Recommending and Implementing a General Model for Technical Communication (TC) Instruction in an Engineering Curriculum

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Abstract
In response to pressing industry demands, revolutionary new ABET* requirements, recommendations from professional engineering organizations, and suggestions from recent engineering graduates, we identify a general model for technical communication (TC) instruction. When flexibly implemented in an atmosphere of collaboration among engineering professors, technical communication specialists, industry advisors, university administrators, alumni, and other stakeholders, this robust model can consistently produce engineering graduates who have relevant, defined TC competencies. Further, the model does not stress an already overcrowded engineering curriculum. In fact, engineering professors who have integrated the model elements into engineering classes report a variety of benefits that include better organized lab reports, improved engineering solutions to case study problems, and more time to help students master engineering theory and practice.

*ABET: Accreditation Board for Engineering and Technology

This article will cover the following six sections:

1. A Message from Recent Engineering Graduates in the Workplace:
   TC Skills are Crucial to Engineering Success
2. Background: Taking the Initiative
3. Challenge and Goal: Integrate Technical Communication Instruction and Practice into the Engineering Curriculum
4. General Model: Description and Discussion
5. Steps for Implementing a Communication-Intensive TC Engineering Program
6. Impacts and Conclusions: UB's Experience; Your Experience

1. A Message from Recent Engineering Graduates in the Workplace: TC Skills Are Crucial to Engineering Success

Numerous industry surveys, managers' comments, and academic studies agree: Although today's fast-paced, competitive workplace requires engineers to convey technical information quickly to diverse audiences, many graduating engineers are inadequately equipped to meet this need.[1, 2, 3] Results of our May 1999 survey of recent University at Buffalo (UB) engineering graduates, who had worked as engineers for three to five years, once again confirmed the crucial role communication plays in today's engineering workplace.[4] Respondents included those who had taken UB's demanding, 3-credit elective course in technical communications or participated in one or more of our short modules, as well as those with no exposure to formal TC instruction either as undergraduates or graduates.

First and foremost, our former undergraduate and graduate students told us loud and clear: TC instruction must become an integral part of the engineering curriculum. Suggestions from survey respondents for improving and expanding the TC program followed common themes:

- Make the 3-credit technical elective, "*Technical Communication for Engineers*" **mandatory.** (See course overview in section 4.1. Also see reference 10.)
- Include TC modules and practice in most required engineering courses.
- Provide more opportunity for students to give oral presentations and receive meaningful feedback.
- Start TC instruction in the freshman year; stress active listening and formulating questions.
- Incorporate instruction in current and emerging technologies and interpersonal interactions (writing effective e-mail; designing and maintaining web pages; holding team meetings; conducting meetings; working in interdisciplinary teams).

Many respondents suggested replacing what they (and many engineering professors) call "creative writing" requirements such as English 101 or 201 with a technically oriented course that covers the TC basics of *writing, speaking, reading, listening, and evaluating technical subject matter intended for a variety of audiences*. They also suggested we extend our instruction options to include "refresher modules or workshops" for practicing engineers who need to improve their TC skills.

While some schools (e.g., the University of Washington) have long had extensive TC programs, our internal 1998 review[5] of 40 engineering schools showed that less than 50 percent offered any formal TC instruction; within this group, the majority dealt only with juniors and seniors. Only 12 percent integrated TC instruction into engineering courses. However, in the last few years, many engineering schools have taken a hard look at their approaches to ensure that engineers graduate with an ability to communicate technical information effectively.[6]

As engineering educators across the nation review and upgrade existing programs in response to ABET EC2000 directives,[7] the feedback from our recent graduates offers data worthy of consideration. Those who took maximum advantage of opportunities to receive formal TC instruction reported a significantly positive impact on their ability to function successfully as engineers. Their TC capabilities helped them advance their careers, often providing "differentiating" value to their employers.

Moreover, as Figure 1 shows, the greater the amount and intensity of TC instruction and qualified feedback, the greater the benefit. Those graduates with a high TC index[8, 11] reported that their TC proficiency helped them obtain and adjust to their jobs, work well in teams, garner recognition and promotion, and build confidence. Those who left college without good communication skills reported they belatedly realized the importance of these skills—and recommended making the presently offered elective course, *Technical Communications for Engineers,* mandatory.

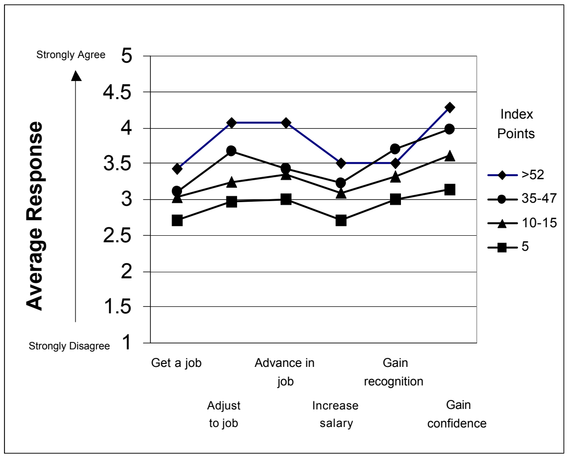

Figure 1: Question posed— "How did technical communication instruction affect your engineering career?" Amount of instruction respondents received correlates directly with career benefits gained.

2. Background: Taking the Initiative

In 1987, largely under the sponsorship of a far-thinking administration, UB's School of Engineering and Applied Sciences (SEAS) initiated a pragmatic technical communication (TC) program, focusing mainly on juniors and seniors. Based on a model originated and proven in the workplace, this program addresses the main problems that scientists, engineers, technical managers, and students consistently identify as the primary barriers to effective technical communication.[9] Almost from its inception, the program benefited from the enthusiastic support of a dedicated Industrial Advisory Committee (IAC), which meets regularly to evaluate overall student performance and to suggest program upgrades based on the constantly changing workplace. Composed of a highly experienced group of engineers, technical managers, entrepreneurs, and TC professionals (both currently employed and retired), the IAC members provide an invaluable link between industry and the engineering school by mentoring our students one-on-one. Because of students' intense schedules, we do not require mentoring; however, students who elect to work with a mentor consistently perform better than those who do not. Clearly, the relationship that develops between a dedicated experienced professional and a young "apprentice" has no substitute.

Between 1987 and 1999, our program grew to reach about 65 percent of our upper-level students at *some level of instruction*—either via our "stand-alone" three-credit technical electives[10] or via short modules integrated into design project, internship, laboratory, and other engineering courses. Our TC faculty tailored the short modules (typically five or fewer instruction hours) to focus on the particular communication assignments in a specific engineering course. For example, assignments can include a senior design project report and presentation, a lab report, an internship progress report, a course-required presentation, or a case-study problem report. Although the instruction and feedback are necessarily less intensive, students are strongly motivated to improve their TC capabilities: TC merit counts for between 10 and 50 percent of the assignment grade, depending on the agreement reached between engineering professors and TC faculty.

Of the 65% of students reached at some level of TC instruction between 1987 and 1999, only about a quarter received TC instruction above the threshold of intensity our respondents deemed significant to strongly and positively impact their engineering careers. Although occasional, short TC modules given by invitation in a few engineering classes helped some students more effectively complete specific assignments, these sporadic interventions may send engineering students wrong messages. For example, students may deduce: "TC is only important on THIS assignment or to THIS professor, but is not important to my academic or professional engineering career".

Quite the contrary is true, as our respondents heartily acknowledged. UB engineering graduates who received relatively limited instruction and feedback (though they may have attended between one and three modules) typically commented that they regretted not receiving more TC training: they clearly recognized their disadvantageous position resulting from insufficient, underdeveloped communication competencies. As one respondent noted:

> "As a young engineer, I find myself involved in projects with senior engineers, who do an excellent job in conveying ideas and concepts. I find that there is some difficulty on my part in conveying my ideas; therefore I tend to remain quiet in meetings. This, I believe, hinders me from proving to the senior guys that I understand the scope of the projects that I am involved in."

Further, 20% of these "low-index" respondents[11] stressed that because TC skills are so important at their jobs, TC instruction at engineering schools should be required. Not surprisingly, the few respondents who stated that TC instruction was not important at all also noted they rarely work in teams. On the other hand, respondents who had successfully completed one of the three-credit electives (in addition to one or more modules, in some cases) noted the importance of TC skills at their jobs. They particularly stressed the major advantages they gained from their *intensive* TC instruction. As one respondent phrased it,

> "When I was in school, I think my classmates thought that good grades [in technical subjects] were all they needed to excel. Communication skills were not a concern for them. At that time, I put a strong emphasis on communication skills for myself. I concentrated my efforts on the ability to communicate complex engineering concepts to laypersons. I still keep in touch with several of my classmates and I am convinced that my efforts in this regard have allowed me to excel far beyond them (as far as vertical company movement/pay scale are concerned.)"[12]

Our survey also revealed that those who had advanced to managerial positions and those who interacted directly with customers, clients, and sponsors had elected to include intensive TC instruction in their college studies. These findings support the idea that advancement to engineering management or positions requiring highly developed interpersonal skills demand excellent communication abilities. As voiced by one respondent: "Communications make the difference between success and failure." Or, as another graduate succinctly wrote: "Technical skills are a given; communication skills differentiate."

The ABET EC2000 initiative formalizes as a mandate what engineering professional organizations have recognized for years: *communication skills are critical for engineers*.
A 1985 study of activities of engineers at one research and development facility estimated "bench"

engineers were devoting more than a third of their time to written and oral communication tasks (e.g., reports, presentations).[13] In 1999 the Society for Manufacturing Engineers named the "lack of communication skills" among the top "competency gaps" in engineers' education.[14] Our research, begun at Battelle Memorial Institute nearly 20 years ago, culminated in our recent survey of UB engineering graduates. This work reveals that while many engineers work in a lab, on the "bench", or alone at a computer, many work primarily in teams or in interdisciplinary groups. They spend most of their time preparing and communicating technical information—discussing, listening, writing, and reading.

Moreover, through the span of a career, most move through a variety of "functions", ranging from entry-level engineers, to product designers, to customer representatives, to high-level managers. Our 1999 surveys show that engineering graduates, working three-to-five years, typically fill a wide range of functions. They reported *spending 64 % of their time communicating*—32 % on writing; 10 % on oral presentations; and 22 % on discussions and meetings. This high percentage among young engineers may reflect the current emphasis on teamwork: respondents reported spending an average of 32 % of their time working in teams.

Thus, we learned several lessons. These suggestions for improving our TC program at UB may well apply to other engineering schools, many of which are under ABET's EC-2000 mandate.

- *TC instruction must become an integral part of the engineering curriculum*—not a separate add-on, not an afterthought, not a small portion of a grade on a few assignments. The average 64% of time that our graduates spend on various types of communication validates industry's requests that engineering schools urgently address this major "competency gap."
- Through their numerical responses and extensive comments, *these graduates provided strong evidence of the impact TC instruction and practice has had on their ability to function successfully as engineers*. This finding correlates well with emerging evidence that communication-intensive instruction across the engineering curriculum (coupled with directed practice and constructive feedback from technical and communication professionals) helps engineering students retain and apply technical core subject material more effectively.[15]
- *Students need extensive instruction.* The greater the amount and intensity of the instruction and feedback, the greater the benefits these graduates reaped.
- *Make oral presentations a requirement*. Despite the small percent of time spent on formal oral communications, our respondents stressed that requiring students to give oral presentations is crucial for their future success. They especially noted that students need more opportunities to practice and receive more feedback.
- *Ensure opportunities to practice*. Since most engineers work in teams at least one-third of the time, students need to develop good communications skills to get their ideas across to colleagues and management. Thus, practice in team discussions, persuasive speaking, listening for content, and audience analysis is essential.
- *Make TC courses mandatory*. Those who left college without good communications skills now realize the importance of those skills—and nearly a quarter of them believe TC instruction should be mandatory.
- *Encompass ALL students*. We are not reaching enough engineering students with the extensive, intensive, and demanding TC instruction and feedback they require to perform well

as practicing engineers.

Engineers no longer function in isolation. To put their findings and ideas into practice and to make the substantial contributions for which they are hired, engineers need more than technical knowledge. They must be able to share that knowledge concisely and meaningfully.

3. The Challenge and Goal: Integrate Technical Communication Instruction and Practice into the Engineering Curriculum

At UB, we are now planning several steps to broaden our TC program in response to this clear message. We have proposed expanding the TC program to cover all four undergraduate years and intensifying TC instruction within engineering coursework. Simultaneously, we are building a consistent program of content models and communication techniques based on our past successes and on our surveyed students' recommendations.

Our overall objective is to provide increased opportunities for engineering students to hone their TC effectiveness and efficiency, as they encounter increasingly complex assignments throughout their undergraduate and graduate engineering careers. Thus, they will be able to successfully meet workplace challenges earlier in their professional careers. To attain this ambitious goal, we have developed a General Model to help:

(1) Establish continually improving processes for identifying, inculcating, and evaluating defined TC competencies that produce measurable improvements according to our standards.

(2) Engender attitudes, transfer skills, and encourage practices that enable our graduates to continue improving their own TC capabilities AFTER leaving formal schooling. They will also be able to foster engineering excellence among their colleagues in the workplace by applying learned TC techniques and strategies that enhance productivity, creativity, and clear thinking.

In this paper, we will focus mainly on:

- Describing and discussing the general model, its key instruction features, and potential benefits
- Suggesting possible steps for *implementing* this model—based on overcoming the numerous obstacles many engineering schools now face.

4. The General Model: Description and Discussion

In view of these needs and experience, we propose the general model depicted in Figure 2. This figure illustrates a roadmap our Center for Technical Communication is using as a basis for helping the engineering school and its departments determine how and where to implement TC instruction within the existing curriculum. Adapting a highly successful model developed by UB's "Student Excellence Initiatives"[15.5], we work together to introduce the TC knowledge sets and practice scenarios that support the continuously increasing degree of difficulty students face as they advance in their studies.

Figure 2 shows how departments might elect to distribute various document types over four years of academic study. As the technical subject matter becomes more specialized and assignments to apply newly acquired knowledge become more demanding, so too do the TC strategies become more complex and difficult.

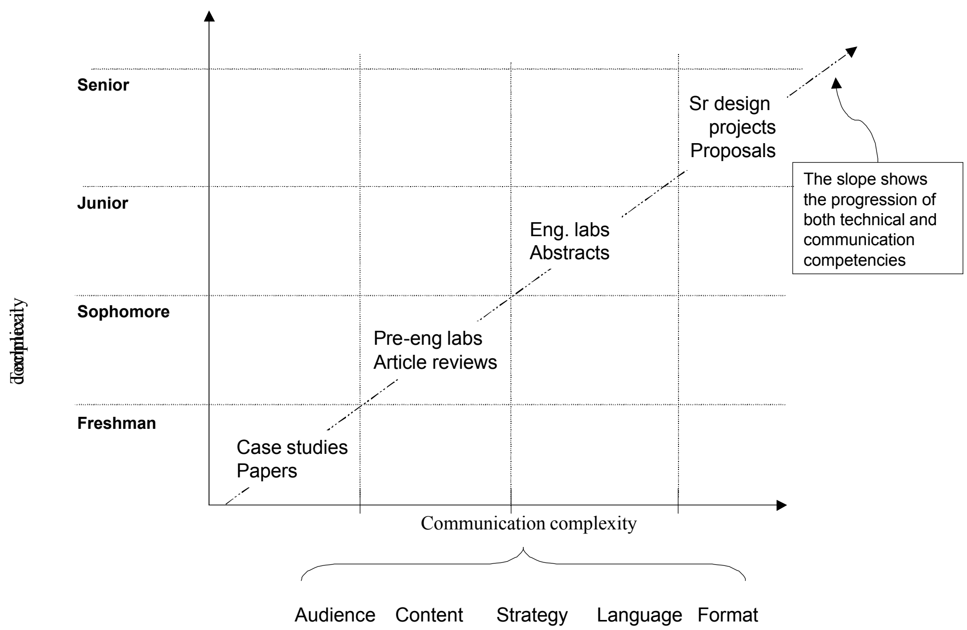

Figure 2: A general model for technical communication instruction

Typically, we suggest integration of TC instruction and practice rooted in course assignments and designed to support technical material retention and exploration of alternative solutions within a specific context. For example, in a freshman course the assignment objective may be simply demonstrating understanding of technical material to a professor. One TC objective of a lab report might be to provide clear instructions and visuals that enable accurate reproducibility of an experiment. A more advanced assignment might include persuading non-technical managers that a technical project is feasible or explaining the environmental impact of a proposed development to a town board. Some assignment types exemplified above could be geared to several levels: e.g., case studies, summaries, evaluations, and oral presentations.

As shown in the example in Figure 3, an expanded grid cell permits instructors to plot equally weighted engineering and TC grades for a specific assignment or for a course. These plots could also be adapted to show students' strengths and weaknesses in improving engineering and TC capabilities, assignment averages, and other relevant data.

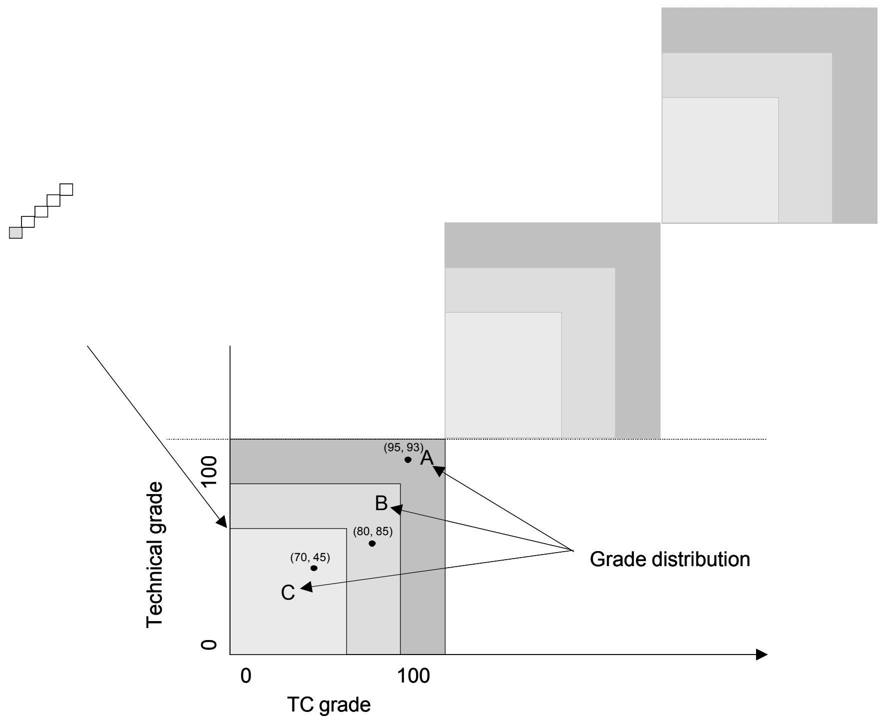

Figure 3: Engineeri ng and TC grades for individual assignments or courses

Three key features underlie this general model: a) Double-5—a problem-solving communication and instruction approach; b) The concept and assurance of "quality" information; and c) Audience awareness and focus.

4.1 Double-5: A Highly Effective TC Instruction-Model

As early as 1987, we at UB were adapting an industry TC program to academic conditions. In fact, the specific charter of UB's Center for Technical Communication (CTC) was to "re-engineer" a highly successful approach for teaching researchers to write so managers could understand, developed at Battelle Memorial Institute in Columbus, Ohio.[16] To meet the needs of both technically trained scientists and engineers and technical and non-technical managers and other decision makers, this model suggests an organizational technique for technical writing that translates the basic steps of the scientific method into contextual terms. The model uses science's problem-solving structure for conveying technical information; but it adds a parallel structure for interpreting technical information into an organizational (e.g., business, industry, government, and political decision-making) context. Thus, we call this model "Double-5".

Using Double-5 as a basis and always keeping *content* at the center of our work, we move deliberately in our three-credit electives from the known to the unknown—we gradually introduce students to a variety of organizational, graphical, editorial, and formatting techniques that enable them to solve a problem. Students learn to convey technical information (both in writing and orally) to achieve a desired action in the recipient. The action could be as simple as acknowledging the author understands a concept (e.g., a professor awarding the student a desired grade), or as complex as providing funding for a project. Instead of immediately focusing on rhetorical principles and grammatical constructions, our students start by clearly articulating a problem and offering a well-argued solution. Beginning on familiar technical ground, they continue through a process of inquiry: How much technical detail should I include to convince my audience without confusing them? Should I introduce this chart when I discuss my technical solution or should I put it in an appendix? Should I write out these findings or put the information in a table? Will my audience be confused if I use this technical term or offended if I "talk down" to them? Does my approach parallel corporate objectives? What are alternative solutions? What are the risks and rewards of each approach? Is my evidence sound? Will my audiences consider my solution feasible in light of their previous experience with this type of technology? Do my long and convoluted sentences prevent rapid scanning? Have I provided essential background information? Twenty-nine successful semesters attest to the model's validity, as reflected in the results of exit questionnaires.

But how do we achieve these effective results with the majority of engineering students? The simplest solution is that given by the respondents to the 1999 survey: Make *Technical Communication for Engineers* mandatory and staff the course accordingly. Meanwhile, in the last three years, engineering students have taken upon themselves to voluntarily submit to the grueling regimen of this course. It demands: 35 written assignments (including a 20-page proposal); attendance at all lectures and recitations; three oral presentations; and rigorous grading based on timely submissions, forced re-writing to achieve steady improvement, and emphasis on results. Since 1999, student enrollment in this elective has nearly tripled.

4.2 Integrating a Quality-Control Framework in a Communication-Intensive Engineering Curriculum

We began with the basics. What makes this TC instruction approach so effective? At its heart is our definition of Information Quality. To pass quality control, we require a technical message to be clear, concise, and useful to the recipient. This definition drives both instructional technique and evaluation. We started by tentatively defining general TC competencies engineering students should develop as they progress through increasingly complex assignments. A TC Steering Committee[17] met to discuss the competencies we outlined and offered numerous valuable comments. For example, they suggested emphasizing basic TC during the freshman year, and presenting technical data in suitable graphic format.

Before suggesting methodologies for integrating TC instruction into the engineering curriculum, we asked one more crucial question: Is technical communication in some way unique?
Why are traditional composition classes insufficient to prepare many engineers for workplace communication realities?

Technical communication is not entirely unique. Its effective and efficient practice requires many of the skills taught in a standard rhetoric or English composition course:
- Developing a clearly stated, restricted thesis

- Organizing ideas effectively through planning strategies, such as topic or sentence outlining
- Revising the tentative thesis as required by subsequent review and research
- Using standard English and generally accepted conventions of usage and grammar
- Achieving structural unity
- Arguing logically and supporting contentions with attributed facts.

Engineering students who have mastered these basic skills have a head start on their colleagues who have not.
However…
Even engineering students whose competencies permit them to "test out" of basic composition face significant challenges when they attempt to adapt rhetorical techniques ideally suited to analyzing a literary work, preparing a library research paper, or expressing a personal opinion on a social issue to the rigors of technical information exchange.

Many college composition and literature courses assume fundamental competencies (which may or may not exist) in grammar and usage, and focus on teaching students to develop and express ideas creatively in personal essays. College English professors do not consider it their job to teach the basics of grammar any more than college mathematics professors consider it their job to teach addition and subtraction. A vast misconception by science and engineering professors may be that English professors teach something similar to what they learned in elementary and high school. Literature courses teach students to interpret and analyze literary works, and to appreciate the ideas and aesthetics of various writers. The broad, yet close reading demanded by English professors is intended to encourage critical thinking and wider perceptions. These are valuable contributions in their own right. In fact, when pressed to give one piece of advice that will most help our students in their adult lives, our mentors consistently advise our students to read more widely.

But…all professions, including engineering, make demands on their practitioners beyond general education requirements. The engineering professions, as currently practiced, demand communication competencies that extend beyond the ability to express personal opinions. They require a thorough understanding of the two-way dynamics of communication and a continual evaluation of the effectiveness of the information exchange during the communication process. Though traditional composition courses teach the rhetorical principles of unity, clarity, and logical argument—all of which are also crucial to effective TC—most focus on teaching the writers or speakers to express their ideas aesthetically. If a model writer (such as a Joyce, Hemingway, or Shakespeare) uses a word or allusion which is unfamiliar, but precisely conveys the author's meaning, then the onus is on the readers to look up the word or reference, if they wish to fully appreciate the writer's meaning.

Engineers who follow this model for technical communication in the workplace are certain to experience frustration. Why? Nowhere is dynamic, two-way communication more important than in engineering. The onus is on the writer or speaker to focus on the needs of the audience to achieve clear, concise, and useful communication. Instead of beginning with the question, "What do I want to say to effectively express my knowledge or opinion?" the technical communicator must begin with "What does the audience need to know to effectively use the special technical information I am providing?"

On the basis of our experience and research we have identified eight *specific* TC competencies. Engineering students must learn how to:

- Profile audiences concretely and allow this profile to drive communication media selection, organizational strategy, language, level of technical detail, and format
- Constructively and objectively evaluate TC on the basis of information quality: clear, concise, and useful to the recipient
- Prepare communications that are complete, accurate, logical, and useful to the target audience
- Use standard language and editorial tools to achieve clear, concise, and accurate technical information exchange
- Apply graphics, design, and formatting tools to show emphasis and permit rapid grasp of key information
- Manage communication tasks efficiently
- Actively listen and effectively speak in formal and informal settings
- Evaluate written and oral communications.

Consistently applying a flexible problem-solving model such as Double-5 for planning and implementing a TC project makes it much easier for engineering writers to attain these eight basic competencies. Engineers following a consistent reporting model find it easier to select information at the right level of technical detail for a specific audience. Double-5 also ensures completeness within the audience's context and addresses the primary complaints engineering professors and industry managers make about engineers' communications:

- Information is hard to scan and grasp quickly
- Organization is poor or cumbersome
- Logic leading to conclusions is unclear
- Conclusions and recommendations are not spelled out
- Document or presentation is incomplete and without context.

These problems remain even if one is skilled in grammar and usage. Thus, while such skills are obviously necessary and pave the way for clarity, they do not guarantee TC proficiency.

4.3 Audience Awareness

The core TC competency from which all others emerge is audience awareness. Knowing your audience and understanding the numerous technical information exchanges that occur during a typical working day are central to producing high-quality, useful technical communications.

Communicating effectively with diverse audiences generally requires engineers to develop competencies in each of the following categories of progressively more difficult technical communications:

1. Evaluate and articulate understanding of a problem, a proposed solution, and the context

(academic or business) within which they reside
2. Explain to audiences having various levels of technical expertise and various reasons for needing information
3. Instruct peers, subordinates, and superiors about concepts, ideas, and activities; and
4. Persuade peers, subordinates, superiors, and laypersons to take a desired action.

These competencies are not exclusive; in some cases, they are additive. By focusing on audience types and their information needs, we are able to help students develop TC competencies in each of the identified areas to support the goals and assignments of various engineering groups. Consequently, we can use proved QC approaches to help engineering departments or groups rapidly identify and articulate specific TC competencies that students graduating from different disciplines must obtain to excel at their future work places and situations.

A major benefit of the Double-5 QC/TC model is *flexibility*. Subject matter experts, professors, or department committees can adapt the model to fit their specific needs to meet a particular engineering discipline's standards. This approach enables the deep involvement of subject matter experts in achieving ABET EC2000 directives. It also provides numerous opportunities for continual improvement as academic courses change, as industry requirements change, and as new technology or new pedagogical approaches emerge.

5. Steps for Implementing a Communication-Intensive TC Engineering Program

As noted, the approach outlined above has two major advantages: robustness and flexibility. With its emphasis on *content*, the instructional model works well with both native English speakers and ESL students. Because the general and the Double-5 instruction models rest firmly on a QC foundation and a science-based content-reporting approach, the model adapts readily to different situations and needs.

Thus, the general model can be implemented in various schools operating under different scenarios. Here are four examples:
1. Engineering schools with no organized TC program
2. Engineering schools with some TC, but with needs to improve
3. Engineering schools with a fairly complete formal program that wish to enhance their offerings or integrate more fully with mainstream engineering activities
4. Engineering schools with a comprehensive program that want a benchmark against which to measure their program.

Schools in each of these scenarios have different needs. However, certain common obstacles are often hard to overcome. We list and discuss some of them below.

5.1 Obstacles to Integrating Intensive TC Instruction into the Engineering Curriculum

The need is pressing. Professors, managers, reviewers, engineers, and students widely agree that *as a profession* engineers communicate poorly and struggle to achieve an understandable level of writing or speaking. Technical communication deficiencies frequently prevent engineers from achieving personal and professional goals (e.g., obtaining funding for projects; receiving promotions to greater responsibilities). Industry spends substantial amounts on training—yet often remains displeased with the results. In spite of rapid interconnectivity via e-mail and the Internet, many remain concerned that usable results of technical research paid for with public dollars are not being issued substantially more understandably than in the past.[18] Yet, to make difficult decisions that impact us all and to compete effectively, government and industry leaders *must* have access to engineering information in a form that is both understandable and useful within specific contexts.

Even so, obstacles to integrating excellent communication instruction into the engineering curriculum remain formidable—especially for Scenario 1 and 2 schools:

- The engineering curriculum is over-stressed.
- Budgets continue to decline at both state-supported and private institutions in the wake of three years of a bear market, state funding cuts, and reduced endowments.
- Professors teaching engineering-discipline subjects often have little time to devote to upgrading their students' communication skills; believe the problem should rightfully be solved elsewhere; have little, if any, formal training in teaching TC; and have no budget to achieve TC objectives. Thus, students can receive numerous conflicting messages about TC.
- Poor communication skills seem to be ingrained in the engineering profession. Complaints about students lacking sufficiently developed TC skills date to the first meeting of the Society for the Promotion of Engineering Education (SPEE) in Chicago in August of 1893! [19]
- Departmental lines are clearly drawn between subject-matter disciplines; multidisciplinary solutions crossing departmental lines are traditionally very expensive and difficult to implement.
- Engineering students typically complain that the knowledge explosion has stressed their workloads to the breaking point.
- More and more students are increasing their outside work loads to nearly full time as the cost of higher education continues to climb and financially strapped institutions cut support.
- College and university administrators reject the introduction of additional cost-drivers (e.g., TC professionals to teach within the engineering curriculum) at a time when they are scrambling to maintain what they consider to be basic subject-matter courses and labs.
- Even if engineering professors could be persuaded to require excellence in technical communication reinforced by the grading system, many have no formal training or extensive experience in designing TC instruction, providing constructive feedback, or developing TC evaluation metrics.
- In the past, many university systems have not rewarded professors and teachers for either teaching innovations or for improvements in student learning. Now, the new ABET requirements are forcing engineering schools to re-examine and revamp this approach.
- Required composition courses (often taught by TAs who have great latitude to design both course content and structure, but who have little or no interest in technical subjects) do not consistently focus on language-usage principles that engineering students can readily transfer to the type of technical communications required at school or in the workplace. *Basic courses in literature and composition serve a useful general education function, but they do not necessarily produce good technical writers or speakers, any more than they produce*

accomplished journalists, novelists, poets, or orators. Their purpose is to expose students to the wealth of knowledge and experience available to an educated mind willing to continue to learn throughout a lifetime, and to serve as a beginning foundation for later specialized instruction given by professionals within a specific discipline.
- The primary language of many engineering students is not English.
- Many engineering students have attempted only a few writing assignments during their undergraduate careers; many have never taken an essay exam, let alone written a report; most chose engineering because they were good at numbers and believed themselves to be poor at language.

So, how do we overcome these daunting barriers? Mainly by proactively looking for viable strategies in our current situation, piggy-backing on existing courses, building a supportive team among faculty, and creating efficient instruction that is effective for students, faculty, the school administration, and the workplace. Our approach, based on the general model, addresses each of these obstacles, suggests some steps that we have used or proposed, and notes some results we have observed. See Table 1.

Table 1: Options for overcoming obstacles

Obstacles	Potential steps and results based on applying the TC/QC problem-solving model
Overstressed engineering curriculum	• Introduce short modules into freshman engineering orientation sessions explaining importance of TC, organization module, what to expect in TC evaluations • Work with Student Excellence Initiatives staff to help students learn to listen more productively, organize TC information for more effective studying • Apply TC approaches to help students solve engineering problems through group discussion, peer evaluation techniques, on-line editing techniques, identifying and articulating problems within different contexts
Ingrained attitudes about engineers being poor communicators "by nature"	• This model produces more proficient and efficient communicators, and more objective communication evaluators who focus on information quality • As students acquire a valid metric, we observe that their evaluations agree consistently with those of their instructors and peers; and as they view effective communication as a problem-solving task, they begin to habitually integrate effective methods into their own work • They also encourage their peers to use these techniques when they realize that improving everyone's work is to their mutual advantage • They come to know from personal experience that being a good technical communicator is a matter of technique and hard work • Workplace realities require engineering students to abandon this "poor communicator" image and begin acquiring industry-standard TC competencies • The suggested model has convinced 29 semesters of our students that this image was just a myth anyway.
Poor communication skills are XXX's fault and it is too late to fix them (substitute teachers, parents, English Department for XXX)	• This model does not permit anyone to play "victim" • Each student begins with the skills he or she possesses, learns the tools required to improve, and has a lifetime to get better • Becoming an excellent technical communicator is a matter of understanding the processes involved, learning the techniques, and practicing the skills

Students are overworked and can do no more	• This model incorporates communication-based time-management and efficiency-building strategies • Students employing these techniques report fewer false starts, less procrastination, fewer misunderstandings of class requirements, less confusion about what they are expected to do • Many report they are actually saving time by doing assignments right the first time, knowing *how* to ask for clarification and seek help • We might actually help our students feel less overworked and stressed by offering workshops in these TC skills early in their academic careers.
Many engineering students are also ESL students	• Since the model is rooted in technical problem-solving within an organizational context, ESL students can function as well as native-born English speakers. • While we require all of our students to write and speak professionally accepted standard English, each student must work on the specific barriers inhibiting his or her ability to achieve clear, concise, meaningful communication, identify the tools needed to achieve these objectives, and do the necessary work to reach these objectives.
Engineering courses do not offer many opportunities for students to speak and write	• If engineering professors had TC-trained Teaching Assistants to help students produce easily read assignments, and present pithy oral briefings, engineering classes could offer engineering students more opportunities to read, write, and speak • Engineering courses could offer bonus credits for students who prepare written reports or briefings, or, for example, who successfully facilitated teamwork—without adding to engineering professors' workloads.

To start attaining our general model's more encompassing instruction goals, we first established an interdisciplinary steering committee comprising engineering faculty from all School of Engineering and Applied Sciences departments, the Dean of Undergraduate Studies, members from our Industrial Advisory Committee, and faculty from UB's Center for Technical Communication. We are examining a variety of alternative TC teaching methods and approaches that could extend current integration or coordination with existing engineering courses, but that offer four to six times as many hours of instruction and opportunities for feedback—both in written and oral communication. Also, we are in the process of defining and refining the competency levels we expect students to reach during each of their four undergraduate years.

Key to achieving steady TC improvement is a system of actions and strategies that ensure:

1. Constructive and timely feedback from both engineering and TC professionals
2. Engineering and TC specialists trained to provide such feedback consistently
3. Opportunities for students to revise, re-write (or re-speak) before receiving a final grade
4. Steadily increasing expectations as both technical and TC levels of difficulty increase over our students' academic careers
5. Continually introduced examples of the importance of learning to effectively and efficiently convey technical information that the intended audience finds understandable and useful.

Table 2: Example of engineering department TC policy

6. Impacts and Conclusions:

UB's Experience

While in school, engineering students' grades often depend on their abilities to prepare various types of reports, assessments, analyses, team projects, and oral presentations. Yet, many engineering students have little formal instruction in technical communication; consequently, some receive lower grades than their knowledge deserves. Others lose spots in desired engineering programs or opportunities for financial support for continuing education because they do not have the technical communication knowledge and skills to prepare winning applications, in spite of abundant technical talent.

In the workplace, employers often depend on engineers to lead both technology innovation and application. Yet, surveys consistently reveal that industry views "inadequate writing skills" and other communication "inadequacies" as a top "competency gap" in graduating engineers' abilities. Further, our own survey of UB graduates shows that practicing engineers spend a total of 64% of their time communicating (writing, speaking, working in teams). Thus, integrating basic TC competencies as part of the engineering curriculum is crucial. Our experience teaches that students who master essential technical communication competencies ask better questions, develop better listening skills, and identify critical engineering concepts more easily. They also work better in teams, reason more effectively, contribute more confidently to class discussions, and more clearly articulate technical ideas to diverse audiences.

Table 2 depicts the capability features that a department could require students to demonstrate in their written and oral communications.

Typical Engineering Department Delineation of TC Policy

Students graduating from the XXX Department, School of Engineering and Applied Sciences, will demonstrate competency to create technical information (oral and written) that is understandable, useful, clear and concise. Each student will demonstrate satisfactory proficiency by preparing technical communications that demonstrate the following characteristics:

Feature	Description
Organization	Enhances understanding via information selection, segmentation, and sequencing
Relevance	The information supplied fulfills the audience's needs
Focus	No extraneous information, no digressions, but provides *all* information essential to purpose
Evidence	Verifiable (in some cases reproducible) supporting data
Accuracy	Numbers, supporting evidence, facts, units of measure, equations, definitions, assumptions
Clarity	Intended reader can understand information, argument, intent
Logic	Whole document and subordinate segments proceed in orderly manner from known to unknown, from simple to more complex, with no unexplained "leaps" to unsupported conclusions
Language	Factual, concise, clear; consistent with generally accepted standards of professional communication
Format and Graphics	Speeds and eases understanding. Uses techniques for visually displaying technical information that help audience compare and contrast, easily grasp major points, and understand emphasis

Unlike other types of writing (e.g., personal essays, editorials, literature) that may seek to evoke an emotion or capture an experience, technical communication usually has one primary purpose: to transfer knowledge from someone who knows to someone who needs to know.

Consequently, most technical communication exists within the context of *solving a particular problem*. Usually, a technical communicator must tailor the information to the needs of a specific audience, or work within the constraints of a specific context. Therefore, effective TC requires competencies that extend beyond writing or speaking in accordance with grammatical and usage standards.

Over 29 semesters, our core group of TC professionals and advisers has included practicing engineers from many disciplines, engineering managers, technical writers, technical editors, publications managers, technical entrepreneurs, R&D scientists and administrators, academic administrators, and professors from numerous science, technical, and engineering disciplines. We have adapted a "best-practices" TC/QC approach based on fundamental problem solving. Originally developed in industry to help technical knowledge workers more effectively and efficiently convey difficult technical information to R&D managers, this approach yields many benefits. Examples from our experience include:

- Better preparation for students to more clearly articulate engineering solutions
- Greater and more in-depth class participation
- Better retention of engineering core material
- Greater willingness to seek interdisciplinary cooperation
- More productive teamwork
- Improved ability to ask focused questions that clarify assignment objectives, thereby reducing wasted time, procrastination, and frustration
- Improved written and oral submissions that are easier to read and evaluate because they are better organized, more focused, better argued, and more conforming to recognized standards
- More time for engineering professors to focus on research and teaching technical disciplines.

An additional benefit of this approach has been the substantial growth of our outreach program, both in the number of courses delivered and in new projects undertaken (e.g., development of operation manuals for a local company). This contact provides a valuable resource for continually improving our instructional offerings. It also offers new insights to emerging changes and trends in industry's communication needs.

We have spent the past two semesters focusing on developing, testing, and modifying very specific grading guidelines for Teaching Assistants working in our three-credit electives. The resulting consistent grading from our expanded TA base convinces us of the value of the work. In exit surveys taken at the close of the past two semesters, students raved about the quality of help they received from our staff of Teaching Assistants. At the request of one engineering professor, we also developed a special module to assist mostly ESL graduate students improve their ability to write theses and technical journal articles.

Every semester since the fall of 1987, we have collected entrance and exit data from our "Technical Communication for Engineers" students. The initial questionnaire identifies the main communication problems students perceive they face. The exit questionnaire summarizes their views, both quantitative and qualitative, on detailed questions about the course. Two results encapsulate their views. On a scale of 0 to 5 (0 = lowest rating; 5 = highest rating), students on average initially rate their written communications at about 2.6, their oral presentations at 2.3. Exit questionnaires show perceived improvements to about a 4 in both these areas. The overall rating for the course as a potential benefit for their future careers has consistently averaged a gratifying 4.5.

Our TC programs are "a work in progress". We are continuing to adapt our model to the realities of an engineering school operating within a state university system in an era of declining budgets, increasing ESL enrollment, stricter ABET evaluation policies, and mounting demands from the workplace.

Your Experience

Many of you, our readers, may be encountering similar realities. However, ABET's new, more stringent requirements may well spawn a surge of creative new methods for expanding and implementing TC instruction. The reasons are twofold: Accreditation is essential for an engineering school's very existence; and the new ABET policies require written and oral reports as evidence of successful engineering course outcomes. Thus, we eagerly seek to learn from your comments, suggestions, and experience descriptions. We hope to make this information available to all engineering educators interested in producing graduates who know how to convey technical information that is relevant, concise, and clear, and in making "Technical Communication" an integral part of the engineering curriculum.

References

[1] Sageev, P., F. Prieto, and A.J. Smaczniak, "Technical communications in the engineering curriculum: an example of industry-university cooperation," Conference Record, 1992 IEEE, Professional Communications Society, IPCC, Santa Fe, 1992.
[2] Gaboury, J., "30 ways to be a better IE," *IIE Solutions*, vol. 31, no 1, 1999, pp. 28-35. In this article, the author quotes Professor Jerry Banks of Georgia Institute of Technology's School of Industrial and Systems Engineering: "Surveys of our graduates continue to tell us that the two most important courses they took at Georgia Tech were public speaking and technical writing." She also cites Dean Fullerton, industrial engineer supervisor at United Parcel Service: "You can't just know how to do your job, you need to be able to communicate."
[3] Vest, D., M. Long, and T. Anderson, "Electrical Engineers' Perceptions of Communication Training and Their Recommendations for Curricular Change: Results of a National Survey." *IEEE Transactions on Professional Communication*, vol. 39, no. 1, March 1996, pp. 38-42.
[4] Pneena Sageev, Carol J. Romanowski, "A Message from Recent Engineering Graduates in the Workplace: Results of a Survey on Technical Communication Skills," *Journal of Engineering Education,* October 2001, pp. 685-693.
[5] Center for Technical Communication, internal technical communication review, Spring, 1998.

[6] Many institutions are exploring a variety of approaches to graduating students with demonstrable communication proficiency. One of the most concise descriptions of Basic Principles we have seen recently is a posting of proposed catalog copy on Iowa State University's web site: "The faculty of Iowa State University believe that all educated people should be able to communicate effectively in a variety of settings and media, including electronic. Consequently, Iowa State University graduates are expected to develop competence in three interrelated areas of communication: written, oral, and visual. This communication competence can best be achieved through the following five principles: (1) Communication instruction and practice are distributed over the student's entire undergraduate experience, both in and out of the classroom, from the first year through the senior year; (2) Communication instruction and practice are distributed across the curriculum, both in communication courses and in courses in the student's major; (3) Active learning and higher-order thinking are fostered through communication; (4) Faculty across the university share responsibility for the student's progress in communication practices; (5) Both faculty and students engage in ongoing assessment for continuous improvement of the student's communication practices. Iowa State University's communication curriculum, based on these five principles, seeks to enrich the student's understanding of the various subjects studied as well as prepare the student to communicate successfully in professional, civic, and private life." Other resources we have found particularly valuable can be found on the web sites of MIT, Penn State, Rose Hulman Institute of Technology, Purdue University, The Gateway Engineering Education Coalition, Clemson University, and The Kellogg Foundation.

[7] "Criteria for Accrediting Programs in Engineering," Accreditation Board for Engineering and Technology, Baltimore, MD, 1999 (updated versions available on the ABET website: www.abet.org)

[8] Sageev 2001. (See reference 4.)

[9] Sageev, P., *Helping researchers write...so managers can understand,* Battelle Press, Battelle Memorial Institute, Columbus OH, 1994

[10] Our 3-credit electives, semester-long intensive courses, address three main topics: (1) "*Technical Communications for Engineers*" covers the main types of documents and presentations engineers produce at their jobs. This flagship course focuses particularly on writing and orally presenting a proposal on a topic students originate; (2) "*Procedure Writing in Industry*" covers writing quality control (QC) documentation and other QC requirements; and

(3) "*Empower Your Technical Language*" emphasizes tools to further enhance students' editorial evaluation skills.

[11] Sageev, 2001. (See reference 4.) Using responses to the type of TC instruction received, we developed an index that corresponds to the number of hours of technical communication instruction the respondents received at UB. Students taking a mini-course module in a lab, senior design, or internship course receive 5 or fewer hours of instruction. The required graduate course, *Managing Engineers' Communications,* compresses 35 hours of technical communication material into 28 hours of instruction. Students in the 3-credit technical electives, such as *Technical Communications for Engineers*, receive 42 hours of instruction. Therefore, we assigned 5 points to mini-modules, 35 points to the graduate course, and 42 points to the three-credit electives. Each respondent's index is the sum of all TC instruction received at UB. For example, a respondent who reported taking a TC lab course module and *Managing Engineers' Communications* was assigned an index of 40.

[12] Sageev 2001. (See reference 4.)

[13] James Paradis, David Dobrin, and Richard Miller, "Writing at Exxon ITD: Notes on the Writing Environment of an R&D Organization," *Writing in Nonacademic Settings*, eds. Lee Odell and Dixie Goswami (New York: Guilford, 1985), 281-307.

[14] Rogers, Jr., D., M.J. Stratton, and R.E. King, "Manufacturing Education Plan: 1999 Critical Competency Gaps," Society of Manufacturing Engineers and SME Education Foundation, 1999.

[15] Rosalind H. Williams, Edward C. Barrett, Leslie C. Pereleman, The Writing Initiative, *Studies in Technical Communication, 1996*. For example, as part of its Writing Initiative, MIT offered a communication practicum associated with specific engineering classes. Each practicum combined coaching on some highly specific assignments with a much more general exploration of the social, managerial, and human dimensions of the engineering process. Requirements included not only writing a ten-page design report, but also a two-page memorandum to a manager without a technical background either recommending the design be implemented or scrapped. Over half the memoranda presented provided sound arguments explaining why the project design approach proved unfeasible and recommending it NOT be implemented.

Also see: Pendergrass, N.A., et al., "Improving First-Year Engineering Education", *Journal of Engineering Education,* Vol. 90, No. 1, 2001, pp. 33-41.

[15.5] William G. Wild, Jr. and Michael E. Ryan, "Reasons to Stay: Re-orienting Toward Retention of Future Engineers, internal report, University at Buffalo, The State University of New York, June 2001. Also, oral presentation to the Dean's Advisory Council, October 2002.
[16]Sageev 1994. (See reference 9)
[17] This committee comprised representatives from all engineering departments, the TC faculty members, the dean of undergraduate education, and representatives from our Industrial Advisory Board.
[18] Thomas E. Pinelli, Rebecca O. Barclay, John M. Kennedy, *NASA/DOD Aerospace Knowledge Diffusion Research Project*, NASA Technical Memorandum 110208, Report Number 36, November 1995.
[19] Teresa Kynell, "Technical Communication From 1850-1950: Where Have We Been?", *Technical Communication Quarterly,* Spring 1999, Vol. 8, No. 2 (143-151)

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