are also informational relationships that exist among the functions. The functions and sub-functions were decomposed further. The functional hierarchy is shown in Figure 6 to provide an overview of the final decomposition.

Figure 5. IDEF₀ A0 diagram for the instructional processes
(From Chompu-inwai and Doolen, 2004)⁹

Figure 6. IDEF₀ functional hierarchy for MWT classroom.
An illustrative decomposition of the A1 branch is provided
(From Chompu-inwai and Doolen, 2004)⁹

(3) The development of the second QFD matrix using the functions or activities defined in the IDEF₀ models in step 2

As mentioned earlier, for the purpose of this study, the QFD process was only concerned with the development of the first two matrices. In this step, the design requirements or the quality characteristics from the first QFD matrix were used as the WHATs in the second QFD matrix and the functions from the IDEF₀ model developed in step 2 were used as the HOWs. Figures 7 and 8 show the second QFD matrices for external customers for non-MWT and MWT classrooms, respectively. These matrices show the relationships of the functions or activities with the design requirements (or quality characteristics) from the first QFD matrix. The primary purpose of these matrices is to make sure those activities or functions meet the design requirements.

Based on the non-MWT and MWT second QFD matrices, a comparison of the activities was completed. The activity of plan for instruction is more important in the MWT classroom than in the traditional lecture-based classroom. This result is consistent with previous results from the literature. In the MWT environment, the teaching pedagogy may be different from those used in a more traditional course¹⁰. The instructor is no longer focused only on the presentation of materials; rather the instructor becomes a facilitator of learning. Instructors may have to plan and design for providing students with a collaborative situation (e.g. creating class activities and exercises), rather than only planning to present the materials as in a traditional lecture-based course. In a MWT classroom, students must also plan. As with a traditional classroom, this includes activities such as reviewing prerequisites or class materials. Students may also have to become familiar with the required MWT before coming to class and must also plan to bring the MWT devices to the classroom. The student roles in the MWT classroom are not only to absorb instructional presentations, but also to explore and participate in the learning environment⁹.

Conclusion

This study illustrates how QFD and IDEF₀ models can be used complementarily to identify customer requirements and provide insight on how to meet these requirements in higher education institutions. The framework described can be used for instructional process analysis for course redesign or improvement, for evaluating the existing instructional program, as well as to derive ideas on what can be done to improve existing programs to better satisfy customers.

First, the stakeholder groups were identified as internal and external customers. The first QFD matrix for external customers was illustrated using ABET requirements, Manufacturing program criteria, and Industrial Engineering program criteria as the external customer requirements. The correlation between the customer requirements and the design elements were identified. The QFD matrix pointed out the most important quality affected elements in the teaching-learning process in the IME classrooms at OSU. The question of how the design element or requirements can be achieved is answered by using the IDEF₀ functional modeling technique. Furthermore, with the use of IDEF₀, functions, inputs, as well as mechanisms and constraints can be identified. The design requirements or the quality characteristics from the first QFD matrix were used as the WHATs in the second QFD matrix and the functions from the IDEF₀ model used as the HOWs.

This study is an example of how QFD and IDEF₀ can be applied in higher education institution. For QFD and IDEF₀ to be successfully implemented within other institutions,

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they must be adapted to the particular situation surrounding their use. Furthermore, the HOWs lists, importance rankings and relationships were identified based on the perceptions and judgments of a very small sample. The cross-functional work of students and staff and a larger sample may be needed for further studies and would be critical to developing more reliable customer requirements.

IDEF ₀ Functions		Design Requirements		Relationships Strong ● 5 Medium □ 3 Weak ○ 1																		
Importance (1-5)		A1 Plan for instruction	A11 Plan for teaching	A12 Plan for learning	A2 Perform instruction	A21 Describe learning objectives	A22 Present and demonstrate class contents and learning material	A23 Participate in class activities	A24 Give feedback	A25 Revise instruction	A3 Assess student performance and achievement	A31 Create or select tools to measure student learning, performance and achievement	A32 Communicate assignment, test and other class assessment objectives	A33 Perform test, do assignments or perform any other assessment	A34 Grade, evaluate or assess student assignment or tests	A35 Communicate test results and provide feedback	A36 Compare student performance and achievement against class learning objectives and criteria defined at planning step	A37 Revise assessment methods	A4 Evaluate course	A5 Determine future improvements		
Teaching methods	197		□	○		□	□	●		□		●	□		○							
Students	121		○	○				○	●			○		●						●		
Instructor qualifications	65		□			□	□	□	●	●		□			□	○	□	□			●	
Facilities, technology and equipment	60		○	○				○				□		○								
Physical learning environment	57		●					□														
Curriculum design	36		●	○																	●	
Material	32		●	□			□					○										
Institution policies	29		●											○							□	
Important ranking	Absolute	2247	1737	510	5046	786	882	1532	930	916	3645	1513	591	694	392	65	195	195	605	592		
	Relative	3			1						2								4	5		

Figure 7. Second QFD matrix for external customers (for non-MWT classroom)

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IDEF ₀ Functions		Relationships Strong ● 5 Medium □ 3 Weak ○ 1		Design Requirements																					
Importance (1-5)		A1 Plan for instruction	A11 Plan for teaching	A12 Plan for learning	A2 Perform instruction	A21 Describe learning objectives	A22 Present and demonstrate class contents and learning material	A23 Participate in class activities	A24 Give feedback	A25 Revise instruction	A3 Assess student performance and achievement	A31 Create or select tools to measure student learning, performance and achievement	A32 Communicate assignment, test and other class assessment objectives	A33 Perform test, do assignments or perform any other assessment	A34 Grade, evaluate or assess student assignment or tests	A35 Communicate test results and provide feedback	A36 Compare student performance and achievement against class learning objectives and criteria defined at planning step	A37 Revise assessment methods	A4 Evaluate course	A5 Determine future improvements					
Teaching methods	197		●	□		□	□	●		□			○	□		○									
Students	121		○	●			□	●	●			□		●						●					
Instructor qualifications	65		●	●		□	□	□	●	●		□			□	○	□								
Facilities, technology and equipment	60		○	○				●	●			□	□	□		□									
Physical learning environment	57		●					○																	
Curriculum design	36		●	○																	●				
Material	32		●	□			□					○													
Institution policies	29		●											○							□				
Important ranking	Absolute	3974	2261	1713	6319	786	1245	2142	1230	916	3579	967	771	814	392	245	195	195	605	592					
	Relative	2			1						3								4	5					

Figure 8. Second QFD matrix for external customers (for MWT classroom)

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Bibliography

- 1 ABET (2003, November 1). *Criteria for accrediting engineering programs*. Retrieved August 12, 2004, from <http://www.abet.org/images/Criteria/E001%2004-05%20EAC%20Criteria%2011-20-03.pdf>
- 2 Brackin, P., & Rogers, G.M. (1999). Assessment and quality improvement process in engineering and engineering education. *Proceedings of ASEE/IEEE Frontiers in Education Conference, Puerto Rico, 29*, 11a1-21- 25.
- 3 Chang, I. & Chia-hung Ku, A. (1995). Engineering and technical education in Taiwan: an observation based on TQM concept. *Proceedings of ASEE Annual Conference, USA*, 2414-2419.
- 4 Ermer, D.S. (1995, May). Using QFD becomes an educational experience for students and faculty. *Quality Progress*, 131-136.
- 5 Koksai, G., & Egitman, A. (1998). Planning and design of industrial engineering education policy. *Computers and Industrial Engineering*, 35(3-4), 639-642.
- 6 Fox, J. (1993). *Quality Through Design: The Key to Successful Product Delivery*. U.K: McGraw-Hill Book Company Europe.
- 7 Haines, L.A. & Evers, K. (1990). An IDEF₀ representation of the instructional system development (ISD) process-why it works. *IEEE Proceedings of the National Aerospace and Electronics Conference*, 2, 806-811
- 8 Sarkis, J. & Liles, D.H. (1995). Using IDEF and QFD to develop an organizational decision support methodology for the strategic justification of computer-integrated technologies. *International Journal of Project Management*, 13(3), 177-185.
- 9 Chompu-inwai and Doolen, (2004). IDEF functional modeling for instructional processes in mobile wireless technology classrooms. *Proceedings of the International Conference on Computers & Industrial Engineering, USA*, 34, 61-66.
- 10 Lowther, D.L., Ross, S.M., & Morrison, G.R., (2001). Evaluation of a Laptop Program: Successes and Recommendations. *Proceeding of National Educational Computing Conference, "Building on the Future"*, Chicago, IL, 1-8.

Biography

RUNGCHAT CHOMPU-INWAI is a doctoral student in the Industrial and Manufacturing Engineering Department at Oregon State University. Chompu-inwai received her B.S. in Industrial Engineering from Chiang Mai University, Thailand in 1997. She received an M.Eng.Sc. in Manufacturing Engineering majoring in Industrial Management from The University of New South Wales, Australia in 2000. Her research is focused on mobile technology use in education.

DR.TONI L.DOOLEN is an Assistant Professor in the Industrial and Manufacturing Engineering Department at Oregon State University. Dr.Doolen received a B.S. in Material Science and Engineering and a B.S. in Electrical Engineering from Cornell University in 1987. She received an M.S. in Manufacturing Systems Engineering from Stanford University in 1991. She received her Ph.D. in Industrial Engineering from Oregon State University in 2001. Her research is focused on manufacturing systems design, lean manufacturing, work group effectiveness, mobile technology in education, error management and reduction, and survey design and methodology.