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Integrating Communication and Engineering Skills in an Industrial Engineering Curriculum Based on Outcome Assessment Results

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Abstract
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Industrial engineering, engineering communications, communication assessment, information exchange

Disciplines
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Comments

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Integrating Communication and Engineering Skills in an Industrial Engineering Curriculum Based on Outcome Assessment Results

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Abstract

To bridge the gap between technical and communication skills of industrial engineering students at Iowa State University, faculty have focused assessment-driven continuous improvement in the curriculum on the integration of communication and engineering skills. Written, verbal, and non-verbal communication skills are addressed through the core communication process (Analysis, Formulation, Creation, Delivery, and Assessment): the focus of a new engineering communications course. This paper describes the creation of this course, including the impetus for inception, course content, structure, and outcome-based learning activities. Student growth and survey results are examined. Long term impact expectations and assessment plans are described.

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1. Introduction
The National Association of Manufacturers identified in their 2005 Skills Gap Report – Survey of the American Manufacturing Workforce that 36% of respondents reported insufficient reading, writing, and communication skills among their employees. In addition, 83% of respondents reported that the gaps in employee skills are currently impacting organizational ability to serve customers [1]. Boeing includes good communication skills (written, verbal, graphic, and listening) on its list of desired attributes of an engineer [2]. Job-posting websites such as Monster.com are filled with advertisements for engineers with “excellent verbal/written communication skills” [3]. Parallel to industry observation and demand, ABET has substantiated the importance and need for engineers to have effective communication skills through outcome item (g) [students will have an ability to communicate effectively] as required in the Criteria for Accrediting Programs [4].

Current literature fully supports the need for increased communication emphasis within engineering programs, and many institutions have discussed their methods for incorporating more written and verbal communication practice into their courses and curriculums [5] [6]. However, little has been said about the role of effects-based assessment in a complete communication process which we consider to be a critical communication skill that will ensure the successful exchange of information. It is not enough to provide more practice without instructing the communicators on how to ask the question: was the communication demonstrably successful? In other words, students must be taught to check for understanding after each communication event, improve as necessary, and incorporate these improvements in future communication. This assessment is a key element of the communication skill set.

2. Impetus for a new course
The evaluations of IE Program Educational Objectives in the Industrial and Manufacturing Systems Engineering (IMSE) department at Iowa State University have indicated that there is a need to improve students’ ability to communicate in a professional context (i.e., departmental objective (4) “prepare and deliver professional
For example, four groups of stakeholders (Year 1 alumni, Year 3 alumni, industry representatives, and faculty) were surveyed to assess the communication skills of recent BSIE alumni and the importance of being able to communicate [8]. Not surprisingly, there was a significant perceptual difference among these groups about the communication skill levels of BSIE alumni with assessment scores ranging from 3.8 to 4.4 (on a scale of 1 to 5, 5 being the highest level). While alumni thought they were very skilled, industry representatives and some faculty did not concur with this assessment. At the same time, communication skill was rated as one of the most important skills with scores ranging from 4.4 to 4.9.

Moreover, the communication skills of the current BSIE majors are assessed by faculty at the end of each semester on ABET outcome (g). Rubric (g) consists of three performance criteria of written, presentation, and team skills. For each performance criterion, three descriptive levels of competency are specified. This direct measure indicates that there is room for improvement in the practice of effective professional communication skills. Figure 1 shows rubric scores which assess written, presentation, and team skills from the capstone design course over a period of five different semesters (number of students assessed ranges from 14 to 37 per semester). Student scores from Spring 2004 through Fall 2007 are consistently in the range of 12.7-15.3, which is considered to be on the high side of “acceptable.” While “acceptable,” faculty agreed that student performance could be better and the standard deviation reduced. It was recommended that instruction in communications begin earlier in the program and be integrated into the curriculum to address performance issues.

Paretti and Burgoyne proposed program outcomes for communication that emphasized audience analysis, goal identification, and other components substantially different from the requirements of good writing and oral presentation skill mastery [9] [10]. In keeping with this recommendation, we examined the contents of multiple engineering and business communication courses in the U.S. and observed that while some included an analysis component for successful communications, most focused primarily on creation and delivery: communication as a fixed task (writing or speaking), rather than an integrated part of professional activities. Our concept for a complete and successful communication process includes five steps – analysis, formulation, creation, delivery, and assessment – with the inclusion of communication event assessment by the participants as a critical component of professional engineering communications. We did not find courses that emphasized and instructed this process as part of an engineering or business communications course. Based on this five step concept, an experimental engineering communications course was developed with the goal of improving students’ communication skills as industrial engineering professionals.

3. Engineering Information Exchange Process

Every communication event in a professional context has a desired outcome. The likelihood of accomplishing that outcome is increased through careful forethought and planning. The foundation of this experimental course is a process analogous to engineering methods in the context of an engineering project. Developed by Jackman and Potter, and described as the Engineering Information Exchange Process (EIEP), it includes five specific steps that can be applied universally to all forms of communication, including written (memos, emails, reports, letters, papers,
proposals, resumes, etc.) and verbal (meetings, formal presentations, poster presentations, telephone, net-meetings, face-to-face conversation, etc.). The five major steps as depicted in Figure 2 include 1. Analysis; 2. Formulation; 3. Creation; 4. Delivery; 5. Assessment.

The first two steps, Analysis and Formulation, are present in some but rarely emphasized in many engineering and business communication courses. These critical stages of the process require higher order cognitive skills. Identifying up-front the problem at hand, the desired outcome, and the relevant variables makes the communication process much more effective. Failure to adequately address these activities results in (at best) zero value-added to the engineering process, and (at worst), a communication or engineering fiasco. The third and fourth steps, Creation and Delivery, are typically the emphases of most engineering communication classes and many business and speech communication classes [11] [12]. These two steps are primarily the “How to…” of communication: how to write a report, how to write a proposal, how to give an oral presentation, etc.

The fifth step, Assessment, is critical to the process for several reasons. It checks for understanding; the communicator must assess and determine if success has been achieved and then direction for further action. It encourages consistent use of feedback, constructive criticism, and listening skills, which in turn guide students toward improvement in their communication skills. Current literature is full of discussion about assessment, but only assessment by others (instructors, peers, industrial partners, etc.) which is rightly necessary for student improvement, but not part of the communication skill set [13]. The relationships between the five steps are shown visually in Figure 2.

This process is critical not only to the success of an individual, but to teams of students and engineers working together to accomplish a task. The EIEP can be used by teams both internally (communication by team members) and externally (communication with entities outside of the team). It facilitates early and successful communication, making teams also more efficient, effective, and productive.

4. Course details

Within the course, assignments include both individual and team activities. Written communication practice includes agendas, email, letters, reports, resumes, and presentation slides. Verbal communication practice includes elevator speeches, roundtable presentations, formal presentations, one-on-one discussion, group discussion, and conference calls. Data presentation and non-verbal communication are addressed. Two textbooks are used, including Business Communication: Process & Product 5th ed by Mary Ellen Guffey and Introduction to Engineering Communication by Hillary Hart [14] [15]. Two exams are administered during the semester so that the students can demonstrate understanding of both the concepts and the skills learned in the course.
For all forms of communication assignments, attention is paid to professionalism, which includes mechanics, etiquette, cultural sensitivity, constructiveness, etc. Every assignment is provided within a practice-based context of industrial engineering workplace activities. Many of the examples and problems are taken directly from industrial partner-provided communication examples.

With every assignment, the five steps of a successful engineering communication exchange are emphasized. Students are required to analyze the need for the communication, the audience, the desired outcome, the potential impact, and the existing barriers. For many assignments, they must determine the best form of media that will lead them to a successful communication exchange, and to determine if consultation with stakeholders is necessary or helpful, and what form(s) that consultation should take. Time is spent helping them understand how to best create and deliver different communication products, and extensive feedback is given covering written, verbal, and professionalism skills. Most uniquely, students are instructed on assessment of communication activities—when to consider it in the process, how to plan for it, and how to constructively conduct the assessment process and use it to improve ongoing communication. Assessment is a critical component of the course, and feedback is provided on an ongoing basis by students, instructors, and other faculty members. Video recording of speaking assignments is used extensively throughout the semester, and students are able to see their progress from start to end.

A unique integration of the course with the capstone design course is another valuable component. Students in the communication course go on a plant tour at the beginning of the semester with the senior design students. Their first major group project is to generate useful information regarding the senior design industrial partner, plant, products, and/or processes, which the senior design students can then incorporate in their client project. The communications students have a unique opportunity to work with industry partners and senior students, practice the communication skills that they are learning, and present their findings in both verbal and written formats. The senior design students provide feedback to the communication students who then return constructive criticism to the senior design students on their feedback.

Grades are based on both individual and team effort, peer evaluations, and professionalism evaluations. Assessments of both actual and perceived skill levels are made at the beginning and ending of the semester. Pre- and post-survey data is also collected on student confidence and enjoyment regarding communication. Finally, ABET rubrics for the outcome items associated with the course are evaluated for each of the students.

5. Pilot Offering Fall 2007
In the Fall 2007 semester, six sophomores completed the course. While the sample size is obviously very small, the progress made and assessment results throughout the semester show promise for this approach. It also provided clear evidence that the course should be offered again during the Spring 2008 semester for a larger student body with the intent of evaluating the scalability of the course.

Assessment of written and verbal skill levels at the beginning of the semester indicated that while students knew many of the rules of good composition (on average, students correctly identified and addressed 80% of punctuation and usage errors on a grammar test), they had difficulties applying those rules to freeform editing or composition tasks (average incidence of major grammar or usage errors in a 300-word text was >3 errors per 100 words). By the end of the semester, students had improved in their English mechanics skills, most dramatically in the correct use of punctuation (all students identified and addressed 90% of punctuation and usage errors on a grammar test, and displayed <1.5 errors per 100 words in a 300-word freeform text). All students also displayed improved attention to register, idiom, and the ability to prioritize and organize information in written text. Their ability to deliver verbal presentations improved significantly from start to finish, again including both the ‘mechanical’ aspects of good verbal and non-verbal skills, and the ability to select and organize pertinent information. Further detail regarding skill improvement is reported in a paper which will be presented at the 2008 ASEE National Conference.

Data from pre- and post-surveys about students’ perceived skill levels, confidence levels, and enjoyment of communicating improved in every category. On a Likert scale of 1-6 with 6 being the highest level, students’ perceived skill levels (written and verbal) increased from an average score of 3.50 (std dev =1.13) to 4.17 (std dev =1.13). As a group, their confidence levels in both writing and speaking increased from a score of 3.55 (std dev =1.04) to 4.39 (std dev =1.00). Their self-assessment of their use of the communication process (analysis, formulation, creation, delivery, assessment) increased from 3.46 (std dev=1.18) to 4.55 (std dev =0.89). Finally, their self-reported enjoyment of communicating increased from a score of 3.61 (std dev =1.24) to 4.33 (std dev
Of course, given the small size of the data set, further data is necessary to corroborate these findings. Overall, students were very receptive to the course despite numerous comments about the workload being significantly higher than that of the regular speech communications course. Qualitative student feedback from the Fall 2007 course included consistently positive comments, including the following responses to the question “What did you get out of this course?”:

- I got a whole new perspective. An entirely updated view on the importance of communication, the steps and aspects involved.
- A better understanding of linking your communication with your technical or engineering data.
- I became more confident at speaking.
- How to apply engineering problem solving techniques to communication.

6. Short and long term changes, expectations, and assessment plans

The content and delivery of the initial course proved to be very effective, and so the majority of the content in the initial offering will be used in the Spring 2008 semester offering. While building the analysis step of the communication process into the course material was straightforward, it was more challenging to build in the assessment step of the process. Because assessing each communication event requires a customized set of responses, much of this activity focused on discussion, awareness, and judgment: how students intended to assess their success, how they actually assessed it, what they found, and how they could use that information. The challenge with this step of the process was in getting the students to internalize the concept of “shared meaning,” and not to think of a successful communication event as a career fair interview that was “very positive,” or as a presentation where no questions were asked. Primary changes to the course include an even stronger emphasis on both analysis and assessment throughout the semester to reiterate their role in professional communication practice, with revision cycles for written documents and presentations built into the syllabus. While some assignments will be altered or standardized to facilitate more extensive data collection, particularly in areas identified as key findings in the initial offering, the same course assessment processes will be used and results will be analyzed at the conclusion of the Spring 2008 semester.

Long term impact will be assessed for both the students and the department. The use of ABET rubrics to assess students at the end of the course provides the opportunity for longitudinal assessment—these same rubrics will be evaluated when the engineering communications students take IE441, senior capstone design. A direct comparison can then be made between students who had the new communications course and students who took the regular speech communications course. For those students that took the engineering communications course, growth in individual communication abilities will also be assessed as a function of time; the students’ improvements from sophomore to senior years will provide interesting insight into the program’s effectiveness at improving communication skills. From a department standpoint, the impact of teaching this course will be evaluated after the Spring 2008 semester is completed. The overhead and expense of teaching this course within the department will be compared to the assessed and perceived benefits to the department and its students. A determination of the need for resources will be made based on the scalability of the course. Another possible option is that the experimental course will have served as an incubator for instruction units that can be extracted and integrated into existing courses. In either case, content integration into the Industrial Engineering curriculum will be addressed. Whatever path is determined to be most productive, a report will be made to the College of Engineering for the purposes of sharing insight with other engineering disciplines at ISU.

7. Conclusions

Changing how the IMSE curriculum emphasizes and instructs communication skills was driven by analyzing and addressing assessment results. While the initial sample size is small, both quantitative and qualitative results from the first offering of a professional interactions course which emphasizes the process for effective communications are very positive. Three major points are made supporting this undertaking.

1. As with any skill set, there is a fundamental process for how to do something. There are five critical steps in the communication process, and ignoring any of the steps leads to communication inefficiency (best case) or fiasco (worst case).

2. Students can’t just be given more “practice” time and tasks for something they don’t know how to do. They must be taught the complete communication process and then be provided opportunities to apply
their knowledge in practice, in a context that emphasizes that process and its relationship to professional activities.

3. The fifth step of the communication process, assessment, isn’t the same thing as instructors evaluating a series of discrete criteria and providing feedback on those criteria. It is the communicator assessing his/her ability to communicate the message, i.e. checking for mutual understanding of shared meaning.

The integration of the course with the capstone design course and the exposure of students to multiple faculty members, multiple audiences (including faculty, industry partners, and other IMSE students), and multiple professional communication opportunities appears to have had dramatic impact on the students’ skills, confidence, and attitudes. The second offering of the course during the Spring 2008 semester will provide insight into the scalability of the course. It will also provide the opportunity for IMSE faculty to assess its long-term viability and effectiveness as either a stand-alone course within the curriculum or as an incubator for communication emphasis activities and material that can be integrated into existing courses. A full analysis of the results of this effort will be reported at the completion of the second offering of the course.

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