AC 2007-221: DEVELOPING COMMUNICATION COMPETENCE: A COMPARISON OF THE INTENSIVE CAPSTONE EXPERIENCE AND DEVELOPMENTAL INTEGRATION

April Kedrowicz, University of Utah

April A. Kedrowicz, Ph.D., is the Director of the Center for Engineering Leadership at the University of Utah. Dr. Kedrowicz received her BA and MS degrees in Organizational Communication from the University of Wisconsin-Stevens Point, and her Ph.D. in Communication from the University of Utah.

Developing Communication Competence: Assessment of the Intensive Capstone Experience and Incremental Integration

Introduction

With the advent of ABET's EC 2000, much focus has been placed on equipping engineering students with the necessary professional skills to be effective in the workplace.[1-3] As such, research highlights various approaches to teaching students how to communicate (write, speak, and work in teams) effectively.[4-5] One primary method through which to facilitate communication skill development includes an emphasis on integrating communication into an introductory and/or capstone engineering course. [6-8] While this approach to teaching technical communication to engineering students does in fact meet the objectives of EC 2000, concentrating the development of communication competence in a capstone course is inadequate. That is, in order for engineering students to be professionally as well as technically competent, they must be continually exposed to communication integration in the classroom throughout their student career.

The CLEAR (Communication, Leadership, Ethics, And Research) approach to improving engineering education involves integrated and developmental communication instruction, through collaboration between the Colleges of Humanities and Engineering. The goal is to prepare engineering undergraduates to occupy positions of leadership in organizations through improving their oral and written communication, teamwork skills, and ethical understanding. This college-wide program is integrated, in that students learn these professional skills in their required, core engineering courses. Further, the program is developmental in that students are exposed to basic level skills in the freshman year and gradually progress to sophisticated skills at the senior level. In other words, rather than teach students formal and informal communication skills in a required technical communication course, we teach students *through* and *about* communication in their engineering courses. This not only enables students to learn discipline-specific knowledge, it also facilitates learning of engineering material through speaking and writing about current engineering topics. The advantages of this program are numerous, including: 1) improving students' communication (oral, written, and interpersonal) and thus, satisfying ABET's call for improved undergraduate engineering education; 2) enhancing students' learning of the engineering material; 3) teaching students about the discipline of engineering and the communication conventions associated with it; 4) demonstrating the interconnectedness of communication and engineering; 5) socializing students (i.e., preparing them to be engineering professionals); and 6) fostering relationships across colleges.

This college-wide initiative is made possible through a grant from the William and Flora Hewlett Foundation, as well as contributions from both the Colleges of Humanities and Engineering. The structure is such that graduate students from Communication and the University Writing program work with engineering faculty to (re)design curriculum, lecture, provide individual assistance to students, and provide evaluations of students' communication performance. This interdisciplinary partnership is effective because both engineering and communication expertise is represented. Although the exact structure varies from department to department dependent upon the uniqueness of the curriculum, all departments utilize this integrated approach and partner with College of Humanities' representatives to teach students communication while teaching engineering. This instills that engineering and communication are inextricably linked. In other words, to be a "good" engineer, you must know more than technical information and computer programs. We teach students that in addition to the technical competencies required, they must also know how to communicate.

While the CLEAR continuous, integrated approach appears successful, it is an innovative program, and as such, there is little research on how this approach specifically influences student performance. The purpose of this paper is to describe and assess two distinct, integrated approaches to communication instruction. Specifically, students' writing improvement is assessed over time in two separate engineering departments that utilize two different instructional approaches: (1) the intensive, two-semester capstone experience in chemical engineering and (2) the incremental, integrated approach in mechanical engineering. As previously mentioned, CLEAR communication instruction varies by department throughout the college, with most departments utilizing an incremental, four-year approach to instruction. However, the Chemical Engineering Department's curriculum constraints demand that communication instruction occur during the senior capstone course. As such, these two different approaches to the development of communication competence are utilized and assessed. Implications of these findings to student learning and professional socialization are discussed.

Chemical Engineering Intensive Capstone Experience

Communication instruction in the Chemical Engineering Department takes place largely in the senior projects lab sequence. Students are briefly introduced to the importance of communication to engineering in the freshman class and receive minimal instruction in writing in a junior class. This takes the form of one lecture on the basics of technical writing. If students choose, they can receive in-depth feedback on their writing in the form of a one-on-one consultation with the CLEAR writing instructor. Few students take advantage of this. As a result, the bulk of students' oral communication, teamwork, and writing instruction occurs in the senior lab. This two-semester sequence emphasizes the "experimental and theoretical solution of realistic problems in heat transfer, fluid flow, mass transfer, chemical-reaction kinetics, and process control by use of semi-industrial-scale and bench-scale equipment."

The writing, oral communication, and teamwork instruction is intense during these two semesters (see Appendix A for a list of communication objectives developed for the Chemical Engineering Department). The Fall semester course, Projects Lab I, emphasizes teamwork in the lab (conducting experiments), two writing assignments (a formal report and a letter report), and one oral report based on one of the experimental procedures the students complete. To prepare students for this work, four lectures are devoted to speaking, writing, and teaming instruction. Students are provided with written feedback on both reports and can rewrite the reports for extra credit. One-on-one consultations are not required in this course, but students can voluntarily seek additional help. The students' oral reports are videotaped and feedback is provided immediately following the presentation.

In the Spring semester, students continue working in the lab in Projects Lab II, a course which fulfills the upper division communication and writing requirement of the university. In this course, students write an individual formal report, a team proposal, and a team final report. They also present an individual oral proposal on a topic of interest in chemical engineering. Three class sessions are devoted to the teaching of relevant communication concepts. In addition, students' formal reports are peer reviewed and student teams are required to meet with the writing instructor to receive detailed feedback on the team formal report. Finally, students review their videotaped presentations from the Fall semester and are required to meet for a rehearsal session with the oral communication instructor prior to delivering their oral proposal in class.

In summary, chemical engineering students receive intensive communication instruction during their two semester senior projects lab sequence. They write a variety of documents, both individually and as a team, and practice their informative and persuasive speaking both individually and as a team. It is hoped that this intensive instruction will prepare students for the types of writing and speaking they will encounter in the workplace.

Mechanical Engineering Four-Year Plan

Communication instruction takes place in three required, core Mechanical Engineering (ME EN) courses, as well as throughout the junior level lab sequence. The oral and written communication and teamwork (interpersonal communication) instruction varies from course to course and builds on the professional competencies learned in the previous years. Table 1 highlights the collaboration in Mechanical Engineering.

*Mechanical Engineering 1000 – Design and Visualization***.** This freshman course exposes students to the engineering design process and the use of visualization in engineering design, including sketching, engineering drawing, and computer-aided design. Students work in teams to complete a competitive design project covering all aspects of the design process, from problem definition and creativity to construction and testing. Because this is a large lecture course with approximately 150 students enrolled in Fall and 75 in Spring, the lab sections enable small group instruction on formal presentations and writing performance. In addition to the technical course objectives, students will speak, write, and work in teams effectively, and communicate professionally upon completion of this course. See Appendix B for the list of communication objectives to be realized upon completion of ME EN 1000, as well as the other mechanical engineering courses.

Students work toward accomplishing these objectives through completing several specific assignments. Teams write five memos, one conceptual design description, and one final design review. In addition, teams prepare and deliver two design presentations. Students are prepared to complete these assignments due to the six lecture sessions devoted to writing, speaking, and teamwork.

In short, ME EN 1000 teaches students that the engineering design process is encompassed by communication. Students, while working on their designs, are communicating about and during the process, both informally and formally.

Year	Course	Theme	Concepts	Skills/Techniques
Freshman	ME EN 1000: Design and Visualization	Description and Information	Linear Model Collaborative Writing Team Dynamics	Organization Technical Voice Visual Layout
Sophomore	ME EN 2000: Manufacturing	Persuasion	Constructionist Model Writing/Problem Solving Team Decision Making	Audience Adaptation Warrants/Evidence Persuasive Structure
Junior	ME EN 3200/3210: Mechatronics	Interpersonal and Organizational Communication	Conflict Resolution Leadership and Power	Negotiation Conflict Management
Senior	ME EN 3910/4000: Engineering Design	Evaluation	Critical Thinking	Listening Consensus

Table 1. Mechanical Engineering Four-Year Plan

Mechanical Engineering 2000 – Manufacturing. Mechanical Engineering 2000 builds upon the principles learned at the freshman level. Students move from description and information to persuasion. This course teaches students about the structure and properties of ferrous and nonferrous materials, casting, forging, welding, heat treating, machining, grinding, numerical control, robotics, and economic analysis. While learning this information, students are again required to work in teams to complete a semester-long project. Although not strictly competition based, as in ME EN 1000, student teams develop a new manufacturing process or product and "pitch" this idea to the management of a small manufacturing firm currently producing small, machined components for various local firms. Students are told that the firm currently has some manual lathes and mills. The business has been stagnating, and the owners have received a source of funding (approx. $ 0.7 million) and they would like to investigate a business investment that will bring in new profits to the company. The firm is trying to evaluate design and manufacturing of new, exciting products. Students are required to complete an oral and written proposal. The oral proposal includes justification of proposed process or product, manufacturing process plan, design changes, economic analysis, equipment, etc. The written proposal clearly and comprehensively presents the proposed solution/initiative. This proposal outlines all necessary technical information on the proposed changes.

To prepare students for this task, four lecture sessions are devoted to instruction in oral and written proposals, team writing, and conflict management. In addition to the proposal writing, presentation, and conflict resolution emphasis, students also complete their first peer review session during class. That is, students are required to bring in a draft of their proposal and exchange it with another student. They then critique each other's writing, thus facilitating a feedback session, but also developing students' writing skills through the exercise of this critical review of writing.

*Junior Level Mechanical Engineering Lab Courses***.** The emphasis in the junior lab courses (including Mechatronics, Strength of Materials, Thermodynamics, Fluid Dynamics, and Heat Transfer) is on developing students' individual writing abilities. As a result, students write several lab memos throughout the year-long lab sequences in accordance with departmental writing standards. The emphasis is on quality and not quantity. So, students write fewer lab memos, but the expectation is that the memos they do write will be continually improved and polished. With the knowledge of and feedback on their writing from the freshman and sophomore courses, students are pushed to further refine and develop their technical writing skills through the writing of lab memos. Students receive feedback on their writing from the course professor, engineering teaching assistants, and communication instructors.

*Mechanical Engineering 3910/4000 – Senior Design Sequence***.** The senior design sequence is a two semester sequence beginning with ME EN 3910. In this course, lectures and group projects lead to the team project proposal including problem identification and definition, team organization, background research, idea generation techniques, needs analysis, scheduling, and budgeting. This culminates in a formal written document outlining the capstone project proposal. This course presents the opportunity for instruction in résumés and cover letters, such that students have to "apply" to be on a project. Students are instructed in the appropriate format to use for these documents, as well as stylistic considerations, and the appropriate content to include. These are reviewed by both the communication instructor and the course professor. Because many of the projects require large sums of money, students often have to engage in fundraising to meet the budgetary requirements for project completion. As a result, the teams make presentations to university organizations (i.e., student government), as well as external funding agencies.

With the semester devoted to design methodology and project selection and proposal behind them, the students begin to work on their project during the second semester in ME EN 4000. The class consists of lectures and team assignments leading to the completion of the detailed design phase including: concept generation and selection, detailed engineering design, application of machine elements, prototype testing, engineering analysis, parameter design, and preliminary economic analyses. This course culminates in design review based on formal presentations of fully documented, detailed engineering drawings of proposed designs and alpha prototype demonstrations. In short, students work on their projects, write update memos and give update presentations approximately once a month. In addition, teams learn about critical and evaluative listening and providing constructive criticism orally and in writing to peers.

In short, the Mechanical Engineering Department's four-year communication plan is integrated and developmental. Students are taught that engineering and communication are inextricably linked. In other words, just as calculus, excel, and pro-engineer are necessary "tools" for engineers, so too, is communication competence. Through teaching students the necessary communication skills beginning in the freshman class and progressing gradually to the senior class, they develop a sophisticated understanding of the oral, written, and interpersonal communication competencies necessary for effective professional development.

Assessment of Instructional Approaches

While the effectiveness of this interdisciplinary, collaborative program is known anecdotally, it is important to assess students' communication competence. As such, students' proficiency in speaking and writing is tracked and assessed. For the purpose of this paper, students' improvement in team writing was assessed to determine the degree of improvement that resulted from CLEAR instruction, and to loosely infer if one instructional approach is more effective than the other. Specifically, two genres of writing (memos and technical reports) were evaluated at two different points in time to demonstrate improvement in students' writing as a result of CLEAR collaboration. The data were analyzed using SPSS. An independent sample t-test was performed and a standard alpha level of $p < .05$ was used to determine if any statistically significant improvements were made.

Chemical Engineering Writing Assessment. Two sets of final team reports (N=9) written by chemical engineering seniors comprise the data sets for the assessment of written final reports. The first data set includes reports written in Chemical Engineering 4903 in Fall 2003, our first semester working with this department. The second data set includes final reports written in Chemical Engineering 4903 in Fall 2005. Although these are both senior classes, students should show improvement in Fall 2005, since CLEAR collaboration and writing instruction had been taking place in other lower division classes for two years.

The data were coded according to seven writing characteristics central to engineering student education with respect to report writing: (a) Genre Considerations; (b) Visuals or the ability to translate concepts into effective pictorials and incorporate them into the text appropriately; (c) Language; (d) Structure; (e) Overall Completeness of the report; (f) Overall Quality; and (g) Overall Readability/Usability. (Note: Each category with the exceptions of "Overall completeness," "overall quality," and "overall readability" contained several subcategories and thus, means reported total more than 5.) Tables 2 and 3 illustrate the 2003 (pre-instruction) and 2005 (post-instruction) data comparison.

The data illustrate general improvement over time (with one exception), with four categories showing statistically significant improvement. Students' incorporation of visuals did not improve, thus demonstrating that greater emphasis must be placed on teaching students how to incorporate graphs, charts, etc. to pictorially reinforce the message in the text. In addition, no significant improvement was shown with respect to structure or overall completeness. The data are encouraging and point to the importance of communication instruction early and often, something that we are still formulating in this department due to unique curricular constraints.

Mechanical Engineering Writing Assessment. Two sets of memos written by mechanical engineering student teams comprise the data sets for the assessment of memo writing. The first data set includes memos written in Mechanical Engineering 1000 in Fall 2004 (N=9). The second data set includes memos written in Mechanical Engineering 4000 in Fall 2005 (N=9). Although these data sets are only one year apart, points of comparison will allude to any significant changes, since the Mechanical Engineering 4000 students have spent two years working with CLEAR courses, whereas the Mechanical Engineering 1000 students are learning how to write memos for the first time.

	Pre-instruction Mean	Pre-instruction Std. Dev.	Post-instruction Mean	Post-instruction Std. Dev.
Genre (55 points)	46.89	4.26	51.13	3.09
Visuals (15 points)	14.00	1.32	13.75	1.83
Language (20 points)	17.00	1.73	19.50	0.76
Structure (20 points)	18.89	1.62	19.88	0.35
Completeness (5 points)	4.33	0.70	4.88	0.35
Quality (5 points)	4.11	0.78	4.88	0.35
Readability (5 points)	4.00	0.87	4.75	0.46

Table 2. Pre-instruction and post-instruction data comparison by mean and standard deviation

	Pre-instruction Mean	Post-instruction Mean	t-value
Genre	46.89	51.13	.035*
Visuals	14.00	13.75	.749
Language	17.00	19.50	.002*
Structure	18.89	19.88	.113
Completeness	4.33	4.88	.069
Quality	4.11	4.88	.023*
Readability	4.00	4.75	.045*

Table 3. Pre-instruction and post-instruction data comparison by mean and t-value

The data were coded according to six writing characteristics central to engineering student education in mechanical engineering: (a) Genre Considerations or the ability to include information pertinent to a memo; (b) Format or the ability to follow prescribed standards for memo formatting; (c) Language or the ability to effectively communicate with respect to grammar and mechanics, parallel structure, conciseness, specificity, and clarity; (d) Structure or the ability to logically and effectively organize the memo; (e) Overall Quality; and (f) Overall Readability/Usability. (Note: All categories with the exceptions of "overall quality" and "overall readability" contained subcategories and thus means reported total more than 5.) Tables 4 and 5 illustrate the 2004 (Freshman) and 2005 (Senior) data comparison.

The data show that statistically significant improvement occurred when comparing the senior students to the freshman students in all categories except language. This illustrates a need for greater attention to teaching students how to be specific and clear, while also being concise. Another possibility is that greater emphasis must be placed on the importance of proofreading.

	Freshman Mean	Freshman Std. Dev.	Senior Mean	Senior Std. Dev.
Genre (25 points)	10.89	5.20	15.33	3.40
Format (15 points)	12.67	1.25	14.39	0.65
Language (20 points)	14.72	2.54	16.11	1.76
Structure (15 points)	7.39	2.04	12.17	2.14
Quality (5 points)	2.06	1.07	3.78	0.44
Readability (5 points)	2.50	0.79	3.83	0.43

Table 4. Freshman and Senior data comparison by mean and standard deviation

	Freshman Mean	Senior Mean	t-value
Genre	10.89	15.33	.048*
Format	12.67	14.39	.002*
Language	14.72	16.11	.196
Structure	7.39	12.17	.000**
Quality	2.06	3.78	.000**
Readability	2.50	3.83	.000**

Table 5. Freshman and Senior data comparison by mean and t-values

Comparison of Assessment Data. Although both data sets demonstrated statistically significant improvement in writing after CLEAR instruction, the mechanical engineering students showed improvement in more categories that were significant at the $p < .000$ level. In other words, mechanical engineering students showed greater improvement in more areas related to their writing. From this, it can be loosely inferred that the developmental, four-year plan does more for the improvement of student writing than the intensive senior capstone experience. This area warrants further exploration.

Conclusions

The assessment data shows that CLEAR collaboration has resulted in student improvement in writing when utilizing both the intensive senior capstone model and the integrated, developmental four-year plan. These results are promising for the future of CLEAR collaboration. What is perhaps more interesting, however, is that student improvement was greater and occurred in more ways when utilizing the four-year plan. This suggests that communication instruction is best integrated into several courses throughout students' academic careers. Not only are students exposed to a variety of writing and speaking genres, they are also taught that communication and engineering are inextricably linked. By presenting the requisite communication instruction necessary for engineering students' professional development in small, manageable pieces over time, students are better able to enhance their communication competence.

Acknowledgments

The author would like to thank the William and Flora Hewlett Foundation for continued support of this program, as well as College of Engineering faculty for their willingness to collaborate and experiment in the classroom.

Bibliography

1. Bjorkland, S. A. and Colbeck, C. L., "The View from the Top: Leaders' Perspectives on a Decade of Change in Engineering Education," *Journal of Engineering Education,* Vol. 90, 2001, pp. 13-19.

2. Evans, D.L., Beakley, G. C., Crouch, P. E., and Yamaguchi, G. T., "Attributes of Engineering Graduates and their Impact on Curriculum Design," *Journal of Engineering Education,* Vol. 82, 1993, pp. 203-211.

3. Katz, S.M., "The Entry-Level Engineer: Problems in Transition from Student to Professional," *Journal of Engineering Education,* Vol. 82, 1993, pp.171-173.

4. Ford, J. D. & Riley, L. A., "Integrating Communication and Engineering Education: A Look at Curricula, Courses, and Support Systems," *Journal of Engineering Education,* Vol. 92, 2003, pp. 325-328.

5. Reave, L., "Technical Communication Instruction in Engineering Schools: A Survey of Top-Ranked U.S. and Canadian Programs," *Journal of Business and Technical Communication*, Vol. 18, 2004, pp. 452 – 490.

6. Terry, J., Ruchhoeft, P., Bannerot, R., & Kaster, R., "A Just-In-Time Model for Teaching Technical Communciations in a Multidisciplnary Capstone Design Course," *ASEE Conference Proceedings, 2004,* session 2661.

7. Norback, J. S., Sokol, J. S., Forehand, G. A., & Sutley-Fish, B., "Using a Communication Lab to Integrate Workplace Communication into Senior Design," *ASEE Conference Proceedings, 2004,* Session 3157.

8. Crain, G. E., & Tull, M. P., "A Capstone Course Targeting Industry Transition," *ASEE Conference Proceedings, 2004,* Session 1325.

Appendix A
Learning Objectives for Communication and Teamwork in Chemical Engineering

Writing to Learn (objectives to be met primarily in lecture-based, quantitative courses, up through the junior year)

1. Write clear, precise, quantitative descriptions of procedures, data, results, principles, concepts, theories, and ideas.
2. Write comparisons that identify key similarities and differences between procedures, data, results, principles, concepts, theories, and ideas.
3. Write clear interpretations of results based on accepted scientific, statistical, and engineering principles.
4. Identify and summarize key ideas and critical points within a body of work; critically analyze these in writing.

Writing to Communicate (objectives to be met primarily in lab-based courses, largely in the senior year)

5. Develop and write a clear, technical story that shows a logical and persuasive progression from the project objectives to the final project conclusions.
6. Produce, as individuals and in teams, clean, professional documents that follow an assigned format.
7. Choose a style and tone that are appropriate for the audience and purpose.
8. Write with a clear understanding of the ethics of writing so that citations are provided, data are not selectively chosen, and other viewpoints are acknowledged.
9. Write a technical paper such that it would b3e acceptable in a professional journal.

Oral Communication

Students graduating in Chemical Engineering will be able to:
1. Define the objectives for a talk.
2. Organize a presentation to support the objectives.
3. Develop strategies to ensure effective delivery.
4. Design clear and appropriate visual materials.
5. Design a talk for an audience
6. Clearly explain technical concepts.
7. Exhibit effective listening and evaluation skills.
8. Design a persuasive presentation with attention to arguments and evidence.
9. Create and deliver a talk such that it would be acceptable at a professional meeting.

Appendix B
Mechanical Engineering Communication Objectives by Year

ME EN 1000

Upon completion of this course, students will:

1) Write effectively
    a) Write memos appropriately with attention to the format
    b) Understand the logic and organization of memos, conceptual design descriptions, and technical design reviews
    c) Write in a technical voice
    d) Demonstrate critical thinking of their design

2) Speak effectively
    a) Organize an informative technical presentation
    b) Outline an informative technical presentation
    c) Exhibit competent vocal and physical delivery skills
    d) Design effective and appropriate slides including attention to language, illustrations, and layout

3) Work in teams effectively
    a) Understand basic team dynamics including roles, norms, cohesiveness, and groupthink
    b) Exhibit effective listening skills
    c) Understand and exhibit individual responsibility for team success and/or failure

4) Communicate professionally
    a) Exhibit professionalism in e-mail and telephone contact
    b) Engage in effective communication during review sessions, office hours, meetings, and all other face-to-face communication with faculty and staff
    c) Recognize the importance of feedback and incorporate constructive criticism

ME EN 2000

Upon completion of this course, students will:

1) Write effectively
    a) Understand how writing as a team is different from writing individually
    b) Write a team document
    c) Adapt technical information to different audiences (technical and non-technical)
    d) Understand the purpose, logic, and organization of proposals
    e) Write a proposal appropriately with attention to format, structure, supporting materials (logical appeals), and style
    f) Write concisely

2) Speak effectively
  a) Organize and outline a persuasive technical presentation
  b) Understand the importance of audience analysis and strategies for reaching a diverse audience
  c) Adapt technical information to different audiences (technical and non-technical)
  d) Understand and apply three logical appeals to persuasive presentation

3) Work in teams effectively
  a) Understand the benefits of inter-team conflict
  b) Understand the various tactics and specific strategies to employ to resolve dysfunctional inter-team conflict

ME EN 3200/3210

Upon completion of this course, students will:

1) Communicate effectively
  a) Understand how to design a poster with attention to visual communication principles
  b) Understand how to use a poster during this informal type presentation
  c) Understand how to use a poster during a question and answer session

2) Work in teams effectively
  a) Understand how to facilitate productive meetings

ME EN Junior Labs

Upon completion of this course, students will:

1) Write effectively
  a) Understand how to write a technical lab memo
  b) Understand and utilize a technical voice
  c) Understand how to demonstrate critical thinking

ME EN 3910

Upon completion of this course, students will:

1) Write effectively
  a) Write effective résumés and cover letters
  b) Write an effective design proposal

2) Speak effectively
  a) Understand how to prepare and deliver a presentation to solicit funds from donors

ME EN 4000

Upon completion of this course, students will:

1) Communicate effectively
   a) Understand how to organize a project update presentation
   b) Provide constructive criticism orally to peers upon completion of their project update
   c) Receive and implement constructive criticism