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# Infusing Technical Communication and Teamwork within the ECE Curriculum

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**Abstract**

*This paper highlights a unique approach to infusing formal training and practice in oral and written communication and teamwork development in the Department of Electrical and Computer Engineering (ECE) at the University of Utah. Faculty and graduate (Ph.D.) students from the College of Humanities have teamed up with faculty from engineering to develop communication and teamwork instruction that is integrated into the existing engineering curriculum. These skills are used as a vehicle to provide better understanding of engineering concepts and their applications.*

## 1. Introduction

Electrical and computer engineering programs are notoriously packed with technical courses, and professors feel strained to cover necessary material in the allotted time. The program may already feel full to bursting, yet today there are many additional demands from industry and accreditation boards to improve students' abilities in oral and written communication and teamwork. Adding additional courses in technical writing or speaking is often seen as the solution to this dilemma, but these courses often lack the direct application to the students' engineering experiences and the ability to track and improve over time. This paper describes a new program in the Department of Electrical and Computer Engineering at the University of Utah to infuse writing, speaking, and teamwork experiences throughout the ECE curriculum as alternatives and reinforcements to the standard "lecture" pedagogy. As such, they are not simply "writing experiences," but rather are used as alternative methods to teach engineering concepts. Students apply communication formats to learn electrical engineering.

This "write/speak to learn" concept applied in a team-oriented environment has been shown to be effective in standard courses [1] . This paper describes 1) how this concept is applied in a full ECE curriculum, 2) the interface of communication professionals with engineering professors, and 3) methods to assess student learning and program outcomes. This effort is part of a 3 year department-level curriculum reform initiative to convert existing required and elective laboratory experiences into project-based designs that span individual courses, multiple courses, multiple years, and in some cases multiple disciplines [2]. These projects are naturally team-oriented, and the writing and speaking experiences have been found to be excellent formats for enhancing student understanding of their coursework and projects.

## 2. Communication Education in Engineering

As students make the transition from student to professional, they are faced with many demands. What is becoming increasingly obvious is that technical ability is necessary for successful transition from school to work, but professional development skills (sometimes referred to as "soft" engineering skills) such as communication and teamwork are needed as well. As a result, engineering educators have had to rethink their approach to education in order to equip students with the necessary professional skills to be effective in industry. As a consequence of the new demands emphasizing professional skill development, engineering educators have made significant changes in engineering curriculum. In addition, a more active, student-centered framework in undergraduate education has "fueled new curricular experiments on many campuses" [3]. As part of these new curricular developments and the kind of "questions that surface from a more scholarly approach to teaching and learning" [3], there has been an increased focus on "communication in the disciplines" activities. While there seems to be a unified call for communication integration in engineering curriculum, what communication is, and how it should be taught in the engineering classroom are not as easily agreed upon. In order to prepare engineering students for their future as professionals, several approaches to teaching have been employed. These include requiring completion of a technical writing course, participation in writing/speaking across the curriculum programs, integrated communication/engineering courses, and integrated communication/engineering programs [4].

Perhaps one of the earliest actions taken in response to the criticism that engineers are poor writers was the addition of a required technical writing course. That is, engineering students in addition to taking the required math, science, and engineering courses, were required to take a technical writing course, usually offered through an English or Communication department. Students in these courses found themselves learning the basics of technical writing with a business focus, along side students from disciplines all across campus. Though a good starting point, one general course in technical writing does little to improve engineering students' appreciation for the various forms their technical writing will take, and does even less for improvement of their speaking abilities [4].

A second approach is exemplified by writing/speaking across the curriculum programs. These programs move beyond the technical writing course requirement to a more specific approach, whereby writing and speaking assignments are developed specifically for the engineering curriculum and are incorporated into various courses. Students in these courses are writing and speaking about and in relation to their engineering tasks, thus gaining practical communication skills and producing documents for various purposes and audiences [4].

Integrated communication/engineering courses represent a third approach. These are often a part of, or result of successful writing/speaking across the curriculum programs and include a partnership between engineering faculty and faculty from other departments that emphasize speaking and writing, such as English, Technical Communication, or Communication. Finally, integrated communication/engineering programs, though rare at this point, offer minors in communication-related fields, or certificate programs in technical communication, for example [4].

In addition to the aforementioned approaches, many universities also have writing/speaking/communication centers that serve to provide individual tutoring to engineering students working on writing or speaking assignments. Most also offer resources to faculty and students alike, including tips on how to complete a writing or speaking assignment, as well as tips on how to evaluate said assignments [4].

More and more, engineering programs are moving toward interdisciplinary collaboration in the form of integration, whether it be courses, programs, or somewhere in between. Reave (2004) suggests that when communication is not integrated throughout an engineering education, it is perceived as a "basic-level skill by professors, administrators, and students." Furthermore, current engineering teaching and curricula teaches students that communication is separate from engineering or, at the very least that communication only occurs upon completion of a project; consequently, students fail to recognize communication as an integral part of engineering. Thus, integration does more than teach students about communication; it teaches students through and about communication, enhances student understanding of coursework, and begins to socialize them into the culture of professional engineering.

## 2.1. Speak and Write to Learn: Active Learning in Electrical and Computer Engineering

In addition to the need for improved engineering undergraduates' communication and teamwork skills, students benefit from programs that encourage them to be active, lifelong learners. In 1998, The Boyer Commission [5] issued a troubling report with data indicating undergraduates in one course after another, "listen, transcribe, absorb, and repeat." In other words, students are trained as passive rather than active learners. If the end purpose of students' education is the ability to act independently—to construct and contribute new knowledge—then knowledge accumulation alone is not sufficient. A transformation is occurring in education that shifts the onus of student learning from the teacher to the student. Active learning (sometimes called student-centered learning) motivates students, emphasizes higher order thinking skills [6] (i.e., Bloom's taxonomy), and maximizes learning [7] one of the basic premises of infusing communication and teamwork skill education throughout the curriculum is to use these professional skills to more actively engage and involve students in the technical aspects of their education. This "write to learn" or "speak to learn" approach requires students to specifically synthesize what they are learning in order to explain it. Thus, the primary goal of this program is to provide a higher level understanding of the technical topics. The secondary outcome of this active learning approach is an increase in students' communication competence, one of the objectives of the Accreditation Board for Engineering and Technology's Engineering Criteria 2000 [8].

This philosophy of teaching and learning draws from constructivism and situated learning. At a basic level, learning is an active process. Students are actively engaged in the construction of knowledge through the sharing, using, and testing of ideas and skills. Several principles of learning guide constructivist thinking. First, learning is an active process whereby the learner is engaged with the world, rather than a passive acceptor of knowledge that exists "out there." Second, people "learn to learn" as they learn. That is, as meanings are constructed, students are better able to give meanings to other sensory inputs that fit similar patterns. Third, the action of meaning making happens in the mind. Fourth, learning involves language, such that language facilitates learning. Learning is a social activity, whereby learning is tied to connections with others including family, friends, peers, teachers, casual acquaintances, etc. Thus, interaction with others and the application of knowledge are integral. Sixth, learning is contextual. Information is not learned in isolation. Students learn in relationship to what they already know, as well as what they believe and value. Seventh, knowledge is necessary in order to learn. In order to assimilate new knowledge, one needs a structure of developed knowledge on which to build. So, in essence, the more one knows, the more one can learn. In order to teach, then, one must consider the learner's previous knowledge, and learning takes time. Learners need time to ponder ideas, use, and revisit them. Learning is the product of repeated exposure and thought. Finally, motivation is essential for learning. That is, learners need to know why something is being learned; that is, they need to know the ways in which knowledge can be used.

Active learning encourages students to take responsibility for their learning through actively engaging the material being taught. In contrast to traditional lecturing and note taking, students engaged in active learning practices must "do" something with the material being taught. That is, they must speak (ask and answer questions, lead discussions, explain homework problems, give presentations), write (keep learning journals, write in-class responses, prepare formal reports or proposals), and collaborate with team members (work together on an assignments or projects). Through actively engaging the material students develop a deeper understanding of the engineering material and are better able to apply and critically evaluate information. A secondary advantage is the development of communication competence. In short, through active learning, emphasizing the understanding of engineering through speaking, writing, and teaming, students learn *through* as well as *about* communication.

## 3. The Center for Engineering Leadership (CLEAR)

Currently, we are applying constructivism and engaging in student-centered, active learning in the Electrical and Computer Engineering Department at the University of Utah to enhance students' learning of both technical and professional development skills. The Center for Engineering Leadership (CLEAR) in the College of Engineering at the University of Utah is an interdisciplinary collaboration between the College of Humanities, and the College of Engineering that fosters active learning of engineering material through speaking, writing, and teaming. In addition, CLEAR seeks to prepare engineering students to occupy positions of leadership, which require well developed interpersonal, oral, and written communication abilities. CLEAR also addresses ethical issues for engineers working in an increasingly technologically dependent and complex world where knowledge is applied to highly constrained problems affecting diverse interest groups with different values. CLEAR seeks to teach communication skills, foster ethical understanding, and expose students to the dynamics of teamwork (problem solving, conflict resolution, listening, accountability, etc.) in an effort to enhance their leadership potential, while simultaneously fostering a deep understanding of engineering material.

In contrast to other communication/engineering partnerships, the CLEAR program is unique in that communication instruction is conducted by graduate (Ph.D.) students (CLEAR consultants) from the Department of Communication and University Writing Program in the engineering classroom. Not only are these consultants actively involved in teaching the engineering students about communication and teamwork, they are in a sense educating engineering faculty throughout this process. In this model, CLEAR consultants utilize small blocks of time (15-30 minutes) a few times throughout the semester to teach students about a specific communication concept (such as how to write a good introduction for a lab report, properly reference background work, prepare a team work plan, or how to prepare a talk for a specific type of audience). Students then apply this concept immediately to engineering tasks already being taught in the course (system design, engineering documentation, defense of concepts, etc.). CLEAR consultants and the engineering professor work together to provide assessment and feedback on the student work, often through guided peer evaluation. This situated approach gives students' the opportunity to apply communication skills in context. This method also facilitates understanding of technical material at a higher level as students are required to explain it to their peers or other audiences. This integrated approach to teaching through and about communication is applied in at least one required engineering course in each year, freshman through senior. Each year focuses on a progressively higher level communication and thought process, emphasized in various courses as shown in Table 1.

The CLEAR center provides a framework for integration within a large curriculum involving multiple professors over multiple years. It facilitates continuity even as the professors and consultants change. Communication and coordination has been an important initial responsibility of the Center, in order to ensure that the program is indeed implemented across the curriculum as planned.

## 4. Speaking and Writing Infusion in the ECE Curriculum

The advantages of infusing communication and teamwork education throughout the ECE curriculum are numerous and include the following: 1) students learn technical knowledge through communication and teamwork instruction; 2) students gain context-specific professional knowledge including appropriate genres of speaking and writing; 3) students are not burdened with additional general education courses; 4) students learn about the conditions for applying knowledge; 5) students are more likely to engage in invention and problem solving; 6) students see the implications of knowledge; and 7) students are supported in structuring knowledge in ways appropriate to later use as a result of working with that knowledge in context.

Perhaps the most common reason faculty indicated for not including additional writing assignments in their classes or not raising their expectations on the writing assignments already given (such as lab reports) was the onus of grading them. The most common reason for not including speaking assignments was not seeing how they could be used, an unwillingness to allocate class time for them, and not knowing specifically what oral skills to teach or how to teach them. These limitations were addressed through incorporation of the CLEAR center. CLEAR consultants in concert with ECE faculty developed a four-year curricular plan for the integration of oral and written communication components into the appropriate, existing ECE required courses. The consultants move between courses as needed, providing either short (15 minute) or long (full lecture) teaching segments on the specific skills desired. The CLEAR consultants also assist with student assessment (both peer and individual evaluation), follow up, and out of class assistance. In very large classes (all of the classes described below) the consultants help to train the teaching assistants to provide effective assignment grading. This reduces faculty workload and ensures consistency and quality teaching of communication skills throughout the curriculum.

The four-year plan is structured around the incremental development of technical communication competencies as shown in Table 1. To enhance this development, students at the first year level work on description and explanation. They are asked to address questions such as how and why concepts and experiments work. During the second year, students increase these initial questioning skills and work toward more complex analysis and synthesis (i.e., they should ask and answer such questions as: What does this work suggest? How does it clarify previous knowledge? Do I understand it similarly or differently from my peers or from professional engineers?) Third year students learn persuasion techniques and how to evaluate evidence, including both how evidence is constructed in the engineering field and how credibly that evidence is presented. What is most or least convincing? What supports, contradicts, or complicates given evidence? Finally, fourth year students "practice the profession." They are encouraged to work more intensively in teams and they employ all previously developed skills in order to create formal presentations and documents geared toward professional industry standards.

**Table 1.** Theme-based communication curriculum.

| Year | Theme | Course(s) |
|---|---|---|
| 1 (Freshman) | Description and Explanation | ECE 1000: Introduction to Electrical Engineering |
| 2 (Sophomore) | Analysis/Synthesis | ECE 2100: Fundamentals of Engineering Electronics |
| 3 (Junior) | Evidence/Persuasion/Credibility | ECE 3300: Introduction to Electromagnetics<br>ECE 3500: Introduction to Signals and Systems<br>ECE 3530: Engineering Probability and Statistics<br>ECE 3700: Fundamentals of Digital System Design<br>ECE 3910: Prethesis<br>ECE 3920,3930: Business of Engineering |
| 4 (Senior) | Professional Practice | ECE 4910,4920: Senior Capstone Design Project |

The framework used to design, construct, and evaluate oral communication objectives is derived from a five-year qualitative study of the University of Utah's Mechanical Engineering program. From an analysis of faculty lectures, course instructor evaluations, student presentations, and course materials from a senior design series, Dannels (2002) identified five features of "speaking like an engineer" (p. 259). Effective technical and professional presentations are simple, persuasive (they sell an idea), numerically rich, results-oriented, and visually sophisticated [9]. This framework was tested at Purdue University in Spring semester of 2004 with CLEAR consultant Damon Hall's design of three sections of a junior-level advanced public speaking course (COM 315) for technology majors.

Research by scholars such as Langer and Applebee, Flower and Hayes, and Bereiter and Scardamalia indicates that "carefully crafted writing assignments engage higher order thinking skills, allowing students to move beyond mere knowledge and comprehension skills into application, analysis, synthesis, and evaluation" [10]. Consequently, write-to-learn activities, inquiry-based processes [11], and active learning theorems inform the writing objectives employed in the program. These concepts, both theoretically and practically, place students at the center of their own learning and thinking. When such is the case, students are able to produce documents more characteristic of those required in the engineering industry. These objectives and theories, considered standard in the fields of education and composition [12,13], have proved effective in courses developed at such institutions as Harvard [14], Clemson [15], and Georgia Institute of Technology [16]. Additionally, Professional Development Instructor Sundy Watanabe found such methods highly beneficial for courses she developed at Weber State University (2000-2004), including specialized courses for Hill Air Force Base employees.

The four-year curriculum plan is outlined on the ECE webpage [17] with examples of assignments below.

## 4.1. Freshman Level: Basic Oral Presentations and Written Documents

- Speech organization, experience, and numerical richness

- Written summaries, descriptions, observations, and questions

Lab Derivation Presentations and Write-to-Learn Activities (ECE 1000: Introduction to Electrical Engineering):

The first two semesters of the engineering core courses incorporate speaking and writing assignments into laboratory sections consisting of a familiar audience of 12-18 peers and a teaching assistant. During the weekly lab lecture, students utilize lab notebooks to write brief paragraphs summarizing the concept or process being discussed (circuit problems, solutions, Matlab$^R$ codes) and describing their observations and questions. The following week, three to five student presenters relay the previous week's information in a five minute talk using the dry-erase board. It is the first technical, numerically rich presentation that they will give as engineers. It is also the first time students learn the importance of audience adaptation, as their audience is familiar with the material and must be convinced to be interested. They may also be critical if the student makes technical mistakes. As many of the students will not have previous experience writing or presenting at the college level, the assignment is evaluated as credit/no credit—similar to most first public speaking or writing assignments. The students give one presentation per semester and complete written speaker evaluations to offer immediate peer feedback. The process of evaluating their peers also improves their future presentations, as they become sensitized to the techniques that make presentations effective.

### 4.2. Sophomore Level: Advanced Oral Presentations and Written Documents

- Results-oriented, verbal explanation to a non-technical audience using visual aids
- Lab Reports, Presentation Proposal and Evaluation Memo

Laboratory Reports (ECE 2000: Fundamentals of Electric Circuits)

Students were introduced to lab notebooks during their first year course work, and they are now introduced to informal lab reports during their second. The CLEAR consultant, in short segments throughout the semester, explains each lab report section (i.e. introduction, methods and procedures, conclusion) and provides written instructions and examples, thus training students to write that particular portion. For each section, students follow a process of write-to-learn, draft, receive peer and consultant feedback, revise, and finalize the written document. The section for which students have received formal instruction and feedback is the only section that receives a grade for writing. As teaching assistants must grade the final document, and it is understood that form (writing) and content (engineering concepts) cannot be evaluated separately, the consultant works with the teaching assistants to develop criteria by which to asses the report holistically. By the end of the semester, students should be able to construct a complete lab report according to engineering standards.

"How it Works" Presentation and Accompanying Proposal and Memo (ECE 2100: Fundamentals of Engineering Electronics):

Students complete process steps that result in two written documents and one final oral presentation delivered in the laboratory setting. The individual, five minute presentation must include an explanation of the application, a summary of how that application works, a description of its significance in real world terms, and a schematic. The objective is to communicate an understanding of the material and to maintain audience interest; therefore, presenters must be able to field follow-up questions and comments.

Students begin the writing process by researching an electronic component and finding an application of interest (often a system) that contains the component. They then draft a proposal indicating the nature of their final oral presentation and a prose outline of the same. They send the written draft via email attachment to the consultant who makes comments to guide their revision process. Finally, they deliver the revised version of the proposal to the instructor, who approves it or suggests additional changes. Final written documents are evaluated on the basis of criteria determined collaboratively by students, teaching assistants, the consultant, and the instructor.

Students prepare to deliver their presentation by attending a practice session with the oral communication consultant. During the presentation, the speaker is evaluated by peers and teaching assistants, according to the five competencies of a technical presentation. After presenting, students collect the peer evaluations in order to analyze and synthesize the comments in a memo written to the instructor. In the memo, the student must evaluate his/her individual process and performance.

As presentations and written documents are initially evaluated by teaching assistants, these teaching assistants are required to attend a two-hour training session covering the fundamentals of assessing presentations and written documents.

### 4.3. Junior Level: Presenting Ideas and Creating Documents with Purpose

- Persuasive group presentations through creative problem solving, utilizing visual aids, and explaining complex concepts
- Rhetorically credible documents containing evidence, interpretation, and critical evaluation

Radio Frequency Safety Group Presentation and Brief Talking Paper (ECE 3300: Introduction to Electromagnetics)

Students conduct general audience research (newspapers, magazines, textbooks, and internet) in order to create a brief "Talking Paper" that leads to a three-five minute oral presentation. Both brief and presentation are tailored for a non-technical, impromptu audience. The topic for the research and presentation is any issue of public concern surrounding radio frequency safety. Students address pertinent questions such as: Are cell phones safe? and Is it dangerous to live near high voltage power lines?

The timing of the assignment, before Thanksgiving or spring break, offers opportunities for students to wrap up research details, write their brief, and present their information to their family members as representative of a non-technical audience. This exercise serves to help students receive important feedback; additionally, it serves as a public relations tool, communicating to the student's family the nature and application of the technical information being learned, and thus demonstrating a return on educational investment.

After the break, the lecture class ($\sim$80 students) divides into small groups ($\sim$11 groups with $\sim$7 students per group). First, students in the group quickly and informally deliver their "family" speeches to one another, using their written briefs as talking points. Second, they draw an "audience" from a hat of various potential audiences, to whom they must deliver the information. Such audiences might consist of a lawyer trying to sue a company, a 10 year old, or a new cell phone user considering moving into a home under high voltage lines. The groups are then given 3 minutes to create a new presentation, adapted to their new audience. In those three minutes, they must synthesize their original individual information into one collective whole and problem-solve to prioritize points for the most effective delivery. Finally, the speech is delivered by the group, or by a designated group member, to the class. The class, instructor, consultants, and teaching assistants provide feedback (oral and/or written) on the effectiveness of the presentation as determined by audience. Individual written briefs are collected by the consultant for comments relevant to research writing.

Assignments such as this demonstrate the practical application of newly acquired theoretical know-how to a public audience. This "in-class" practice models reality, in that safety concerns are always ripe topics for conversation, both for the non-technical public and the expert engineer. The assignment also teaches students how to analyze and determine what information is relevant for a specific audience and the importance of adapting it to that immediate audience.

Bandwidth Allocation Design Project (ECE 3500: Signals and Systems)

A brief, spontaneous, brainstorming session with the authors of this paper resulted in an effective assignment designed to address three realities. First, a professor of a traditional lecture course ($\sim$80 students) was frustrated with his students not fully appreciating the significance of a theoretical concept relevant to his course: bandwidth allocation as it applies to society. Second, the professor knew that speaking and writing to learn would encourage higher level thinking skills, such as creativity, and would help students understand concepts better. Third, the professor was leaving for a conference and had three "open" lecture days which could be used to convey the importance of this concept.

Given the need to address such realities, the professor finds a short article that demonstrates the costly and competitive economics and politics behind bandwidth allocation. The article is detailed, specific, and technical. Additionally, it uses many analogies, examples, and is simple to understand. Working collaboratively, the instructor, his two teaching assistants, and the consultant design a speaking assignment that challenges the students to create a new product for a particular bandwidth. This new product would need to be socially valuable and profitable enough to receive the competitive bandwidth allocation.

Students form groups, read the article outside of class, and, in class, develop products based on the professor's signals and systems course material. These products are then "sold" to the two teaching assistants who judge the technical, social, and economic merit of the designs as they observe each group during the first "open" class session. The best five group designs, from a total of 12 groups, are chosen to present their projects during the second open class meeting. During the third class session, 15 minute group presentations are delivered. From these five presentations, students vote for their favorite design, designating one top choice. All presentations are video-taped by the consultant and given to the professor on a DVD.

The authors have found students to be enthusiastic about this assignment. Their presentations are elaborate, with prototypes, PowerPoint slides, and video-taped segments created to make it appear as though the product were a functioning design. Such creative freedom is the catalyst for a successful merging of engineering and communication concepts. When it occurs late in the semester, after students have an opportunity to absorb critical concepts, it is an important move from pure to applied theory.

Meanwhile, a corollary writing assignment occurs in another course, attended by many of the same students in the signals and systems class.

IEEE Transaction Articles – Critical Response Paper (ECE 3910: Junior Design)

All ECE students are required to take a junior seminar course, designed to introduce students to local (and where possible, national) companies—their spokespeople, current projects, and professional issues. The purpose of this introduction is to prepare students to choose and pursue senior projects informed by real world concerns. As part of that preparation, students are required to critically explore an engineering issue of their choice, utilizing 3 IEEE transaction articles and resulting in a formal 8-10 page paper.

This assignment is a natural extension of, or corollary to, the signals and systems research on bandwidth. The same groups created for presentations there form teams to conduct collaborative writing research for junior seminar, possibly exploring the same safety issues. Together they gather pertinent articles, ask evaluative questions, discuss and interpret concepts, and work through design problems. The PDI serves as facilitator and resource: explaining the writing concepts involved, providing examples, modeling research inquiry, consulting, and commenting on drafts.

Both the bandwidth and transaction response assignments are effective because they require active learning and because they are intellectually complex. Students are required to develop and deliver two persuasive presentations to an authentic audience of their peers. They then use the thinking, designing, and teamwork strategies developed there to help them complete the junior seminar assignment, i.e. composing a formal, research document of transaction article length. Step by step, students use higher level thinking skills, such as creativity, interpretation, and evaluation to enhance their understanding of engineering concepts [18]. Finally, these assignments assist students as they transition to their culminating university experience: the senior design project.

### 4.4. Senior Level: Presentation and Document Synthesis for the Professional World

- Persuasive, numerically rich, results-oriented presentations that are visually sophisticated
- Formal, team-oriented documents that adhere to industry/professional standards

<u>Senior Design Symposium Presentation and Writing Awards</u> (ECE 4900, 4910: Senior Design)

Each senior must participate in a year-long design project consisting of approximately 200 hours of engineering research. These projects are designed to be accomplished either in groups (called clinics) or as individuals. Consultants work with senior design faculty and students as trainers and cheerleaders while students learn to research, write, design, and present collaboratively. In early April, students present their research projects during a formal symposium held at a conference center on campus. The students give 15 minute presentations to industry and faculty judges, with a five minute question and answer period immediately following. Two weeks following the symposium, students turn in a final written report. The oral and written presentation of their projects is required for graduation. The written report has been judged since the 1960s, awarding winners with a trip to present their papers at a western engineering conference. Historically, the oral component has not been judged equivocally.

However, in 2005, the oral communication consultant, supported by faculty members, secured funding for prizes and the hiring of eleven communication graduate students to judge the formal presentations. Based on the judges' comment sheets, three speakers were awarded cash prizes at the awards banquet dinner following the symposium. This change in design emphasized the quality of the professional presentations. This motivated students to compete for these prizes and encouraged practice and thoughtful presentation design. Additionally, the students appeared more poised and confident to the audience of family, friends, alumni, faculty, and donors.

## 5. Assessment

The vast majority of assessment in the program is conducted by peers, which enables near-instant feedback either in writing or in oral feedback form. Both have been found to be effective. In order to make peer feedback most highly effective, it is critical to guide the students in what they should be evaluating. First, when the assignment is given, the instructor or consultant should make very clear what constitutes a "good" performance. For instance, when learning to write lab report summaries, the instructor should provide a list of the information that should be in a good summary (motivation, methods, results, discussion, for instance). Students should then write their summaries, and should formally provide self-assessment (which should include checking off the list of information that should be in a summary.) Normally students bring these to class or lab, where they are passed to a peer for evaluation. In addition to checking for the expected information (which by then is nearly all present), the peers should also comment on the readability and clarity of the summaries, and specifically what makes the summary more or less clear. By assessing the reasons for lack of clarity, both peers (evaluator and the person being evaluated) are learning to think, speak, and write more clearly. Peer evaluation is essential in most university settings, where limited instructor grading time is available. Instructors can choose how to use the peer feedback for grading, but so far no instructor has chosen to actually grade students based on peer feedback (other than just credit/no credit for completing both the assignment and the assessment). The students are expected to improve their writing based on the peer feedback before turning it into the teaching assistants, who grade it under the direction of the CLEAR consultant.

Peer feedback is only as good as the guidance the students are given. For instance, if peers are asked to assess most oral presentations, they will write "good presentation" and little more. If instead they are asked to give a certain number of positive and negative comments, the value for the presenter being evaluated is significantly improved. If they are given even more specific instruction, such as evaluate the ability of the speaker to construct their argument in a logical, linear fashion, the value is more focused on the specific skill being taught at the time.

This program has been in place in the University of Utah ECE curriculum for only 1 year, so full assessment is not complete. Individual observations and student feedback indicate that both oral and written communication skills improve in specific, definitive ways when the students are taught what is desired and then given time to practice the desirable trait. An ongoing assessment effort will evaluate how well students transfer the specific skills learned in earlier classes to later classes, and whether or not this integrated program works better than our previous model of taking individual technical writing classes.

## 6. Conclusion

The importance of communication and teamwork skills have been recognized throughout the engineering education community. This paper has described a program that integrates both the teaching and practice of these skills throughout a typical 4-year ECE curriculum. The purpose of the integration of CLEAR into the ECE curriculum is first, to enhance students' higher level engineering skills and second, to improve their communication and teamwork skills. Graduate students from the College of Humanities work with ECE professors in order to provide both the teaching and the assessment. Guided peer evaluation is used to provide much of the feedback to the students, who also learn as they provide feedback to others. The integrated program progressively expands the students communication skill set from Year 1: Description and Explanation, Year 2: Analysis/Synthesis, Year 3: Evidence/Persuasion/Credibility, and Year 4: Professional Practice.

The assignments, teaching materials, peer evaluation sheets, etc. are available on line at [17] and are available for use by other educators.

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