

Journal of

INDUSTRIAL TECHNOLOGY

Volume 18, Number 1 - November 2001 to January 2002

QFD-based Technical Textbook Evaluation – Procedure and a Case Study

By Mr. Jacob Chen and Dr. Joseph C. Chen

KEYWORD SEARCH

***Curriculum
Quality
Teaching Methods***

Reviewed Article

The Official Electronic Publication of the National Association of Industrial Technology • www.nait.org

© 2001



Mr. Jacob (Chi-Ming) Chen is a Ph.D. candidate in the Department of Industrial Education and Technology at Iowa State University (ISU). He has taught an introductory design course in manufacturing technology program to include teamwork, parametric solid modeling, and design for manufacturability. This course has helped many students to understand the relationship between design and manufacturing. His teaching and research areas are computer-aided manufacturing, automated manufacturing processes, cellular manufacturing system, quality control to include QFD. His Ph.D. research topic is to develop an on-line real-time tool wearing monitoring system in vertical machining center.



Dr. Joseph Chen is an associate professor in the Department of Industrial Education and Technology at Iowa State University (ISU). His teaching and research interests are automated manufacturing processes (CNC lathe and milling), computer aided manufacturing, integrated manufacturing system design, simulation, machining control via sensors and intelligent mechanisms, and design for manufacturability. He currently serves as the principal investigator of an NSF ATE project titled "Competitive Manufacturing by Design."

QFD-based Technical Textbook Evaluation – Procedure and a Case Study

By Mr. Jacob Chen and Dr. Joseph C. Chen

All rights reserved. This study or parts thereof may not be reproduced in any form without written permission of the authors. This paper has not been published or submitted for publication in any other journal.

Introduction

In today's classroom, textbooks serve as a tool, tutor, guidebook, and gauge (Association for Supervision and Curriculum Development, 1997). Teachers throughout the world base approximately 50 percent of their weekly teaching time on textbooks (Schmidt, McKnight, and Raizen, 1996). Therefore, selecting a proper textbook for a class has been one of the most important tasks for teachers. In order to help teachers select the proper textbooks, much research has been done to evaluate different textbooks. However, very little research is devoted to evaluating the textbooks used at the college level. Thus, it is no surprise that there is no research done in regards to selecting textbooks for courses in the field of manufacturing or industrial technology. While there is no indication of patterns of how college instructors select textbooks and the exact role of textbooks played in the classroom, which needs further study, at least one thing is certain—a majority of the instructors teaching technical courses would like to have a textbook that would best fit their students and also become a good resource for lab teaching.

The design of education has mainly been controlled by professional educators who decide what and how to teach (Castro, 1994). Therefore, it is not surprising to discover that the selection of textbooks in the field of manufacturing technology is traditionally based on

the preferences of the instructors. If the instructor of a manufacturing class likes a book or has been accustomed to using a certain book, it is likely that he or she would continue to use that book for a long period of time. In other words, the textbook that the instructor chooses would basically satisfy the instructor, while whether students' needs concerning the textbook are met is not certain. Some of the students, whose needs are not met, will lose interest and complain that they spent too much money on the textbook.

Also, from the constructivist's point of view, which is gradually accepted by most of educators now (Forcier, 1999; Forrester & Jantzie, 2001), students (the receivers of the education) are the center of the learning. The constructivist in the field of educational psychology believes that learning really takes place when the student can construct the new information into his original cognitive system. In other words, students' needs have to be met in order to reach the goal of meaningful learning. Therefore, it is sensible to incorporate students' desires when considering the selection of textbooks in order to meet their needs.

Besides instructors and students' needs, there is another consideration that is also important for the selection of technical textbooks. Since technology in the manufacturing field is ever changing, teaching technical courses requires instructors to equip themselves with the most up-to-date knowledge and technology. This is also true for technical textbooks. Therefore, one of the qualities of technical textbooks teachers should be looking for is adaptability. The textbook should not only be adaptable to new technologies, but also be adaptable to the needs of

local employers, based on the fact that most of the graduates from industrial technology find jobs locally. Most technical textbooks are written in the view of being used nationwide, but they may not necessarily parallel the needs of the local employers. For example, due to the nationwide use of manual NC programming, manufacturing processes textbook writers may have to focus on manual NC programming. However, the local employers may like to use more CNC machines with CAM programs. Therefore, identifying the local employers' needs and incorporating them into the consideration of selecting textbooks is also important.

Textbooks may not be able to be rewritten periodically, but the selection of textbooks can be done on a periodical basis. It is advised that the evaluation of technical textbooks should be ongoing and frequent. For example, teachers could evaluate textbooks every 2-3 years. Besides, when teachers evaluate technical textbooks, the "voices" of the students and the local employers (the needs of the students and the local employers in their own language) and the instructor's teaching content would always have to be taken into consideration.

There are several ways to account for different voices. One of the ways is to have their voices heard through the use of surveys. Individual surveys provide the information of needs from the aspects of students, local employers, and instructors. However, surveys alone cannot incorporate all the information. To incorporate all the voices, it is necessary to find a helpful tool. Quality Function Deployment (QFD) is an extremely handy tool in this case. QFD has been known as a very useful "decision machine" to help customers/users select the best product among several available choices (Lockamy and Khurana, 1995). However, QFD is best known for its capability of transforming the desires of the customer/user into the language required to implement a product. Therefore, this paper attempts to include customers' voices (from students and future employers) using

QFD to determine and select a proper textbook for manufacturing-related technology courses.

Purpose of the study

The purpose of the study consisted of two parts, and they were:

1. Introducing a QFD-based approach to select functional requirements for the purpose of evaluating technical textbooks and selecting the best-fit textbook based on customers' voices;
2. Demonstrating systematically a case study, which had been successfully conducted for selecting a text for an "Automated Manufacturing Processes" course.

Overview of QFD and its application

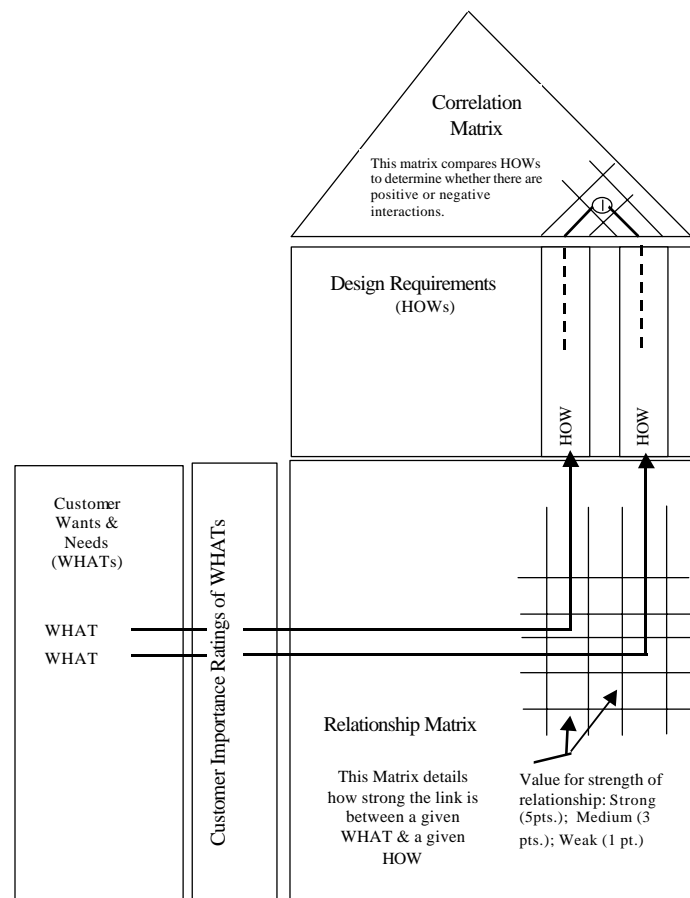
Quality control has been in existence for a long time, but it was not until the 1920s that statistical theory began to

be applied effectively to quality control as a result of the development of sampling theory (Prins, 2000). Since then, the method of statistical quality control (SQC) with sophisticated tool control charts has been applied to many manufacturing areas.

SQC was introduced to Japan after World War II and became the central quality activity. SQC was transformed into Total Quality Control (TQC) in Japan during an evolution period from 1960 to 1965 (Menks, 2000). While SQC emphasizes the quality control of production only, TQC is the application of quality principles for the integration of all functions and processes within the organization (Lockamy & Khurana, 1995). Among many tools used in TQC, Quality Function Deployment (QFD) is one of the effective tools for product and process development.

QFD was conceived in Japan in the late 1960s by Yoji Akao. It did not

Figure 1. The House of Quality



become a viable methodology until 1972 when it was applied at the Kobe shipyards of Mitsubishi Heavy Industries in Japan (Prasad, 1998). QFD reached its peak in Japan in the 1970s when Toyota Auto Body developed a quality table that had a “roof” on top, and nicknamed this quality table as a “quality house,” which is also known as “the House of Quality” (see Figure 1) in the United States (ReVelle, et al, 1998). The formal introduction of QFD to the United States and Europe was not until 1983 (Menks, 2000). And the first recorded case studies in QFD were in 1986 when Kelsey Hayes used QFD to develop a coolant sensor, which fulfilled critical customer requirements (Prasad, 1998). As QFD became more popular, QFD users started to realize that including more tables and matrices could make QFD more useful. The “Four Phase approach” (see Figure 2), developed by the American Supplier Institute, is among the most popular approaches that could assist in the design of complex tasks (ReVelle, et al., 1998).

Since then, QFD has not only been implemented in several major industries and service organizations but also successfully reported in the field of education in the United States. In the spring of 1991, the Mechanical Engineering (ME) Department of the University of Wisconsin-Madison used QFD to obtain students’ feedback on the ME undergraduate curriculum and to help change the curriculum. This has been claimed as the first application of QFD in education (Ermer, 1995). There have been other studies of quality done in the field of education with the implementation of QFD, such as to improve the quality of teaching (Lam & Zhao, 1998), to improve the academic programs (Pitman, et al., 1996; Benjamin, et al., 1999), to improve the school system (Kushner, et al., 1994), to improve higher education access and persistence (Stampen & Hansen, 1999), to improve the academic advising process (Barrows & Murray, 1997), and so on. With the experiences gained from using QFD to provide a structured approach for planning in academia in different areas

at Florida A & M University, Benjamin and his colleagues came to a conclusion that QFD is effective in facilitating effective communication, timely information transformation, and efficient resource utilization (Benjamin, et al., 1999). In light of the successful cases with QFD in curriculum planning at Florida A & M University, the authors were convinced that, even without any previous cases, the study of QFD in evaluating textbooks could also be practical as a part of curriculum planning.

With above mentioned literature reviews, one could conclude that QFD has been a successful tool implemented in both the industry and academia arenas for product design via customers’ voices. Therefore, the authors would like to further the research to the study of textbook evaluation with the QFD approach. The following will be the proposed QFD-based procedure for textbook evaluation in the study.

Proposed procedure of QFD-based approach for textbook evaluation

The intent of this study was to introduce the procedure of a proposed QFD-based approach to include the voices from local employers and students in the evaluation of textbooks. The voices heard from these two

groups also have different purposes. Therefore, the task is more complex than what a single house of quality can do. Thus, researchers decided to use a two-phase approach to the House of Quality, which was modified from the four-phase approach. The procedure for the textbook evaluation was proposed to consist of six steps.

Step One: The product is identified

The product of the study would be the textbook(s) of the course. In this step, it is necessary to identify the course competency/objectives and review the departmental curriculum core.

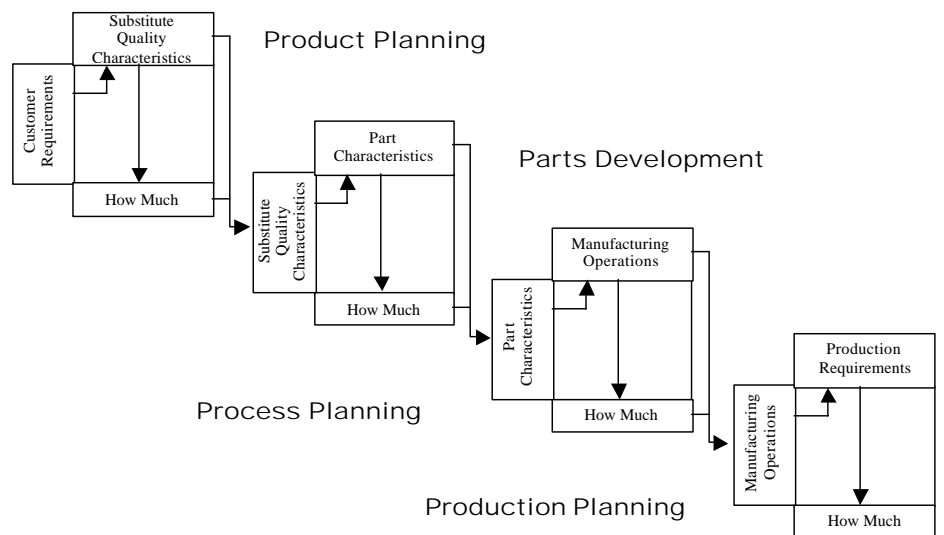
Step Two: The voices of the internal and the external customers are collected

The opinions of students (internal customers) concerning the textbooks for the course are gathered. Also, the desires of local and related industries (external customers) that have a demand for the outcome of the course for the students are collected

Step Three: Customer requirements are documented

In this step, student opinions of textbooks for a certain course and the key knowledge that local and related industries require are documented.

Figure 2. Four phases of QFD (ReVelle, Moran, and Cox, 1998)



Step Four: The house of quality of course planning

After collecting the local employer requirements, the students’ opinions about the textbooks, and the course outline, the house of quality of course planning could be built as indicated in the first step of Figure 3. This phase of the house of quality focuses on having the local employers’ voices heard. For the purpose of textbook evaluation, five tasks are identified for this process as follows:

1. The customers’ voices from the result of the survey of the local employers are transferred to be the “local employer needs” (see Figure 3).
2. The importance scale of each customer need is determined on a scale of one-to-five, based on the result of the survey with one as the least important and five as the most important.
3. The course design features are listed, which are basically based on the course outline.
4. The relationship between the customers’ voices (the local employers) and the course design features is decided.
5. The absolute weight for each course design feature is calculated by adding all the cell numbers, each multiplied by its importance scale.

Step Five: The house of quality of textbook evaluation planning

After the first phase of house of quality is built, the second phase of the house of quality is to identify the textbook evaluation features via the voices from (see Figure 3). Similar to the construction of the house of quality for course planning, there are five tasks in developing the textbook evaluation planning house of quality as follows:

1. The course design features are transferred from the first phase to be the voice of customer (VOC) of the second phase.
2. The absolute weights from the result of the first phase are transferred as the importance scale from one-to-five, whereas one is the least important and five is the most important.

3. The items from the survey of students of what they feel should be the important features of the textbook(s) for the course are listed.
4. The relationship between the weighted course design features and the textbook features from the opinions of the students is determined.
5. The absolute weight for each textbook feature is calculated by adding up the cell numbers, each multiplied by its importance scale. Then, the relative rankings are produced through prioritizing the absolute rankings. These become the rankings for the textbook evaluation features, starting from one as the highest absolute ranking and moving to two, three, etc.

Step Six: The finalized items for the evaluation of textbooks are identified, and the evaluation of several textbooks is conducted.

The top five to seven prioritized textbook features from the second phase of the house of quality for the textbook evaluation matrix are chosen. Then, at

least two raters evaluate all the available textbooks with these finalized items. The final scores of the textbooks would be the totals of the scores from all the raters. From the final scores, one is able to identify/select the best-fit textbook for the course.

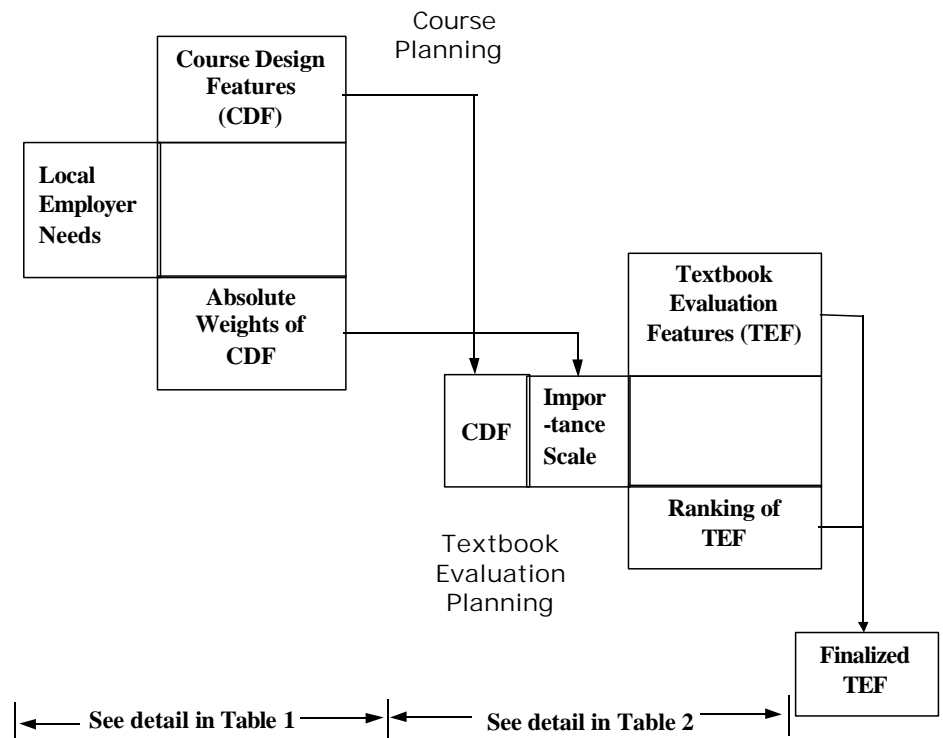
A Successful Case Study

The proposed approach has been implemented successfully in a course in the institution of the researchers. The following is the detailed procedure in our case following the proposed procedure of the QFD-based approach for the evaluation of textbooks mentioned previously.

Step One: A course entitled “Automated Manufacturing Processes” in the institution of the researchers was identified. The course description and objectives are summarized in Table 1.

Steps Two and Three: Surveys to local employers and students and interviews with local employers, advisory board members, and former students were collected and documented.

Figure 3. Two phases of house of quality for textbook evaluation.



After collecting the basic information for the study (surveys from the local employers and students and the course outline), the major procedure of the study (Steps Four, Five and Six), is recorded as follows:

Step Four: The first phase of the house of quality (the house of quality of course planning). This phase of the house of quality involved assessing the needs of local employers as the external customers of the program and how their needs have been incorporated into the course design. The tasks of building the house of quality were as follows:

Task 1: The local employers' requirements were identified through a survey and interviews with several local employers and the advisory board members. The most mentioned items were listed as the "Local Employer Needs" (see Table 2).

Task 2: The value of the importance scale for each local employers' needs were assigned from one-to-five, based on the results of the survey with one being the least important and five being the most important.

Task 3: All the important course design features have been identified according to the course outline from this class as the "Course Design Features (CDF)" in Table 2.

Task 4: All four raters met to determine the relationship between the local employers' needs and course design features with a scale from one-to-five, with one being the least related and five being the most related.

Task 5: The cell numbers were multiplied by the corresponding importance scale for each course design feature, which resulted in the absolute weight. For example, the absolute weight of "G/M codes introduction" = $5 \times 5 + 5 \times 5 + 3 \times 3 + 5 \times 4 + 3 \times 5 = 94$.

Step Five: The second phase of the house of quality (the house of quality of textbook evaluation features). The second phase of the house of quality

involved accessing the opinions of the students, the internal customers of the program, about the textbooks of automated manufacturing processes and incorporating the results. The tasks of building the second phase of the house of quality were as follows:

Task 1: Transfer the course design features to be the customer requirements in Table 3.

Task 2: Transfer the absolute weight from the house of quality to be the importance scale for each course design feature by dividing the absolute ranking by twenty and rounding off to the next whole number. For example, the weight for "G/M code introduction" is 95. Therefore, an importance scale of 5 is assigned as shown in Table 3.

Table 1. "Automated Manufacturing Processes" Course information

Course description	Students will gain familiarization through working with NC programming operations for CNC mills and lathes. Students will be able to transfer parts descriptions into detailed process plans, tool selection, and NC machine codes. Computer-assisted CAD/CAM NC programming for 2D machining is emphasized.
Course objectives	<ol style="list-style-type: none"> 1. Acquaint students with various forms of numerical control data storage and input methods while providing hands-on experience in numerical control programming, process planning, and cutting tool selection. 2. Application of previously acquired knowledge of manual machine tool methods to automated machining technology. 3. Exercise knowledge of numerical control programming by cutting parts as assigned on the CNC machines in the lab. 4. Develop the ability to manually write NC programs in terms of defining work coordinate systems, tool offset and compensation, tool motion, feed function, tool function, miscellaneous functions, and reference point return. 5. Use computers to write NC programs with CAD/CAM software (MasterCAM).

Table 2: The first phase of the House of Quality (course planning) that Incorporates the Voice of Local Employers

Importance Scale 5-1
5: most important
1: least important

Relationship Scale 5-1
5: very strong
1: very weak
blank: no relationship

Course Design Features (CDF)	Importance Scale 5-1	G/M codes introduction	G/M codes examples	G/M codes exercises	Cutting parameter introduction	Cutting parameter examples	Cutting parameter exercises	Documentation introduction	Documentation examples	Documentation exercises	Tool selection/Tool life introduction	Tool selection/tool life examples	Tool selection/tool life exercises	CAD/CAM programming theories	CAD/CAM programming applications	
Local Employer Needs																
Basic G/M codes	5	5	5	5	4	4	4								5	5
Optimization programming	5	5	5	5	5	5	5								5	5
Documentation setup	3	3	3	3												
Understand CNC controller	4				5	5	5	3	3	3					2	2
Understand tooling setup	4	5	5	5				3	3	3	5	5	5	3	3	
Tool life prediction	3				5	5	5				5	5	5			
CAD/CAM interface	5	3	3	3											5	5
Absolute Weight		94	94	94	80	80	80	39	39	39	35	35	35	95	95	

Task 3: Collect students' opinions about what a good automated manufacturing processes textbook consists of and list the results as the "Textbook Evaluation Features (TEF)" (see Table 3).

Task 4: Conduct the rating. All the raters met again and determined the relationship between the CDF and TEF with a scale from one-to-five. Again, one is the least related and five the most related.

Task 5: Calculate the rating as example shown in Task 5 of Step Four. With the ranking numbers, one could find that the "Adequate tables, figures, and photos" feature (Table 3) stands out as the most important in deciding the textbook for the automated manufacturing processes curriculum.

Step Six: The final evaluation of the textbooks, which was the final and most crucial step: evaluating all the available textbooks and selecting the best-fit textbook for the course. The top seven items were selected from the results of the second phase of the House of Quality as the finalized evaluation items for selecting the best textbook from four textbooks (*) about automated manufacturing processes. There are four reviewers that provided their rating of each textbook based on these seven items. The final result from adding up the scores of all the raters is shown in Table 4. The textbook authored by Lin (1994) is selected as the textbook for the course by implementing this QFD-based approach. This book has been used for a couple of years since the study was done. Both the students and the local employers are satisfied with the teaching with the aid of this book. The evaluation of textbooks is going to repeat again in the near future once new textbooks are available.

Note(*): These four textbooks were:

Gibbs, D. and Crandell, T.M. (1991). "An introduction to CNC machining and programming", Industrial Press, Inc.: New York, New York.

Table 3: The second phase of the House of Quality (Textbook Evaluation Planning) that Includes the Voice of Students

Textbook Evaluation Features (TEF) \ Course Design Features (CDF)	Importance Scale 5-1 5: most important 1: least important		Relationship Scale 5-1 5: very strong 1: very weak blank: no relationship												
	Importance Scale 5-1	Adequate programming exercises	Adequate information of optimization	Tool life introduction	Proper home work practices	Adequate hints for difficult/tricky homework questions	Clear explanation of concepts	Adequate tables, figures and photos	Fewer lengthy passages	Easy to read	Adequate examples	Adequate sequence	Explanation of relations to industrial practices	Up-to-date information	Suggestions for additional resources
G/M codes introduction	5	3			4		5	5	5	2		2	5		5
G/M codes examples	5	5	2		4			5		2	5	2			
G/M codes exercises	5	5	2		4	5		5		2		2			
Cutting parameter introduction	4	2	5	3	4		5	5	5	2		2	5	4	5
Cutting parameter examples	4	2	5	3	4			5		2	5	2		4	
Cutting parameter exercises	4	2	5	3	4	5		5		2		2		4	
Documentation introduction	2		1		4		5	5	5	2		2	5		5
Documentation examples	2	3	1		4			5		2	5	2			
Documentation exercises	2		1		4	5		5		2		2			
Tool selection/tool life	2	2	4	5	4		5	3	5	2		2	5	5	5
Tool selection/tool life examples	2	2	4	5	4			3		2	5	2		5	5
Tool selection/tool life exercises	2	2	4	5	4	5		3		2		2		5	5
CAD/CAM theories	5	2			3		5	3	5	2		2	3	5	5
CAD/CAM applications	5		3		3			3		2	5	2	5	5	5
Importance Ranking	Absolute	123	140	75	198	70	95	228	95	104	95	104	110	140	140
	Relative	6	3	13	2	14	10	1	10	9	10	8	7	3	3

Table 4: The Evaluation Sheet and the Results for the Four Textbooks

	Gibbs & Crandell	Krar & Gill	Lin	Pusztai & Sava	
Adequate programming exercises	5+4+4+4=17	4+3+3+4=14	5+5+5+5=20	3+3+2+4=12	
Adequate information of optimization	3+3+2+3=11	2+2+2+3=9	5+4+5+2=16	3+3+4+2=12	
Proper home work practices	4+4+4+5=17	3+4+4+3=14	4+4+5+3=16	1+1+1+2=5	
Adequate tables, figures and photos	4+4+4+5=17	4+4+5+4=17	4+5+5+5=19	3+4+4+4=15	
Explanation of relations to industrial practices	5+5+5+4=19	4+4+4+4=16	4+4+4+4=16	3+3+3+3=12	
Up-to-date information	3+4+4+4=15	4+3+3+4=14	4+4+4+4=16	3+3+2+3=11	
Suggestions for additional resources	4+4+4+3=15	3+3+3+3=12	4+4+5+3=16	2+2+1+3=8	
Total (with all four raters)		111	96	119	75

Please evaluate these four textbooks and assign point 0-5 for each cell.

5: excellent

4: above average

3: average

2: below average

1: bad

0: if you cannot find any information in that book.

Krar, S. and Gill, A. (1990). "CNC technology and programming", McGraw Hill: New York: New York.

Lin, S.C.J. (1994). "Computer Numerical Control-from programming to networking", Delmar: Albany, New York.

Pusztai, J. and Sava, M. (1983). "Computer Numerical Control", Reston, Inc.: Reston, Virginia.

Conclusion

A modified QFD "decision machine" that incorporated the voices of instructors, students, and future employers was successfully built for the purpose of selecting the best-fit technical textbook for the course "Automated Manufacturing Processes" through the QFD-based procedure introduced in the paper. The authors would like to present this new approach of selecting textbooks to the field of industrial technology as an alternative for all the technical textbook selection.

QFD is a very effective and efficient tool for the evaluation of technical textbooks, program review, and curriculum development as indicated in this paper. In the future, the authors plan to implement the QFD theory to more education aspects for quality improvement, such as laboratory activity selection and the content of instructor training.

The results presented above were mainly issued from the data collected from the local employers and ISU students. The four textbooks chosen in this study were ones researchers had on hand, which may not speak for all the good CNC textbooks on the market. Therefore, researchers in this study want to emphasize that these results may not apply to other situations. However, the purpose of presenting the idea and the approach of selecting the best textbook has been served.

References

- Association for Supervision and Curriculum Development. (1997). "Education Update", v39, n1.
- Barrows, R. and Murray, B. (1997). "Using Quality Function Deployment to improve academic advising processes", NACADA Journal, spring 1997, v17, n1, pp. 22-31.
- Benjamin, C.O., Watkins, M. and Murtaza, M. (1999). "A QFD framework for curriculum planning", ASEE 1999 Proceeding.
- Castro, K. (1994). "A learning oriented education", NGE News, May 1994, v2, n4, <http://www.clark.net/pub/nhp/neg/lib/news/newsv2n4.html>.
- Ermer, D.S. (1995). "Using QFD becomes an educational experience for students and faculty", Quality Progress, May 1995, v28, n5, pp.131-136.
- Forcier, R.C. (1999). "Behaviorist and Constructivist Perspectives Compared." <http://spectrum.Troyst.edu/~maca/6607online/models2.htm>
- Forrester, D. & Jantzie, N. (2001). "Constructivism: Background Knowledge" http://webspi.hypermart.net/constructivism/constructivism01_background.htm
- Kushner, S.N., Carey, L.M., Carey, J.O. and Jensen, M.M. (1994). "A quality function deployment analysis of customer needs for meeting school improvement goals: the voice of the school principal", Paper presented at the annual meeting of the American Educational Research Association (New Orleans, LA, 1994). ED 374 510.
- Lam, K. and Zhao, X. (1998). "An application of quality function deployment to improve the quality of teaching", International Journal of Quality & Reliability Management, April 1998, v15 n4, pp. 389-413.
- Lockamy, A. and Khurana A. (1995). "Quality function deployment: total quality management for new product design", International Journal of Quality & Reliability Management, June 1995, v12, n6, pp. 73-84.
- Menks, D. (2000). "SENG 613 Quality Function Deployment (QFD) presentation notes", <http://www.ucalgary.ca/~dbmenks/seng/seng613/notes.html>.
- Prasad, B. (1998). "Review of QFD and related deployment techniques", Journal of Manufacturing Systems, v17, n3, pp. 221-234.
- Pitman, G., Motwani, J., Kumar, A and Cheng, C.H. (1996). "QFD application in an educational setting: a pilot field study", International Journal of Quality & Reliability Management, April 1996, v13, n4, pp. 99-108.
- Prins, J. (2000). "Engineering Statistics Handbook, 6.1.1 How did Statistical Quality Control Begin?" NIST/SEMATECH, <http://www.nist.gov/itl/div898/handbook/pmc/section1/pmc11.htm>.
- ReVelle, J.B., Moran, J.W. and Cox, C.A. (1998) "The QFD handbook", John Wiley & Sons, Inc.: New York, NY.
- Schmidt, W.H., McKnight C.C., & Raizen, S.A. (1996). "Splintered Vision: an investigation of US science and mathematics education", U.S. National Research Center for the Third International Mathematics and Science Study, Michigan State University.
- Stampen, J.O. and Hansen, W.L. (1999). "Improving higher education access and persistence: new directions from a "systems" perspective", Educational Evaluation and Policy Analysis, Winter 1999, v21, n4, pp. 417-426.