Development of Communication Skills Across the Engineering Curriculum

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Abstract

The ability to communicate effectively has been identified as an important attribute of a well-rounded engineering graduate. We have identified four major areas of emphasis in the ME curriculum: written, oral, graphical and electronic communication. An across-the-curriculum approach is taken whereby each of these is introduced early on and then reinforced throughout the curriculum through a variety of different experiences. This paper describes the methods used to develop students' abilities in each of these areas, the ways in which each of these areas are incorporated and integrated vertically into the ME curriculum.

Introduction

Over the past several years the goals of engineering education have expanded to include emphasis on non-technical attributes that complement a strong technical foundation to produce a well-rounded engineering graduate. These include communication skills, the ability to function in teams, knowledge of societal and contemporary issues, development of global perspective, and ethics awareness. Some have referred to these as "soft" skills. This characterization is misleading though, implying that these abilities are secondary to or more easily developed than "hard" technical expertise. On the contrary, a great importance of these abilities to engineering education has emerged over the last decade[1] and ABET Engineering Criteria 2000 has targeted many of these as essential program outcomes in order for engineering programs to be accredited. It is probably more appropriate to refer to these as contextual and process skills, the term used by the National Advisory Council[1], in its report "Engineering Education for a Changing World." Co-chair of this council and former Martin Marietta CEO Norman Augustine coined the term Socioengineering[2] that sought to describe the combination of the contextual and process skills with the elements of traditional engineering education, all seen critical for success in the twenty-first century. In particular, he cited the lack of the ability of engineers to communicate effectively as the greatest shortcoming in current engineering education. Geppert[3] contends that the ability of engineers to communicate effectively has always been important to industry and academia but it matters even more today because of the growing complexity of systems and the cross-disciplinary-team approach to engineering.

Consequently, many engineering programs are now addressing the issue of communication. There are a variety of ways to teach students about communication. One method is to offer a formal semester long course (or courses) on communication (see for example Friauf and McGeen[4]). These types of courses are taught primarily by faculty in communications

departments who work closely with engineering faculty. Another model is to integrate communication skills into the existing courses into the curriculum, such as writing or oral communication across the curriculum[5,6,7]. This latter approach was recommended for communication skills as well as for the other contextual and process abilities[1]. Regardless of the method, it is believed that development of effective communication skills in students requires that they exercise these skills frequently and receive constructive feedback.

In the mid 1990's a major effort was taken to redesign the undergraduate mechanical engineering curriculum at Union College. A mission statement was developed along with program objectives and specified student outcomes. In the fall of 1996 a significantly new curriculum was introduced. This curriculum maintains a strong emphasis on fundamentals and is reinforced by significant laboratory, design, and research experiences for the students. In addition, other components were added to the curriculum that addressed the need to provide a better societal and global context. These include a required international experiential component, liberal arts courses and a recommended minor in the liberal arts and emphasis throughout the curriculum on developing the ability to communicate effectively.

With respect to communication skills, we use an "across-the-curriculum approach" in which these skills are introduced and practiced within the existing engineering and General Education courses in the curriculum, as opposed to a concentrated communications course taught or co-taught by faculty from the humanities. In our approach, ME faculty are responsible for a significant part of the instruction in communication skills, particularly in the technical areas. Having ME faculty provide instruction and then evaluate student performance in these areas, we believe, has a positive effect, showing the students, by example, the importance of developing these skills even for professionals who work in highly technical areas. Students also develop communication skills in non-technical areas through their required courses in the General Education Curriculum. This is done within the context of existing courses in areas such as literature, civilization, and social sciences taught by liberal arts faculty.

We have identified four major areas of emphasis: written, oral, electronic, and graphical communication. Each of these is introduced and then reinforced throughout the curriculum, through a variety of different experiences. This paper describes the methods used to develop students' abilities in each of these areas, the ways in which each of these areas are incorporated and integrated vertically into the ME curriculum.

Written Communication

This section describes the different forms of writing and how it is integrated into the ME curriculum. There is a significant amount of writing in the ME curriculum. This is due, in part, to a College-wide writing requirement. All students in the College must satisfy a Writing-Across-the Curriculum (WAC) requirement in order to graduate. There are three main components to this program that all students must complete: 1) the First-Year Preceptorial; 2) five WAC-certified courses; and 3) a senior writing experience. The five WAC courses must come from two of the three possible areas that include science and engineering, social sciences,

or humanities. These courses are within the normal disciplinary offerings and have writing built in as an important and clearly evaluated part of the coursework.

The typical course approved for WAC credit has three to five writing assignments that receive written faculty response. The kinds of assignments vary greatly depending on the discipline. They could take the form of expository essays, creative writings, journals, logs, lab reports legal briefs, summaries or problem sets. Depending on the length and number of assignments, faculty might also consider the value of peer critiques, and group or individual conferences to improve student writing. Faculty submit proposals to a Writing Board to have their courses certified as WAC courses. They must have their courses recertified periodically. Certification is for both the course and for the faculty. Each faculty teaching a given course must apply for and receive certification. With respect to the overall WAC requirement, the current ME curriculum has several WAC-certified courses with the senior project satisfying the senior writing experience requirement.

The College supports the writing activities by maintaining a Writing Center. This center is staffed by student writing consultants. The student tutors are available to help writers in getting started, writing drafts, and final editing -- in academic and nonacademic writing tasks. Upon recommendation by faculty, the Writing Center hires some engineering students who can serve as consultants for technical writing.

We feel it is important for students to have a broad exposure to different types of writing. Students practice technical as well as non-technical writing. The technical writing comes in the engineering courses and is accomplished through lab reports, design reports, and design notebooks. Most of the courses in the ME curriculum have attached to them either a laboratory or a design studio. These serve as the forum for most of the technical writing done in the curriculum. Non-technical writing is done primarily in the humanities and social science courses taken as part of the General Education Curriculum.

In the laboratories of the ME courses, a variety of formats are specified for use by the students in communicating the laboratory results. These include written reports, oral presentations, and electronic submissions. Guidelines are established for these reports by each professor. For the written forms we use full laboratory reports and memo reports. It is important for engineers to practice both types of formats. As Levitt[8] notes, sometimes it is important for engineers to communicate effectively with managers by communicating like managers, using brief concise language with decisive conclusions. Consequently the memo format provides for this type of interaction. Full reports are typically 5-10 pages in length and include an abstract and a detailed description of background, theory, procedures, results, discussion, conclusion, and appendixes. Memo reports are usually 1-2 pages and include a condensed description of what was done and the key findings. These different forms of reports are introduced and used in the sophomore year in the introductory mechanics course and then used subsequently in rest of the sophomore courses – materials science and strength of materials, and then in the junior level thermal-fluid courses – fluid mechanics and heat transfer. The faculty go over detailed guidelines about how to prepare these different types of reports. Both types of report are graded on the basis of the

content as well as the writing. In some cases, students are permitted to do rewrites and make corrections and improvements for additional credit.

ME students have several design experiences throughout the curriculum. Many of these require them to prepare written design reports. Most of the projects involve teams. Therefore preparation of the reports requires a coordinated effort among the team members. Instruction in writing design reports begins in the introductory engineering course taken in the first trimester of the freshman year. Students are taught about design reports, and then must do one for the team design project in the course. Design report writing is practiced again in a term design project in the sophomore level mechanics course and in the junior level advanced dynamics and kinematics course. These experiences in the first three years prepare the students for the two senior capstone design courses: one in mechanical design and one in thermal fluid design. The mechanical design course involves a large team project in which subgroups of the large team must write interim progress reports and then the team must submit a detailed design report to the faculty and to the industrial sponsor. In the thermal fluid design course, smaller teams of 4-5 students work on 4-5 different projects and submit team design reports for each of the projects to the faculty.

The design projects also require the students to maintain individual design notebooks to document their work. The concept of design notebooks is introduced in the freshman engineering course. The importance of documenting one's work is emphasized. Foley[9] provides a nice description of design notebook guidelines. The notebooks are collected at the end of the project and graded. Bulleit[10] indicates that design notebooks help students develop time management skills.

For all of the technical writing components, significant feedback is given. In the lower level courses very detailed grading sheets are used by the faculty. These show the evaluation of different specific aspects of the writing. The grading sheets are distributed to the students in the lower level courses before they write the lab report. An example of a grading sheet from our sophomore level mechanics course is attached in Appendix A. Note the detailed level of grading criterion given to the students to help them write their lab reports. As the students progress to upper level courses, the grading sheets are less detailed. In Appendix B we have included a grading sheet from a junior level heat transfer course. In the junior level courses the grading sheets are not distributed before the students write up the lab but are instead used as a feedback mechanism.

Non-technical writing is done primarily in the humanities and social science courses taken as part of the General Education Curriculum. Some is also done as part of the senior seminar in Mechanical Engineering. One of the topics covered in this seminar is engineering ethics and decision-making. The students are required to write an essay on one of a number of case studies examined, such as the Challenger Accident or the case of the Citicorp tower.

Another objective of the ME program, discussed earlier, was to provide the students with a global perspective and an appreciation of other cultures. Beginning in 1996, all ME students (and all engineering students) were required to fulfill an international component of the

curriculum. There are many options to fulfilling this requirement but the overwhelming majority of these involves studying or working for a significant period in a foreign country. This part of the program is described in detail by Wilk et. al.[11]. Approximately 90% of ME students participate in international study, in one of a number of different programs throughout the world. Each of the programs has a limited number of openings, so the selection process is competitive across campus and the application process involves a few different components used to select participants. One of these involves a written essay by the student explaining why they would like to participate in a program in a specific country. The academic advisors are available to help the students refine their essay. The students can also consult with the tutors in the Writing Center. The essays are evaluated by a committee comprised mostly of faculty in the humanities. The essay is an important deciding factor in determining which students get selected. It is important for engineering students to effectively communicate their ideas in this essay, especially since they are often mostly competing with liberal arts students for a limited number of openings in each Term Abroad program.

Additional non-technical writing is done in the required history, literature and civilization courses in the General Education Curriculum. Engineering students are often in these classes with mostly liberal arts students and are held to the same high standards in the area of writing.

The final writing experiences in the curriculum surround the senior project. The senior project is the cornerstone of our program. It is a required two-term (with optional third term) experience where students complete an engineering project. The experience is designed to be flexible, and can be based on the individual student's personal interest and goals. Students may choose to work on a design-oriented project or on a research-oriented project. The design projects typically involve students working individually or in small teams designing, building and testing mechanical components, devices or systems. Since ABET-required capstone design is covered in the design courses, the senior project does not necessarily have to focus on design. Therefore the research projects typically involve individual students working closely with a faculty member (on occasion these are team projects). The project topic is generally related to the faculty member's research but not exclusively. However, the focus is more on "research" i.e. learning something new, than it is on design.

Students choose a project at the end of their junior year and submit a formal written proposal to the department for approval. Formal instruction in proposal writing is covered in the early weeks of the senior seminar (which actually begins in the spring term of the junior year and continues through the senior year). Students are required to keep a laboratory/design notebook (journal) that is available for review by the department; to apply for internal funding for the project if necessary; submit a written progress report at the end of the first term and a final report at the end of the second term to department chair and project advisor. Students who are eligible for honors must also complete a thesis based on their senior project.

Oral Communication

We do not offer any formal courses on public speaking at Union College but instead believe that giving students the opportunity to speak in public (with appropriate feedback) is the best way to

teach them. Therefore we have designed our curriculum to provide many and varied speaking opportunities for students. These start in the freshman year and continuing through the senior year.

Mechanical Engineering students make a number of formal and informal oral presentations during their career at Union College. By design, these presentations tend to be short and focused in the freshman year and they become more open ended and of longer duration by the senior year. A number of oral presentations are required as part of a course, however the department also strongly encourages students to participate in outside speaking events. Students make a number of presentations as a member of a team of students and they also give individual presentations.

In the freshman engineering course year all students are required to make short ten to fifteen minute presentations related to the course design project. In groups of three they present their final design to a panel of (3-4) faculty member and are required to defend their design. Students are given some instruction on giving oral presentations. The students perform a similar presentation in the sophomore level mechanics course which also includes a design project. In this case the presentations are made to the professor and the entire mechanics class.

In the junior year ME students start giving longer, more technically oriented presentations. In the fluid mechanics course and the heat transfer course they make a 15 minute group presentation on the results of a laboratory experiment. The presentations are made to the professor and the class. The presentations are videotaped and students are required to review and critique their presentations. In the Advanced Dynamics and Kinematics course they make design project presentations.

Oral design presentations are used in the two senior design capstone courses in mechanical design and thermal fluid design. In the mechanical design course they work in large team (8-10 students) on a project and are required to make a series of oral presentations on the design to department faculty or outside reviewers from industry. In the thermal fluids design course they work in smaller teams of 4 to 5 students on 4-5 different projects. Each team makes a 20 minute project oral presentation at the end of each of the projects. In addition to these two capstone courses the students do a two or three term senior design or research project. At the end of each term they make a 10-15 minute individual oral presentation on the project to the department faculty and students.

In addition to the formal in class presentations our students have many opportunities to make a non-course related oral presentations. The Mechanical Engineering Department has a strong summer undergraduate research program and at the end of the summer (or start of the fall term) all summer students make a 10-15 minute presentation to the faculty and senior class on their summer research. Every spring Union College celebrates its commitment to Undergraduate Research with a campus wide Steinmetz symposium. In general about 75% of the ME students make 15 minute presentations at this symposium. In addition several ME students attend the National Conference on Undergraduate Research where they make an oral presentation. To be eligible for honors in Mechanical Engineering our seniors are required to compete in a spring

term speaking contest and the top two speakers are sent to compete in the ASME Speaking Competition at the Regional Student Conference. We have had 2 regional winners in the past 6 years who have gone on to compete at the National Old Guard competition held annually at the ASME International Mechanical Engineering Conference and Exposition.

Students also make presentations on their term abroad experiences. In the fall term of their junior year a majority of our students go on a term abroad. When the return they make presentations on their term abroad experience to the department faculty and ME sophomores who are trying to plan their own term abroad.

We encourage students to attend and critique outside presentations. Several of the faculty in the department require students to attend 4-5 talks at the Steinmetz symposium and write a critique of each. In addition we run a senior seminar program and bring in outside speakers from industry and academia.

In the first two years we use only informal feedback to the students on their oral presentation techniques. All are given some general tips on public speaking but the goal in the first two years is to get them used to making oral presentations. In the junior year we tape the oral presentations and have the students perform self-evaluations on their speaking style. This has proven to be one of the most effective ways of helping students with their oral presentation skills. In the senior design courses the student presentations are evaluated by their peers and by the professor. Each group is given feedback on their presentation that focuses primarily on organization and content. Faculty work one-on- one with students as they prepare their senior project presentations and provide critique on organization as well as presentation skills.

In an informal survey of our current senior class the students reported giving on average 20 oral presentations at Union with more than 50% of those presentations being over 10 minutes long. They also report that most of these (approximately 90%) presentations were given in their engineering courses. All report that the experiences have improved their public speaking skills.

Electronic Communication

Electronic communication skills take the form of using email, course web pages, student web pages, project web pages, using the web to find information. Almost all students at Union (or anywhere) arrive knowing how to use email. Email is used extensively for communicating between students and course instructors in most of the Mechanical Engineering courses. As a small residential private college we actively encourage students to come to our offices for help. We do not, by design, use blackboard type on-line forums and discussion groups. However, some faculty use email office hours in the evenings when off campus.

Most of the ME courses have web pages which students access for homework assignments, homework solutions and course schedules.

Students are required to maintain web pages for their senior project. They must use the web page to report project progress and publish their final report. In the junior level fluid mechanics course students make a web page and use it to report progress on a 3 week lab exercise and present their final results. Some faculty members have also experimented with electronic submission of lab reports.

At Union we also run an International Virtual Design Studio (IVDS) project. Students are teamed up with students at the Middle East Technical University in Ankara Turkey and complete a design project. Much of the communication between the team members is done over the internet using email and chat rooms and exchanging image and text files.

Graphical Communication

Instruction in graphical communication includes proper techniques of drawing and sketching, graphical, and tabular presentation of data, and work schedules, and formal training in CAD. These are all presented in the freshman year and then used subsequently in the upper level courses. Graphical and tabular presentation of data, Gantt Charts for scheduling projects, and Pugh Charts for design selection are covered in the freshman engineering course. An engineering graphics course taken in the freshman year presents the principles of technical drawing and introduces the fundamentals of 3D modeling through the use of the CAD package SolidWorks. The topics covered in this course include: multiview sketching, orthogonal, sectional, and auxiliary views, projections, assembly drawings, drawings standards, manufacturing processes, design for manufacture and assembly, dimensioning, tolerancing and fits. Students are fully expected to prepare detailed CAD drawings when applicable in subsequent design courses. All parts made in machine shop for senior project and other design projects require a CAD drawing that is checked, and signed off by the faculty advisor.

Assessment of Communication Skills

As part of the assessment plan developed for ABET EC 2000, several performance criteria were developed for evaluating achievement of outcome 3g, the ability to communicate effectively (oral, written, graphical, electronic). Appendix C. presents the current performance criteria used, lists the assessment method used to measure the attainment of that performance criteria, and results from the class of 2000. Feedback from the students and alumni (items 10 and 11 in Appendix C) is one of the major sources of data for assessment. The class of 2000 was the first graduating class to go through the new curriculum (in which this extensive across-the-curriculum approach to teaching communication skills was implemented). Therefore no alumni data is available yet. We plan to survey that class in our alumni survey going out this year.

Summary and Conclusion

The ability to communicate effectively has been identified as an important attribute of a well-rounded engineering graduate and is a major student outcome from our program. We have identified four major areas of emphasis in the ME curriculum: written, oral, electronic and graphical communication. An across-the-curriculum approach is taken whereby each of these

types of communication is introduced early on and then reinforced throughout the curriculum through a variety of different experiences. Students work to achieve this outcome by completing the Union College Writing Across the Curriculum (WAC) requirement, giving formal oral presentations before an audience, writing essays, term papers, lab reports, research reports, design reports, proposals and progress reports, technical papers; conveying information graphically such as creating formal technical drawings; communicating information via email, obtaining information from the worldwide web and creating their own web page. Appendix D. presents a summary of the curricular components used throughout the engineering part of the curriculum to reinforce the different types of communication skills.

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Appendix A: Lower level grading sheet (Mechanics I course)

Particle Kinematics and Kinetics Lab

CATEGORY	POSSIBLE POINTS	EARNED POINTS
TECHNICAL EVALUATION		
Title Page Was it included? Was all of the requisite information present?	2	
Introduction Was it included? Did it properly introduce the lab? Was the objective stated? Was the Method of the report forecasted?	7	
Experimental Procedures Was the cannon used in this portion of the experiment described? Was a figure of the cannon included? Were the projectiles described? Was the experimental procedure used to determine the exit velocity of the two projectiles at the three settings explained in detail? Was the experimental procedure used to calculate the maximum horizontal distance traveled by the projectiles explained? Was a figure illustrating the experimental configuration included?	20	
Results Were the equations of motion developed for the exit velocity determination? Were the free-body and mass-acceleration diagrams included and properly labeled? Was a table containing the measured values of the exit velocity included? Were the equations of motion developed for the determination of the maximum horizontal distance traveled included? Was the free-body and mass-acceleration diagrams included and properly labeled? Was a table containing the theoretical and experimental values of the maximum distance traveled included? Was the determination of the setting which would land the ball in the basket discussed and were these results discussed?	25	
Discussion Were the experimental results for the exit velocity of the projectiles discussed? Were the experimental results for the maximum distance traveled compared to the theoretical results? Were the errors between the experimental and theoretical results explained? Were any other interesting points about the outcome of the lab discussed? Were summary figures used? Were the results for the steel and nylon projectiles compared and discussed?	25	
Summary Was the objective of the laboratory restated? Were the main results of the lab summarized? Were recommendations made? Does it concisely summarize the lab?	7	
Acknowledgments and References	2	
WRITING EVALUATION		
Organization	4	
Presentation	4	
Grammar and Spelling	4	
TOTAL	100	

Comments:

Appendix B: Upper level grading sheet (Heat Transfer course)

Turbine Blade Cooling Lab

CATEGORY		Pts	Comments
TECHNICAL EVALUATION			
Abstract Was it included? Does it provide a brief summary of the lab? Are the main findings stated?	10		
Introduction Was it included? Does is state the purpose of the lab? Does is provide other introductory information? Does it forecast the rest of the report?	10		
Procedure Was it included and correctly explained? Was the model properly described?	10		
Results Gird Optimization Effect of cooling Flow Rate (h) Effect of Cooling Hole	 10 10 10		
Discussion Were the results discussed and interpreted? Did the student clearly understand the lab?	15		
Conclusion Was it included? Did it summarize the lab? Were any recommendations made?	5		
WRITING EVALUATION			
Organization and Presentation	10		
Grammar and spelling	10		
TOTAL	**100**		

Comments:

Appendix C: Performance criteria, assessment method and results for EC 2000 Outcome 3g.

OUTCOME g **The ability to communicate effectively (oral, written, graphical, electronic). (ABET EC2000 Criterion 3g).** Performance Criteria and (Assessment Method Used to Measure Attainment of Performance Criteria):	**RESULTS**
1. 100% of the students satisfy Union WAC (Writing Across the Curriculum) requirement (Degree Audit).	1. 100% of graduates satisfied Union College Writing Across the Curriculum requirement.
2. 100% of students create and maintain a web page for their senior project (MEAC Audit).	2. 100% of graduates created a web page for their senior project.
3. 30% of students participate in Steinmetz or NCUR or other professional conferences (Senior Exit Survey).	3. 50% of graduates participated (presented papers) in the Steinmetz Symposium, NCUR, or other professional conference.
4. 100% of students make at least 10 (5 min or longer) oral presentations (Degree Audit).	4. 100% of students achieved this.
5. 100% of students write at least 10 (5 page or longer) written reports (MEAC Audit of Course information, WAC courses).	5. 100% of students achieved this.
6. 100% of students prepare formal technical drawings using a CAD package as part of senior project (or a course) (MEAC Audit of senior project reports, course information).	6. 100% of graduates achieved this.
7. 100% of students will demonstrate that they can send and receive email.	7. 100% of graduates achieved this.
8. The department will continue its participation in ASME speaking contest (MEAC Audit using information from ASME Faculty Advisor).	8. ME department continues participation (hosted conference in 2001).
9. 100% of the students who do a co-op will be rated at least very good by their employer in both written and oral communication (Employer Co-op Survey).	9. 100% (2/2) rated either excellent or very good in oral communication.
10. 90% of the respondents on the senior exit survey indicate they have achieved this	10. 64% of respondents agreed and 36% agreed somewhat with the statement: “I am able to

outcome (Senior Exit Survey). 10. continued	communicate in writing to a variety of audiences." 79% of respondents agreed and 21% agreed somewhat with the statement: "I am able to make effective oral presentations to a variety of audiences." 79% of respondents agreed and 21% agreed somewhat with the statement: "I am comfortable expressing my views and questioning others in a group discussion situation." 86% of respondents agreed and 7% agreed somewhat with the statement: "I am comfortable communicating electronically/ email) with a variety of audiences." (7% no response.) 64% of respondents agreed, 21% agreed somewhat and 15% were neutral with respect to the comment: "I am able to create a web page for a specific purpose. 64% of respondents agreed, 15% agreed somewhat and 21% were neutral with respect to the comment: "I am proficient with at least one CAD application package."
11. 90% of the respondents on the senior exit survey indicate they have achieved this outcome (Senior Exit Survey).	11. N/A for year 2000, 2001 graduates.

* MEAC = Mechanical Engineering Assessment Coordinator

Appendix D: A summary of the curricular components used throughout the engineering part of the curriculum to reinforce the different types of communication skills.

	Written	**Oral**	**Electronic**	**Graphical**
Year 1	design notebook, design report	short design presentation	email, course web pages	Excel, CAD and graphics introduction, SolidWorks, Gantt chart, Pugh chart
Year 2	short summary lab reports, full lab reports	short design presentation	email, course web pages	SolidWorks design project; plotting data, curvefitting for lab assignments
Year 3	memos and full lab reports, senior project proposal	long lab presentation, design presentation	email, course web pages, student-developed web page for lab	SolidWorks, COSMOS, StarCD, plotting data, curvefitting for lab assignments
Year 4	design reports, senior project reports, ethics paper, design notebooks, lab notebooks	long design presentation, senior project progress report and final presentations	email, course web pages, student-developed senior project web page	Drawings for senior project using SolidWorks (required).