AC 2010-218: INFUSING COMMUNICATION SKILLS IN AN ENGINEERING CURRICULUM

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Infusing Communication Skills in an Engineering Curriculum

Abstract

The development of a new electrical and computer engineering program offers a rare opportunity to design an innovative and modern curriculum that incorporates important skills and content. The envisioned program is project-based and includes innovative and multidisciplinary aspects in its curriculum, organization and its operation. This work discusses methods and content developed to be embedded into an engineering curriculum to teach students effective communication skills and the efficient use of modern communication techniques. The results of this research effort, conducted by a multidisciplinary team of faculty from Communication Studies, the Arts and Media, English, Information Science, and Engineering are presented in this article. The objective of this activity is the design of efficient and innovative ways to infuse communication education into engineering courses, lectures, laboratories, projects, and seminars with adequate assessment methods for a set of well-defined learning outcomes. However, the infusion of communication skills is useful in nearly any field of study making this work a valuable reference for a very wide academic audience.

1. Introduction

Adequate communication skills constitute a requirement for engineering program accreditation by ABET and an essential component of an engineer's professional function. However, in modern days, communication has exceeded its traditional verbal and written aspects. Technological advances in presentation, computers and the rise of the internet have allowed communication to incorporate presentation, technical, graphical, media, and artistic concepts as well as communication techniques targeted to different audiences.

Engineering curricula are already overburden and difficult and must conform to many educational and institutional constraints. Most states or institutions impose a limit on the number of courses or degree credit hours. Consequently, teaching communication skills must be infused in required courses adding to the general education portion of the curriculum and without replacing cognate or core engineering material. The challenge is to provide a solid and modern engineering education where students will naturally and ubiquitously acquire efficient and modern communication skills.

This presentation discusses some of the research results of this project including the development of a modern technical writing course, the integration of communication skills into engineering materials, and multidisciplinary methods that combine students enrolled in the Arts, Media, and Communication Studies with engineering teams.

Communication is a multidisciplinary activity that encompasses broad areas such as oral, written and visual forms while engineering relied mostly on mathematics and the sciences at the expense of more interdisciplinary instruction in ancillary fields such as communication. The situation changed in 2000, when ABET recognized the importance of communication for engineers, who often work on teams and who need to disseminate technical results in an effective manner.

ABET now requires that engineering programs have a communication component for accreditation. But beyond accreditation requirements, effective communication by engineers is seen as important for the efficient functioning of projects in an industrial or research environment. [1, 2, 3]

There have been various approaches to meet this mandate from ABET as well as the more general concern of educating engineers to be effective problem solvers who use good communication skills. A review of the literature concerning the role of communication in engineering programs reveals several recurring themes:

1) Identifying suitable learning objectives and outcomes that will meet both ABET criteria and industry needs. This concern also should incorporate current theories of communication to develop a meaningful taxonomy that will provide a structure for organizing the learning objectives. For example, Keane & Gibson identify the need to integrate visual and written communication components. Their research also points to incorporating interpersonal skills such as group communication, negotiation, listening and telephone skills. [4, 5]

2) Identifying relevant courses, and if needed, to develop new courses which will meet the learning objectives identified in point one above. Moreover, Julia Williams noted that the ABET criteria mandated that skills should be integrated into the engineering courses themselves, and that these skills should be refined and reinforced throughout the course of the engineering student's undergraduate experience.[6] The problem then is not just to supply courses with communications components, but also to build a curriculum that embeds communication skills within the context of engineering practice. Often some form of team approach, that can incorporate team building exercises and listening skills within an engineering course, can be used as an "infusion" technique. [7, 8, 9]

3) Identifying the means and methods of delivering courses and their assessment. For example, Moodie Brammer and Hessami, suggested more effective feedback on laboratory reports [10], while O'Moore & Baldock, relied on peer assessments and summative feedback. [11] Dannels, Anson, Bullard & Peretti developed communication specialists to act as consultants within the actual class times and labs.[12] Hargreaves recommended student-generated examinations, project-based learning and peer assessments. [13] Magin & Churches also noted that peer tutoring is beneficial. [14]

2. Learning Objectives and Outcomes

Often the first step in developing a curriculum, particularly in these times when assessment is paramount, is the identification of what students are expected to learn, or learning outcomes. In their guidelines for accreditation, ABET helpfully provides some general direction, but greater specificity is needed for purposes of effective and discriminating evaluation of student progress and achievement. Fortunately many communication programs (Texas A&M, Arizona State, University of Utah, and the University of Kentucky, for example) make public (via the Internet) the learning outcomes for their curricula. These specific outcomes for communication programs, in turn, must be then connected to engineering concerns. Gert Brinkman and Thea van der Geest suggested a model using the general ABET criteria that placed specific communication learning outcomes within middle layers of greater abstraction and generality. [15] A taxonomic scheme such as this one helps to organize the specific outcomes into cohesive subsets of the most general learning outcomes. Using generally accepted concepts and practices found in the fields of communication, art and media literacy, the following conceptual scheme is developed, along with a list of attributes that help define each category as shown on Table 1.

Table 1. Categories and attributes of communication skills

Category	**Attributes**
1. Form	Mechanics, style, word choice, design
2. Content	Sufficiency, validity, coherence, organization, appropriateness
3. Context	Appropriateness, audience evaluation, credibility, subjective and objective evaluation, invention, using feedback and evaluation (rhetorical sensitivity), message design
4. Visuals	Comprehensiveness, hierarchy, effectiveness, usefulness, design elements, presentation professionalism
5. Presentation	Credibility, paralanguage, physical appearance, feedback, eye contact, facial/body language, adaptation, listening, perception, timing

Within each of the categories in Table 1, learning outcomes are defined to facilitate assessment of the corresponding attributes.

I. Form

- **I.1** Understand proper writing mechanics, including spelling, capitalization and grammar.
- **I.2** Recognize effective writing style through structure, conciseness, readability and tone.
- **I.3** Produce clear organization of ideas to help reader/listener navigate information.
- **I.4** Adopt appropriate words and formality for the particular situation/audience.
- **I.5** Edit one's own work and the work of others.

II. Content

- **II.1** Present adequate information for the purpose of the assignment or task**.**
- **II.2** Present information truthfully and ethically.
- **II.3** Present information with consistency and logically.
- **II.4** Organize ideas and information in technical reports and presentations
- **II.5** Be critical of ones' ideas and the ideas of others.

III. Context

- **III.1** Utilize appropriate content for the purpose and audience.
- **III.2** Adapt to audience needs while presenting information.
- **III.3** Demonstrate speaker credibility during presentations.
- **III.4** Execute an appearance that is appropriate/professional for particular audiences**.**

IV. Visuals

- **IV.1** Create understandable visual presentations that effectively convey information
- **IV.2** Utilize visual hierarchy to successfully convey the relative importance of concepts
- **IV.3** Create graphics and symbols which communicate across diverse audiences.
- **IV.4** Understand and use the elements and principles of design in visual presentation

V. Presentation

- **V.1** Utilize appropriate vocalic components in presentations.
- **V.2** Enact effective eye contact, facial expressions, gestures, and body movements during presentations.
- **V.3** Present information within given time constraints.
- **V.4** Apply active listening skills.
- **V.5** Adapt presentation methods to different audiences.
- **V.6** Provide proper feedback in a positive manner

4. Assessment Tools

A set of eight assessment tools are proposed for the outcomes listed in the previous section

- **M1** E-portfolios (self evaluations, journaling, all handouts and visuals)
- **M2** Cross-disciplinary peer evaluations *
- **M3** Class presentations
- **M4** Lab Reports
- **M5** Quest Presentation**
- **M6** Videos of presentations
- **M7** Visual Presentations
- **M8** Essays and written material

**The Communication Media and the Arts (CMA), a multidisciplinary group of higher rank students, aka "The Circuit", ideally drawn from members of capstone courses in Engineering, Communication Studies, Media, and the Arts, in which a component of the class is devoted to the communication skills assessment of engineering students. The circuit will consult with engineering students in classes that have a communication component.*

*** Quest is an institution-wide annual conference where students and faculty are invited to present research and project work. Quest offers an excellent venue for Engineering students to present their projects to a university- and community-wide audience.*

5. Embedding Communication Skills

In developing a curriculum to infuse communication into the engineering programs, the ABET requirements provided guidance by the principle that engineering communication takes place in a particular setting and context. Learning to communicate as an engineer, moreover, is co-extensive to learning about engineering and its various contexts. Engineering is more than simply problem solving in this view. It involves a set of practices that are:

1) verbal and non-verbal,
2) quantitative and non-quantitative,
3) embodied in coordinated action to solve particular problems and
4) located in organizational settings that "express" particular expectations.

This point of view takes an approach that is not always embraced by communication specialists in the engineering community. A group from Georgia State University found that, in articles that are concerned with communication within engineering, most of the papers considered communication in two ways – either informal oral communication or written formal communication. The conclusion was that there needed to be other areas addressed by infusing communication skills into the engineering curriculum. [16]

The approach of this effort is to see communication as having not only written and oral aspects, but also acknowledging that there is a visual dimension as well. In the first year of study, engineering students will take foundation courses in written, oral and visual communication.
While communication skills are part of every class where reports are written or class presentations are given, a few courses within the core engineering coursework have been selected to serve as specific communication skills courses. This selection is obviously not unique and may undergo adjustments as the plan is conducted. During the freshman year, a set of courses, part of the general education requirement, are offered to teach communication skills. These skills are then reinforced as they are applied in the remaining year of study. Table 2 summarizes the curriculum plan.

Table 2. Curriculum plan for communication skills

Course	**Learning Objectives**	**Methods of Assessment**
Freshman Year		
ART 103E – Visual Multimedia	IV.1 through IV.4	M1, M7
COM 100 (Interpersonal/ Small Group Communication)	I.3, I.4, I.5 II.1 through II.4	M1, M3
ENG 102 80E (Written)	I.1 through I.5 II.1 through II.4	M1, M8
ECE 101 – Intro to Engineering	I.1 to I.5, II.1 to II.5	M4, M8
Sophomore year		
ECE 211 – Electric Circuits & Lab	I.1 to I.5, II.1 to II.5	M4, M8
ECE 233 – Signals & Systems	I.1 to I.5, II.1 to II.5	M4, M8
Junior year		
PHL 301 - Professional Ethics	I.1 to I.5	M1, M8
ECO 120 - Economics	I.1 to I.5	M1, M8
Senior year		
ECE 491 - Capstone Preparation		
ECE 401 - Senior Seminar	All	M1-M7
ECE 492 - Capstone Project	All	M1-M7

As students move through their studies, advanced engineering courses will build on these basic skills by enhancing and reinforcing the primary communication skills gained in the foundation courses. Since the students will have been exposed to fundamental theories and skills in the introductory courses, written, oral, visual and multimedia communication components can be woven into the more advanced courses with relative ease. A final aspect of curriculum development is that at each stage of the curriculum, the courses are matched with the learning objectives, so that by the senior year, all the outcomes have been met.

6. Curriculum Delivery and Assessment Strategies

The actual implementation of the curriculum assumes that outcomes have been defined, and the curriculum has been developed. As part of the implementation plan, methods of delivery and assessment procedures must be put into place. Students will be given instruction and feedback using the usual instruments**:** class presentations, lab reports videos of presentations, visual presentations and essays and written reports.

Most of the courses will be taught be full-time faculty, but as a state-supported institution with limited resources, it would be desirable if some other way to assist in delivering content and making assessment could be made. Some interesting models for these have been proposed by several universities concerning these facets of implementation. A team from the communication department at the University of Utah uses graduate students from that program to help deliver communication skills to engineering students. [17] Another model, from Michigan State University, again uses graduate students, but in this case from Engineering, to act as "peer assessors" in terms of the content of the work by undergraduates. [18]

The Circuit

The conceptual frame that peers could be used to provide substantive assessment was attractive to the curriculum team. In the absence of graduate students in Communication Studies or Engineering at this time, enlisting undergraduate students from the Arts, Media, and Communication Studies department was considered to help deliver content and to assist with assessment. This group of students, nicknamed "The Circuit" will enroll in a special class that will present students with methods of teaching and evaluating communication concepts. They will work with upper-division engineering students who will help evaluate the content of the work done by their peers. Using this strategy allows:

1) use desirable "peer-driven" techniques to provide greater effectiveness of learning in courses,

2) reduce the number of faculty members who need to be involved in delivery and assessment, and

3) provide Circuit members with opportunities to practice relevant theories learned in their studies.

Peer feedback and assessment have received positive results and have been utilized to address challenges such as timely and efficient feedback [19] as long as expectations and feedback are consistent [20] and peers are properly trained. [21] Engineering students in the upper level courses will also be able to provide feedback to the lower courses

Another key aspect of assessment involves both the long-term reflections of students about their learning experiences, and capturing what they learn into some persisting structure. A method that has gained considerable acceptance among assessment analysts is the use of e-portfolios. [22] Students will be introduced to e-portfolios in one of the core communication courses in their first year, with it being periodically updated over the course of their studies. The obvious positive results of using e-portfolios are that the progress of students can be evaluated over time, and that the students themselves have an awareness of the continuity of their studies. As a tool, e-portfolios provide a structure that integrates learning, in this case communication skills, across the entire span of a student's experience.

Finally, the public presentation of scientific and technological results is an important element in institutionalized production of knowledge. An annual presentation of research work by students, as well as faculty is organized by the institution. Students in the engineering program will be required to make presentations at this annual event. Not only will there be faculty and students in the audience, but members of the local professional engineering community will be in attendance to help evaluate the presentations.

In terms of delivery and assessment, a three level structure that consists of students, faculty and professional engineers is developed. The students will provide "peer level" criticism and support, the faculty will have the more traditional role of "mentor", and finally, the engineers will provide the norms of the wider professional community.

7. Future Directions

Determining the final content of courses in this proposal and the actual implementation of the curriculum obviously still needs to be done. The assessment procedures described in this article will be implemented, tested, and reported within a few years of the engineering program start up and it is likely that some adjustments will be necessary.

New technologies continue to be developed that will affect the way that media will be used in this curriculum, and the ways that these technologies can be used in our institutional and instructional environment must be considered. Assessing the impact of this interdisciplinary approach requires continuous and substantive monitoring. Thus, quantitative and qualitative analytical models to assess the effectiveness of this curriculum must be adapted and adjusted. In addition, evaluating the nature and productivity of peer assessment may provide useful knowledge as the curriculum experiment develops, both for engineering students and the intramural students involved in the Circuit.

As with any professional curriculum, engineering has a series of normative goals that must be accomplished to fulfill the objectives of the program. As a long-term project, the collection through assessment procedures and other methods, of not only quantitative by also qualitative data on student learning, provides an opportunity to observe the ways that engineering products are created through social interaction. Themes from the "social construction" of technology have been present in the literature of science and technology studies from the 1970s to the present. What has not been examined thoroughly in this literature is the way that pedagogic practice, particularly in undergraduate settings, can form the ways that engineers work, interact and create new technologies. Finally, while this work has been completed for the development of an Electrical and Computer Engineering program, communication skills are essential in nearly all fields of study and disciplines. Consequently, this work should be useful to a large audience and may provide methods for various adaptations and implementations.

Aknowledgment

This work was funded by a generous grant from the Engineering Information Foundation. http://www.eifgrants.org/.

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