Teaching Quality: An Integrated TQM Approach to Technical Communication and Engineering Design

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Abstract - Sophomore Engineering Clinic I, the third course in a required 8-semester design sequence, serves the dual purpose of introducing students to formalized engineering design techniques and technical communication practices. To achieve these ambitious goals, the course is team-taught by faculty from the College of Communication and the College of Engineering. While the need to effectively teach communication within engineering is well recognized, the means of integrating the two is still a topic of debate. Asking writing faculty to grade reports does not constitute integration. Furthermore, even a linked course does not guarantee real connections if lectures focus solely on communication and laboratory periods focus solely on engineering. The most effective bridge between these seemingly disparate topics is their common ground in quality. The underlying theme of Total Quality Management (TQM), already heavily stressed in the engineering design modules, is also an ideal forum for evaluating and producing technical communication. Indeed, it is possible to employ the same design tools in both the engineering and communication assignments. For example, the House of Quality is a design tool that enables engineers and management to relate the attributes that a customer might associate with a quality product to the engineering characteristics responsible for such attributes. This process is analogous to what occurs as a writer designs a document for a reader: writers must use document characteristics to realize the expectations of readers, and they must evaluate the consequences and benefits of their design decisions. Yet importing an engineering design tool into the communication classroom does more than give students a model for creating documents that meet their readers' needs, although this is certainly important. In many ways, "borrowing a tool" integrates the dual emphases of our course at a deeper level. Students learn that communication is an interactive and creative process rather than a static tool or artifact, and thus that it is integral to their work as engineers.

I. INTRODUCTION

A. The Engineering Clinic

In 1992, local industrialist Henry M. Rowan made a generous donation of $100 million to the then Glassboro State College to establish a high quality engineering school in southern New Jersey. This gift has enabled the university to create one of the most innovative and forward-looking engineering programs in the country.

The College of Engineering at Rowan University is composed of four departments: Chemical Engineering; Civil Engineering; Electrical and Computer Engineering; and Mechanical Engineering. Each department has been designed to serve 25 to 30 students per year, resulting in 100 to 120 students per year in the College of Engineering. The size of the program has been optimized such that it is large enough to provide specialization in separate and credible departments, yet small enough to permit the creation of a truly multidisciplinary curriculum in which laboratory/design courses are offered simultaneously to all engineering students in all four disciplines. Indeed, the hallmark of the engineering program at Rowan University is the multidisciplinary, project-oriented Engineering Clinic sequence.

Table 1. Overview of course content in the 8-semester Engineering Clinic sequence.

Year	*Clinic Theme (Fall)*	*Clinic Theme (Spring)*
Frosh	Engineering Measurements	Competitive Assessment Laboratory
Soph	TQM	Multidisciplinary Design Project
Junior	Product Development	Process Development
Senior	Multidisciplinary Capstone Design Project	

The Engineering Clinic is a course that is taken each semester by every engineering student at Rowan University. In the Engineering Clinic, which is based on the medical school model, students and faculty from all four engineering departments work side-by-side on laboratory experiments, design projects and research. The solution of these real-world problems requires not only a proficiency in the technical principles, but also a mastery of written and oral communication skills and the ability to work as part of an multidisciplinary team[1,2]. Table 1 contains an overview of course content in the 8-semester

engineering clinic sequence. As shown in the table, while each clinic course has a specific theme, the underlying concept of engineering design permeates throughout [3].

B. Sophomore Engineering Clinic

In the Sophomore Engineering Clinic I, all engineering students complete four compact, open-ended design projects sponsored by each of the four departments. Each module demonstrates the design principles inherent in various classes of design problems. As outlined in Table 2, during the course of the semester each student completes the following modules: design of a product, design of a simulation, design of a structure, and design of a process. In the Fall 1998 semester, sophomore engineering students from each of the four departments completed the following four 3-week design modules: design of a can crusher, design of an analog filter, design of a sheet pile wall and design of a kevlar heat treating process.

Table 2. Design modules in the Sophomore Engineering Clinic I (Fall 1998).

Design Class	*Design Module*	*Department Sponsor*
Product	Can Crusher	Mechanical Engineering
Simulation	Analog Filter	Electrical and Computer Engineering
Structure	Sheet Pile Wall	Civil Engineering
Process	Heat Treating Process	Chemical Engineering

While there are aspects unique to each of the design modules, the unifying aspects of design theory are stressed throughout. This objective is accomplished by introducing students to a Total Quality Management (TQM) approach to design. Using this approach, multidisciplinary student teams organize engineering specifications using the House of Quality[4], develop several conceptual designs using various brainstorming techniques, evaluate these designs using Pugh's method[5], and perform guided iteration to identify optimum designs. Following their formal introduction to TQM, all engineering students complete the four 3-week open-ended design projects sponsored by each of the four engineering departments.

The Sophomore Engineering Clinic I serves the dual purpose of introducing students to formalized engineering design techniques and technical communication practices. To achieve these ambitious goals, the course is team-taught by faculty from the College of Communication and the College of Engineering. While the need to effectively teach communication within engineering is well recognized, the means of integrating the two is still a topic of debate. Asking writing faculty to grade reports does not constitute integration. Furthermore, even a linked course does not guarantee real connections if lectures focus solely on communication and laboratory periods focus solely on engineering. The most effective bridge between these seemingly disparate topics is their common ground in *quality*. The underlying theme of Total Quality Management (TQM), already heavily stressed in the engineering design modules, is also an ideal forum for evaluating and producing technical communication. Indeed, it is possible to employ the same design tools in both the engineering and communication assignments.

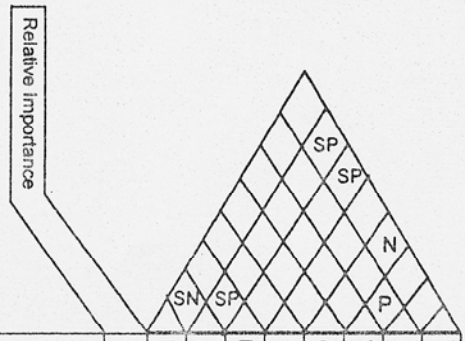
II. TQM AND TECHNICAL COMMUNICATION

The intersection of quality and TQM principles with the teaching of technical communication first suggested itself in the form of the House of Quality. The House of Quality addresses three interrelated problems of design, which are defined in terms of a focus on customer satisfaction above other design goals, such as innovation and feasibility[6]. One is that customer perceptions of quality involve several dimensions, and it can be difficult to meet expectations for all of them in a single product [5]. Another is that customer perceptions of quality are often vaguely defined, and it is therefore a challenge to translate them into specific design attributes that yield quantifiable engineering characteristics. Finally, by their nature these two conditions preclude a traditional, linear production process whereby a concept is developed by designers, passed along to manufacturers, and then presented by marketers. Interpreting customer desires involves figuring out from the start how those desires will be realized in the end product, and thus calls for a design process that is concurrent, interactive, and recursive [6].

These problems are analogous to those presented by technical communication situations. Writers must consider how and whether all expectations can be met in any given document. They must employ particular document characteristics to realize the often unclearly stated expectations of readers. And too often, the writing process resembles the "throw-it-over-the-wall" approach of linear design processes [6]. Writers design and produce documents by drawing on ability, experience, and/or convention, and then "throw them over the wall" to readers who may or may not be satisfied with the results.

In the classroom, these roles overlap but the same sort of process obtains. Instructors propose designs that are to varying degrees open to input from students, and throw them over the wall to students. Students manufacture documents within the parameters of their instructor's

design, refining or embellishing them as they see fit. They then throw the documents back over the wall to their instructors, who now assume a role that may best be described as a fusion of design evaluator, quality control inspector, and customer.



Can Crusher House of Quality		Less Input Force	Large mechanical advantage	Peak Crushing Force		Clearance	Weight	Crusher stroke	Transmission Angle
Easy to crush	8	SP	SP	SP				SN	SP
Easy to place	6					P		P	
Easy to remove	6					P		P	
Can doesn't move				SP		N		N	
Crushes to small size	8								
Inexpensive									
Easy to clean	4					SP		MP	
Wall mountable	4					N			
Safe operation by children	8	SP					N	N	
Doesn't break or bend		SP		SN				SN	
Doesn't Jam		P							
Easy to handle		P				SP			
Compact							SP	SP	

Figure 1. House of Quality for can crusher design.

Of course, the writing process is not as blind, arbitrary, and serendipitous as the throw-it-over-the-wall image makes it out to be, neither in the workplace nor in the classroom. Particularly in the classroom, writers are given tools and strategies and other forms of guidance to assist them with success in their "design." Nonetheless, what this image emphasizes is the linearity that the writing process typically exhibits. Objectives are independently defined and evaluated at various stages of the process as the product passes through the hands of various people, potentially causing repetition and/or contradiction.

Linearity in writing, like linearity in design, means that the beginning and end--need and response, initiation and outcome, concept and product--are not in touch with each other. Linearity results in a design strategy based on an inefficient "build, test, and correct" sequence [6]. In writing courses, students "try out" a design, and then "fix" it after their instructor grades it. To return to the House of Quality, what this method offers is a way to represent the entire process in a way that relates beginning and end. In the case of technical communication, the House of Quality relates the expectations of readers to specific document characteristics in terms of function. The House of Quality draws attention to the ways in which the seemingly idiosyncratic preferences of readers can be organized according to function and translated into what are often--surprisingly--quantifiable, or at least fairly systematic, textual attributes. (For example, the impact on readers of justified versus ragged right margins has been empirically studied.) But what is most important is the construction of the diagram itself. It is not enough to present writers or students with a completed House of Quality; they must participate in generating it themselves. In this way, writers or students have a hand in interpreting reader expectations, formulating objectives, identifying relevant design strategies, and assessing decisions.

As discussed in the previous section, the House of Quality was used to develop specifications for the engineering design modules in the Sophomore Clinic[7]. A partially filled House of Quality developed for the can crusher problem is given in Fig. 1. The left side room shows the Customer Attributes (CA's). These are the attributes as described in a non-technical manner by the consumer, such as "easy to crush, "safe to use", etc. As shown in the figure, these attributes are assigned a relative importance weighting from 0 to 10 based on consumer preferences. The top room displays some of the technical parameters, popularly known as Engineering Characteristics (EC's). These are the technical characteristics of the device in engineering language, such as "crushing force", "weight", etc. The middle room provides the relationships between customer voices and the technical characteristics. In this room, relationships between the CA's and EC's are labeled as:

SP, for strongly positive,

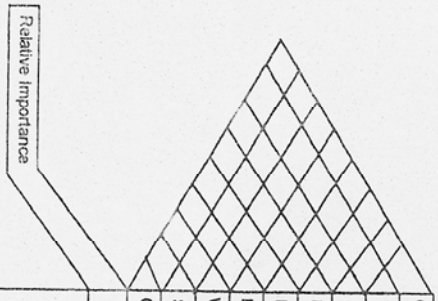
P, for positive,

N, for negative, and

SN for strongly negative.

This room not only provides very useful information in understanding the complex relationships among the CA's and EC's, but also helps to identify any missing CA's or EC's. Another useful feature of the House of Quality is its ability to identify the conflicting requirements amongst the various EC's. In the attic, the labeling procedure outlined above is used to identify the tradeoffs between the various EC's.

Figure 2. House of Quality for designing a proposal.



	House of Quality for Designing a Proposal		Consistency	Sections, Headings	White space	highlighting	Background, Theory	Details	Method, procedure	Straight forward	Objectives, goals, focus
Easy to Read	Looks professional	8	P	SP	P	P	P	SP	P	P	P
	Find what you are looking for	8	SP	SP	P	SP		N	P	P	P
	Easy to look at	7	P	SP	SP	P		SN		P	
	Friendly appearance	6	P	P	SP	P		SN		P	
	Read efficiently	6	SP	SP	SP	SP	NN		P	P	P
Knows what he/she is doing	Knowledgable	8	P	P	N	P	SP	SP	SP	P	SP
	Qualified	7	P	P		P	SP	SP	SP	P	SP
	Knows field, background	6	P	P		P	SP	SP	SP	P	SP
	No padding, kissing up	6	P	P	N	N	N	N	P	P	P
	Specific, Interesting	6	P	P	N	P	SP	SP	SP	P	P
	Purpose, value, benefit	8	P	P		N	P	P	SP	P	SP

Figure 2 shows a House of Quality that was generated during a discussion about writing a proposal. Students were asked to come up with a list of reader expectations, corresponding to what are called "customer attributes" in engineering design. In engineering design, of course, actual customers are surveyed. In the classroom, students were first introduced to what is known as the "rhetorical situation" surrounding the proposal. The rhetorical situation consists of the factors that shape the reception of a document. Proposals, for example, are requests for resources, are usually in steep competition with many other requests, are usually part of a large pool and thus read quickly and critically, and are usually submitted in a more or less standardized format. The audience may favor certain organizations or companies or projects, and may expect certain levels of expertise or experience. Based on this, students were asked to imagine themselves as readers under these circumstances and to describe what they would consider to be positive reactions to a proposal. Lists of customer attributes purposely preserve the wording used by the customers. The intent here is to allow their nonspecific impressions to be comprehensively interpreted by all members of the design team [4]. Thus, this room of the House of Quality in Fig. 2 preserves the wording of the students' responses. Two general areas of expectations emerged, representing two demands on the proposal writer: one, that the proposal be "easy to read," and the other, that it demonstrate that the writer "knows what he or she is doing."

Next, students were asked to list the attributes of a proposal--the textual characteristics--that would meet the expectations expressed by the reader attributes. Two corresponding categories were created to address the two sets of demands. "Easy to read" is a demand met primarily by format and organization, while "knowledgeability" is met primarily through content. Students drew on their own familiarity with proposals and with the expectations of scientific research, as well as what they had learned in class about document layout, to identify these characteristics.

The positive and negative correlation between reader attributes and textual characteristics were only informally discussed in class as general tradeoffs between, for example, detail and simplicity. The principal objective of using the House of Quality heuristic was to demonstrate to students that composing decisions, whether about design or content, are directly accountable to specific expectations by a reader. This functional approach provided a foundation for understanding both design and content decisions as deliberate and systematic, even quantifiable. Students learned that "easy to read" is not merely an aesthetic quality, nor is it only a matter of convenience. A well-designed layout communicates order, coherence, hierarchies, and other relationships. They also learned that knowledgeability is not simply conveyed through detail and complexity per se, but rather that specific kinds of information are sought by readers for specific reasons.

As Fig. 2 shows, however, a full-fledged analysis of the relationships between reader attributes and textual characteristics is possible, and, indeed, the use of such a detailed analysis would enrich students' communication skills in important ways. Although technical communication probably would not be significantly improved through the use of competitive benchmarking (usually the third and fourth "rooms" of a House of Quality), the analysis of correlations between reader attributes and textual characteristics would help writers prioritize and evaluate choices, and would focus their attention on the dominant needs and expectations of their readers. This analysis also reinforces and even reveals relationships between reader attributes and textual characteristics. For example, when Fig. 2 was completed for this paper, the characteristic of being "straightforward" in terms of content turned out to be strongly correlated to all of the reader attributes. On the other hand, the negative correlations that formatting devices often had with attributes related to knowledgeability were a good reminder that writers should lean toward a conservative and balanced appearance. Neither finding is surprising, yet writers often do not think consciously or systematically about such decisions. Writers may learn about the consequences of certain decisions only through the inefficient medium of experience. Better analysis through total quality methods produces "a better gameplan," and a better chance of success the first time [6]. Because the House of Quality gives writers a method of assessing the impact of their decisions

on readers concurrently with composing the document, they understand that communication is an active, creative, and deliberate process whose results can be controlled.

The use of this particular TQM heuristic can facilitate the teaching of technical communication on several levels. First, importing an engineering methodology into the communication classroom helps to bridge the two curriculums. Integrating the two components of the Sophomore Clinic has proven more difficult to carry out in the classroom than anticipated. Borrowing engineering methodologies is one of many practices by which technical communication instructors can situate themselves as knowledgeable participants in engineering culture, which is vitally important if they are to be seen by students as reliable authorities. The House of Quality also makes use of cognitive aptitudes that are being cultivated by the engineering curriculum, so that writing seems less difficult and "alien" to engineering students. Engineering students often resist writing and writing instruction because they perceive it as "soft," unpredictable, mysterious, and, as noted, arbitrary and idiosyncratic. A familiar method of analysis also makes more sense to them than a heuristic from the communication and English disciplines would.

Most important, the fully carried out House of Quality involves students in the articulation of communication objectives, which leads to some of the same benefits that are achieved in concurrent engineering design. A long-standing problem in teaching communication is the question of whether students are able to apply what they do in assignments for their writing courses to "real life" writing situations where rhetorical conditions, and hence reader expectations, can vary a great deal. Writing instruction can be fairly said to often lack what is known in TQM as "robust functionality," a measure of a design's capacity to meet customer expectations under the full range of conditions encountered during use [6]. Like a "pampered" engineering design, the product in the classroom--the document--has often been "tweaked" to fit a narrow range of performance conditions: the assignment requirements, the instructor's preferences, and the student's inclinations, ability, and experience. As a result, the document's "design" may fail when subject to a wider range of conditions. However, when design is the result of rigorous analysis of customer expectations and the ways in which they can be realized through specific engineering characteristics, the design is more likely to be robust. Likewise, when a student's facility with a particular type of document design, such as a proposal, has developed out of an analysis of textual characteristics in terms of function and need, he or she is more likely to be able to design proposals that successfully respond to a range of demands.

Beyond the goal of developing students' practice of TQM methods, it can also be said that TQM provides the foundation for an effective, efficient, and ultimately robust pedagogy as well. From this perspective, the student is the customer and the product is the learning experience itself. As engineering educators, we would do well to take TQM to this level and assess our own design process, as well as the resulting product, in terms of how well we meet our "customer's" expectations. This focus would give students a much larger role in developing objectives for educational "products." By better relating our students' needs to the pedagogical resources we utilize, we could be that much closer to consistently achieving a level of quality that transcends the conditions of the classroom and produces world-class engineers **and** communicators.

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