INTEGRATING COMMUNICATION TRAINING INTO LABORATORY AND DESIGN COURSES

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Recently, an increased awareness that good communication skills are essential in the engineering professions has led many chemical engineering departments to stress technical communication in the undergraduate curricula. In fact, a recent informal *Chemical Engineering Progress* survey[1] of the communication requirements in 156 U.S. and Canadian chemical engineering departments found that "with few exceptions, most of the departments that responded [to the survey] were placing greater emphasis on communication skills." As this survey indicates, chemical engineering departments take a variety of approaches to incorporating communication into the curriculum: some departments require a course in technical communication from another division of the university; others have developed courses which specifically emphasize technical communication within chemical engineering; while a third common approach is to integrate communication training into existing courses.

We initiated our communication program at the University of Illinois in 1989 by offering a junior-level communication-intensive course which emphasized the interrelationship between technical problem solving and communication of the results. Over the semester, the students completed several short technical projects and one longer one, each requiring some technical writing, revision, and oral work. Each project specified a particular audience and goal to be reached so that the students learned to structure their problem solving with the ultimate communication goal in mind. Limited to thirty students, the course provided individual attention and feedback, opportunities for discussion among students, writing workshops to help build composition skills, peer editing of both oral and written work, mock meetings and interviews to simulate professional experience, and an opportunity to view videotaped presentations for self-evaluation.

Encouraged by the success of this elective course, the department decided to extend practical writing and speaking experience to all students by stressing communication in the required senior-level laboratory and design courses, and we have continued to concentrate on this integrated program the past three years. Although students in the unit operations laboratory course and the design course always have been required to present their work through either written or oral reports, simply requiring communication work does not necessarily help students communicate more effectively. Therefore, to supply focused instruction and feedback, we have employed a communication instructor (CI) (someone from the English Department, hired for a two-thirds time position) to help integrate communication training into these senior-level courses. As this article will explain, through their experience in these two courses the students not only practice writing and speaking through a series of assignments evaluated for communicative ability and technical content, but they also receive instruction on technical communication, they learn to revise and edit their work as well as

the work of their peers, and they gain experience in collaborative writing and speaking.

We have found that this integrative approach provides an opportunity for students to practice technical communication despite a tight curriculum which otherwise limited their communication work to a freshman rhetoric course. More importantly, though, it offers our students experience in writing and speaking within their own discipline.[2] Working on communication within a discipline provides students with professional experience and promotes learning through writing and speaking. Unlike technical communication courses where assignments may be artificially created for students to practice communicating, emphasizing communication in existing courses enables the students to use writing and speaking as tools for discovery. Research in the teaching of writing has also shown that students can learn material more fully through writing.[3] As C. W. Griffin points out, "We are beginning to realize that writing is not just the end product of learning; it is a process by which learning takes place."[4] Similarly, oral presentations can be approached as a learning tool. At Illinois, we are working to create opportunities for students to investigate and assimilate technical information through writing and speaking. When communication is approached as an integral part of the learning process, students start viewing it as an essential part of their work in engineering rather than as a chore which takes times away from learning technical material.

DESCRIPTION: COMMUNICATION COMPONENT

Unit Operations Laboratory Course

The communication component of the laboratory course includes instruction on writing and presenting experimental reports, a series of individual writing assignments, a revision exercise, and two oral presentations.

Course Description • Table 1 outlines the course requirements. The class is divided into lab sections of, at most, fifteen students. Each lab section is supervised by a graduate chemical engineering teaching assistant (TA) and meets in the lab for five hours per week. The oral presentations are held during the first hour of the lab period in a separate classroom, preferably equipped with an overhead projector. When the lab section is large (twelve to fifteen students), we divide the oral presentations into two rooms to save time. The professor and the TA then evaluate one set of talks each, and the CI rotates through the two rooms. Table 2 further outlines the required resources for the communication component in terms of teaching, space, and equipment.

TABLE 1
Course Descriptions

Course	Enrollment	Group Size	Assignments	Written Reports*	Oral Presentations*
Unit Operations	20-55 students	3-4 students	6 labs	4 minor (3-5 pp.) 2 major (8-10 pp.) 1 revision of 1st major	2 (15 minutes each)
Design	20-55 students	2-3 students	1 design project	2 preliminary (5 pp.) 1 final (20 pp.)	2 (10 minutes each) 1 (20 minutes)

**In the unit operations course the written and oral reports are prepared individually, whereas in the design course they are prepared in groups.*

TABLE 2
Required Resources for Addition of Communication Instruction

Course	Teaching Resources	Classroom Space	Equipment	Salaries
Unit Operations (50 students)	• One professor • One communication instructor • One 25% time TA per 15 students	• One laboratory and two seminar rooms for oral presentations	• One overhead projector per seminar room	• $6,000/academic year for 33% time communication instructor
Design (50 students)	• One professor • One communication instructor • One 25% time TA per 15 students	One classroom and one seminar room for oral presentations	• Two overhead projectors • Two videocameras • One VCR for viewing videos	• $6,000/academic year for 33% time communication instructor

All of the reports, including the revision, are graded for technical content by the TA or the professor, and the two major reports and the revision are graded by the CI as well. The oral presentations also are graded for both technical and communicative quality. In assessing the communicative quality for both written and oral reports, the CI emphasizes that successful expression of technical ideas requires more than good grammar skills or stylistic choices. Thus, the communication grades on the major reports and the revision are based primarily on the orga-

nization and use of the technical format; the writing style, grammar, spelling, and punctuation are checked but are not emphasized. The communication grade for the oral reports assesses the level of organization, the degree of preparation, and the presentation skills displayed. Altogether, the communication component comprises thirty percent of the grade for the course.

Throughout the semester the CI holds office hours, and students are encouraged to consult with the instructor individually, especially before revising their first major report. The CI also attends class and discusses how to prepare and organize written and oral reports, provides details on the technical format for written reports, and reviews stylistic concerns for technical writing. To provide further instruction on the technical format, the CI distributes a manual that details information about technical laboratory report writing. (This manual is written in the form of a technical report, so it provides an example of the technical-report format while also providing information about writing technical reports.)

Analysis of the Communication Component • Several attributes have contributed to the success of the communication component in the laboratory course. First, effective communication is approached as an integral and important part of the course. For some students, simply knowing that they will receive a communication grade encourages them to spend more time and effort in writing their reports and preparing their presentation.

Second, the course stresses that writing is a process rather than just a finished product to be evaluated. This approach is particularly emphasized through the revision exercise. After receiving substantial commentary from both the CI and the TA, the students are given two weeks to revise the report and resubmit it for technical and communication grades. The revision exercise gives the students a chance to apply feedback from written comments on their first draft, to recognize positive changes in their writing, and to learn how to improve their writing. In fact, in evaluating the revision process after the spring semester in 1992, ninety percent of the students surveyed noticed improvement in their second draft, half of them felt that their second draft showed "a lot" of improvement, and eighty percent indicated that the revision exercise helped them understand how to strengthen their writing.

An interesting student response to the revisions has been improved original drafts of the first major report. Many students are spending more time editing their first draft in an attempt to avoid significant revision. Ironically, these students are, in effect, completing multiple revision exercises. We find it encouraging to see students approach writing as a sequence of composing and editing stages since the editing and revision skills they are developing will undoubtedly prove useful to them in the future.

To incorporate further revision opportunities and to encourage individual contact with the CI during the writing process, we intend to hold office hours during the lab in a newly renovated Instructional Computer Lab (ICL) adjacent to the Unit Operations Laboratory. With lab sections scheduled for five hours and with, at most, twelve students per section, we can allot a portion of class time to writing conferences in the ICL, while the remainder of class time is spent taking data in the Unit Operations Lab.

Design Course

The communication component of the design course complements the communication work in the laboratory course. In particular, the design course places more emphasis on oral work and provides experience in collaborative writing.

Course Description • Table 1 also describes the requirements for the design course. The students collaborate on the written and oral reports and receive group grades on all work completed. The written and oral reports receive both a technical and a communication grade, with the communication grade comprising thirty percent of the group grade for each report and presentation. The CI also provides instruction on writing and presentation techniques, distributes a manual on the technical format for design reports, and shows a video of an oral presentation from a previous semester. The first set of oral presentations are videotaped, and the students are required to view and evaluate their own presentations. When the class is large (fifty students), we divide the students into two rooms for the oral presentations, to save class time. The professor then grades one group for technical quality and communication, and the CI and the TA evaluate the second group. In addition, the students evaluate each other during the oral presentations, using a peer-evaluation form. Table 2 further outlines the required resources for the design course.

Analysis of the Communication Component • Several aspects of the communication work in the design course have proven successful. First, we have found it useful to provide samples of both written and oral assignments at the beginning of the

course. The sample-report manuals, similar to the ones used in the lab course, are useful in helping students organize their reports. Over half of the students who seek individual help from the CI ask questions about organizing their report, and (especially in the design course) students often are unsure of what information to include and where to put it. Therefore, providing a standard to follow as a guideline has proven beneficial. Providing examples of professional design reports would also be useful, although we have not distributed such samples in the course thus far.

Similarly, the video shown at the beginning of the semester offers a more tangible guideline than can be explained in a lecture. This sample is not a "perfect" presentation (if one exists), but it demonstrates some good techniques to follow and some blunders to avoid when speaking. The video is shown after a lecture on preparing and organizing talks, and a discussion of the videotape follows its presentation. The video illustrates points introduced in the lecture (thereby setting a standard for class presentations), and the discussion gives students a lesson in peer evaluation. Throughout the remainder of the semester the students evaluate their classmates' oral presentations, using the form illustrated in Table 3. We purposely designed this form with only a few questions in order to give students more time to write comments. Even though peer evaluation is not a component of the grade, students have taken it seriously and have offered each other many helpful suggestions.

Videotaping the talks and requiring students to view and evaluate the videos has also been a successful exercise. For most students, especially those who have never seen themselves speak before, it is quite an eye-opener. Actually seeing their own difficulties and successes in speaking helps them identify areas which need improvement and gives them more confidence in their abilities. The students generally dislike watching themselves, but in the end admit that it was useful to them. Certainly, self-evaluation helps students prepare for their upcoming presentations; during the semesters when talks were videotaped and evaluated, the subsequent presentations showed great improvement.

Finally, the design course provides good experience in collaborative communication. Collaborative work, whether written or oral, has become increasingly common in the engineering professions. In the workplace, collaboration may involve working with others on research, or actually composing with others, or having others review and edit an already composed work, and the extent of collaboration varies according to the job and the specific group of people working together.[5] Thus, requiring students to collaborate on several stages of a large project—from planning to analysis and presentation—helps to develop essential organization, relational, and communication skills. A recent article on small-group interaction during writing projects noted that a well-written report "represents the team's successful working through of both small group and writing problems."[6]

Furthermore, collaboration teaches peer review. To aid the students, the CI discusses what to look for when editing others' writing and distributes a "Checklist for Collaborators."[7] (See Table 4.) According to a questionnaire distributed after the spring se-

TABLE 3
Oral Presentation Evaluation Form

Speaker _____

Place an X in the blank that represents your assessment of the category listed. Add some comments to explain your assessment. Then circle a number to represent an overall rating for the speaker. Write general comments at the bottom.

	Weak				Strong
1. Technical Content Relevance, clarity, technical competence **COMMENTS**	---	---	---	---	---
2. Planning Organization, transitions, continuity **COMMENTS**	---	---	---	---	---
3. Speaker's Manner Voice, eye contact, gestures, confidence **COMMENTS**	---	---	---	---	---
4. Visual Aids Visibility, simplicity appropriateness **COMMENTS**	---	---	---	---	---

Overall Rating (Circle) 1 2 3 4 5 6 7 8 9 10

Comments:

mester of 1992, when working in groups the students either split up the writing and then edited and proofread each other's sections, or they composed and revised together. Two-thirds of the respondents mentioned that they "revised," "edited," or "corrected" each other's work, indicating that they participated in peer review.

DISCUSSION OF THE INTEGRATIVE APPROACH

Through our experiences over the past three years we have discovered other successes and difficulties of integrating communication work into existing engineering courses. Certainly, one distinct attribute of our program is the opportunity to work with students in two separate courses. Since most of the students take the lab and design courses in the fall and spring of their senior year, they have two sequential semesters of intense communicative work. By the end of the second semester the CI has worked with each student on at least five written and two oral reports. To help facilitate connections between the courses, the CI also keeps a log of individual difficulties and progress to help students identify their specific strengths and weaknesses in writing and speaking.

Although the CI is integral to our program, we realize that hiring a person without a chemical engineering background creates too sharp a distinction between the technical and communicative elements of written and oral work. In reality, a well-written report or speech must be both technically correct and well composed; the two aspects cannot be separated. To a large extent, the existing division is lessened by the interactions between the CI, the professor, and the TA. To achieve successful results, the communication work must be approached as an integral part of the course material. The professor must emphasize the importance of the writing and speaking assignments, not only when designing the course but also when addressing the students. Likewise, since the TAs grade the reports, they also must keep in close contact with the CI to help maintain consistency. When the communication component is given adequate value and acknowledgment, we have found that the artificial division between communicative and technical elements can actually help the students recognize that outstanding technical knowledge means little if they cannot effectively communicate their knowledge.

A second difficulty in hiring a non-technical instructor is that some understanding of the material is necessary for a complete reading. Fortunately, since basically the same material is covered each semester, the CI can become familiar with it over the course of several semesters.

One benefit of involving a non-technical instructor is the opportunity it provides for students to communicate with someone who does not share their

TABLE 4
Checklist for Collaborators

Collaborative writing requires that you read and edit your peers' writing. Therefore, the following checklist is provided to help you identify areas which could be improved and revised in others' writing and in your own. Remember that revising takes time, and plan accordingly.

1. Check the overall organization of the draft.

- ☐ Is the content presented in appropriate places? (*e.g.*, A discussion of results does not belong in the introduction.)
- ☐ Are the points sequenced logically?
- ☐ Is enough information included for complete comprehension? (Could the writer delete some information?)
- ☐ Does the report live up to its promises (from the abstract/introduction)?
- ☐ Does the writer avoid unnecessary repetitions?
- ☐ Are there logical transitions between the paragraphs/sections?
- ☐ Do the headings/subheadings help articulate the structure of the text? (Could the report use some subheadings?)

2. Check the paragraphs.

- ☐ Do the paragraphs keep to one central idea?
- ☐ Do the paragraphs reflect a continuity of logic?
- ☐ Does the writer avoid contradictions within a paragraph?
- ☐ Are the paragraphs an appropriate length?

3. Check for style. Revise to make the language clear and direct.

- ☐ Does the writer follow these principles for clear writing? (These are principles, not rules; apply them judiciously.)
  - Keep sentences short and to the point
  - Vary the sentence length
  - Use simple words
  - Avoid indirect expressions
  - Use familiar words • Avoid jargon • Define terms
  - Avoid unnecessary words
  - Write to *express*, not to impress
- ☐ Does the writer follow these guidelines for using vigorous verbs?
  - Use as many active verbs as possible
  - Avoid nominalized verbs, or verbs trapped inside a noun
  - Look for words ending in *-ion, -ment, -ing, -al* which could be made into an active verb
  - Try to change sentences which use wordy verb constructions, such as *there, this, it, these,* combined with forms of the verb "to be."
  - Ask if the verb should be past or present. Generally, describe work done in the past tense, and state principles and conclusions in the present tense.

4. Check grammar, spelling, and punctuation.

- ☐ Are the grammar, spelling, and punctuation correct to the best of your knowledge?

technical background. Although the oral and written reports are addressed to a technical audience, when working individually with the CI the students must express technical ideas to a non-technical audience. This actually helps to develop a better understanding of the material and is a challenging communicative exercise in itself.

Finally, we recognize that integrating communication training into existing courses does not allow for as much instruction as could be offered in a separate communication course. There is not enough time to require helpful reading materials on speaking and writing, or to evaluate and discuss published articles, or to offer workshops on writing and speaking. Many students would benefit from more intense instruction—particularly on technical writing. But, acknowledging that good communication skills are never "learned" once and for all, we feel that by providing some limited instruction and significant practice and evaluation, we are at least helping students to improve their skills. As one student remarked, his writing improved partly "because [he was] actually writing for a change." An integrative approach is certainly a step in the right direction. We also still encourage students to take communication courses outside the department and to use campus resources such as the "Writer's Workshop," a writing tutorial center sponsored by the Center for Writing Studies.

As we work to provide our students with better communication skills, we must remember that developing expertise in writing and speaking is a lifelong process. Integrating communication training into existing chemical engineering courses may not be extensive enough for some students, but it does provide a significant amount of practice in both speaking and writing, leaving students with some professional experience and, hopefully, with an awareness of the value of communication.

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7. Some of the ideas for this checklist were adapted from Clark, David G., and Donald E. Zimmerman, *The Random House Guide to Technical and Scientific Communication,* Random House, New York, Chap. 10 (1987) ❐

Process Control Lab Course

Continued from page 187.

The last experiment in the second phase is called "Hardware." In it, the students are required to study the features of Metrabyte cards such as DAS-8, DAC-02, DDA-06, PIO-12, and to hard-wire a data acquisition system for monitoring temperature in six polymer reactors with different initiators or different initiator concentrations. A multiplexer board (Metrabyte EXP-16) is used to connect the different thermocouples. The students thus learn about multiplexers, thermocouples (how the cold junction is set up on the EXP-16), A/D converters, D/A converters, electro-pneumatic transducers, and other important features in data acquisition and digital control. The reaction is then started, and the students monitor the temperature change in each reactor simultaneously. The students study the effect of changing sampling rate on data acquisition since six different temperatures are monitored simultaneously.

CONCLUSIONS

These six laboratory experiments are an effective supplement to classroom lectures. Students gain hands-on experience in controller tuning, data acquisition, and control. Various process control concepts are emphasized, and the students develop a thorough understanding of the practical meaning of the concepts. The laboratory sessions cover almost all the topics discussed in class except certain advanced control strategies such as feedforward control or cascade control. Some of the available computer simulation packages are used to illustrate a few of these advanced control strategies. Interested readers may obtain complete information on the equipment or writeups of the experiment by contacting the author. ❐