

Communication-based learning objectives in a four-year engineering curriculum: a longitudinal analysis

Mary M. Staehle, Amy R. Reed, Harriet S. Benavidez & William T. Riddell

Rowan University
Glassboro, New Jersey, United States of America

ABSTRACT: Effective communication has been identified as a critical skill for engineering graduates. In this article, the authors identified specific communication-based learning objectives in existing Rowan University engineering courses that are designed to provide instruction in technical communication throughout the curriculum. The objectives fall into four primary categories: rhetorical awareness, writing, oral presentations and interpersonal communication. Within these categories, the authors have identified several sub-objectives and have mapped these to the revised Bloom's Taxonomy based on the level of competency expected of students in each course. The purpose of this exercise is to provide a robust framework for evaluating the treatment of communication skills longitudinally through the entire curriculum, rather than piecewise, so that gaps or unreasonable expectations of jumps in skill from year-to-year can be identified. The authors expect that this approach can serve as a model to analyse and design engineering curricula at other universities as well.

Keywords: Communication, learning objectives, longitudinal curriculum analysis

INTRODUCTION

In 1998, the Accreditation Board for Engineering and Technology (ABET) released a substantially changed version of its engineering criteria, since known as ABET 2000 [1]. One of the most significant changes involved identifying the A-K objectives, which are sometimes collectively referred to as the professional skills [2]. One of these objectives specifies that engineering students be able to *communicate effectively* [1]. However, there are many aspects of communication that fall into this broad requirement. In this article, the authors identify specific aspects of effective communication that have been identified as course objectives in existing syllabi and university requirements, as well as through surveys of engineering graduates that have been published in the literature [3][4] and use the revised Bloom's objectives [5] to trace the anticipated progress of communication skills throughout a four-year sequence of project-based learning courses.

The purpose of this exercise is to provide a robust framework for evaluating the treatment of communication skills throughout the entire curriculum, rather than piecewise, so that any gaps or unreasonable expectations of jumps in skill from year-to-year can be identified. It is anticipated that this approach can serve as a model to analyse and design engineering curriculum at other universities as well.

All undergraduate students at Rowan University are required to complete College Composition I, a first-year composition course that focuses on the objectives outlined by the Council of Writing Program Administrators [6]. Beyond this, the primary mechanism for developing the so-called professional skills at Rowan University's Henry M. Rowan College of Engineering is the eight-semester Engineering Clinic sequence.

The project-based courses in this sequence differ from traditional engineering courses by emphasising important aspects of professional development like teamwork and open-ended problem-solving, preparing engineering students for practice in ways that traditional courses cannot [7][8]. Each semester, students take a course in the sequence. In the freshman year, students are introduced to the profession and learn to work on teams through modules based on the concepts of measurements and reverse engineering [9-12]. In the sophomore year, students practice technical writing and public speaking while developing design skills [13-16]. These courses prepare the students for the Junior and Senior Engineering Clinics, where teams are mentored by faculty to work on externally funded projects for local and federal agencies or businesses [17]. Deliverables from Junior and Senior Engineering Clinic projects include reports to

sponsors, as well as papers and presentations at national symposia. The clinics are an excellent way to reinforce engineering concepts, introduce new material and strengthen professional skills, such as synthesising information from multiple sources, solving open-ended problems, communication and teamwork.

The approach of this effort is to first identify broad communication skills that are addressed in existing syllabi, map these skills onto the revised Bloom's taxonomy and, then, to use this map to identify gaps or jumps in expectations throughout the existing curriculum.

REVIEW OF PREVIOUS STUDIES

There have been numerous surveys and studies that identify various communication skills as being important in engineering practice. Furthermore, Dym argues that communication between team members is an essential aspect of the design process [18]. Prior to the implementation of ABET 2000, Katz surveyed employers, and identified ability to work on a team, ability to communicate and awareness of workplace expectations as three common abilities that recent graduates lacked [19].

A survey of graduates described by Sageev and Romanowski was used to gauge the importance of communication ability in the workplace [3]. Specifically, graduates were asked how much time they spent on written communications, formal oral presentations and *other* oral communication, such as meetings, discussions, etc. Respondents reported spending significant (64% total) portions of their time on communication-based activities, and all were universally considered important by the recent graduates. This study is typical of most surveys in that it clearly identified communication as an essential skill.

Nicometo et al had interviewed individuals and groups in practice, asked freshman engineering students to use scripted interviews with practicing engineers, and used electronic surveys of engineering alumni to determine how engineers define *effective communication* in practice [20]. From these surveys, three themes to effective communication were identified. First, they describe the *big picture awareness* as the ability to communicate with people with different backgrounds. Next, *willingness to engage*, is the initiation of communication with others to gain additional information. Finally, *being a good listener*, enables engineers to deliver what their customers and managers want.

Donnell, et al developed a review of feedback on recent engineering graduates' performance in communication-based activities, both from the viewpoint of the graduates and of the employers [21]. Chief among the findings is the need for engineers to write in both a concise and well-organised manner. They summarised an important disconnect in engineering education: engineers tend to learn much of their communication skills directly from the work environment, but the professional community expects engineers to graduate fully prepared for practice. A major source of this conflict is the different audiences and goals between writing in educational and practice settings. Further, Donnell et al recommended more clearly defining course goals and specific communication skills that are desired for students. Finally, in regard to future research efforts, the authors implored:

...we do not need yet another study that comes to the final conclusion that communication skills in engineering are important. No one disputes this. What we need is a study that mines down to determine the important things about communication we are teaching well and what we are failing to teach...[21].

As a first step toward this goal within their own curriculum at Rowan University, the authors of this article have developed a longitudinal analysis for identifying specific communication skills that are covered in all sections of the communication-intensive courses in the engineering curriculum.

ASSESSMENT OF CURRICULUM

Based on results of surveys, it is clear that graduates need to be well-versed in preparing written documents, giving oral presentations and practicing effective interpersonal communication. An assessment of the course objectives in the communication-intensive courses in the Rowan engineering curriculum identified the same major categories. In addition to reviewing surveys, the authors consulted a well-regarded position statement on first-year writing desired outcomes [6], and determined that an overarching fourth category of rhetorical awareness skills was implied or implicit in many of the survey responses and reviewed course objectives.

These skills are imperative as they help students assess and understand the demands of new communication situations, allowing them to transfer communication skills to new contexts. Therefore, four broad categories of communication skills have been identified to be critical for engineering graduates: rhetorical awareness, writing, oral presentations and interpersonal communication. Under each of these broad categories, objectives have been identified from course syllabi and university requirements. The authors have listed the categorised objectives in Table 1 and provided some explanation of, and motivation for, these objectives in the following paragraphs. They note that this list is not exhaustive of all topics covered in these courses, but rather represents overarching categorical topics that the authors feel to be of particular import in learning to *communicate effectively* [1].

Rhetorical awareness is essential to all communication efforts. Specific indicators in the syllabi have been grouped to include audience assessment, where an engineer must assess the target audience to identify important factors, such as level of technical background and the general receptiveness to the ideas presented. The most appropriate form of the communication must be identified. For example, information can be conveyed in a variety of ways, ranging from a formal technical report to an informal conversation. Expectations of the community regarding the nature of communication must be identified, assessed and satisfied. Finally, a number of objectives regarding identifying, assessing and citing potential sources of information are found throughout the curriculum.

In preparing written documents, students are expected to be able to write in several genres that are specific to the engineering profession, for example: professional memorandums, laboratory reports and design reports. Objectives in the curriculum related to the improvement of written communication also include familiarity of the students with the stylistic conventions in technical writing, so that their writing is accepted by the community of engineers once they graduate. Data presentation must be mastered, as figures convey a significant portion of information within technical documents, and students must practice writing mechanics, such as syntax, control and grammar. Objectives focusing on these skills, as well as the practice of collaborative writing were also identified throughout the curriculum.

Developing and delivering effective oral presentations involves a litany of skills that are introduced and practiced throughout the Engineering Clinic sequence. Specifically, to be successful in giving oral presentations, students are expected to develop an understanding of spoken communication as a multi-step process. They must be audience-centred throughout the speech making process, and practice the ability to adapt speech content and delivery based on audience analysis in real time. Students must be able to research, design and deliver effective oral presentations for a variety of purposes to include informative, technical and persuasive speaking, and to recognise the different structures of each. Synthesising and incorporating research for use in individual and group oral presentations and adapting technical information to a non-technical audience must be practiced. Being able to recognise and use effective visual/audio aids to enhance oral presentations is a necessary component.

To successfully communicate with others in a work environment, students must be able to understand the importance of effective interpersonal communication and to apply learned skills to various communication interactions. Students are expected to identify and understand both the verbal and nonverbal interactions between individuals who have some type of relationship or connection. Shared meaning through effective message construction and active listening are essential for individuals to work well together. Students need to respect different frames of reference when interpreting communication events and be sensitive to diversity. Since conflict in relationships is inevitable, students need to know how to identify and manage conflict in order to communicate effectively. Understanding and refraining from negative communication, such as ethnocentrism and stereotyping, and avoiding misuses of power and influence, such as sexual harassment and power plays, will enable students to be more productive in the work environment. While these interpersonal communication skills are rarely defined explicitly in course syllabi, all courses examined required teamwork and most included learning objectives related to teamwork. The sub-categories in the interpersonal communication category were, therefore, determined based on the authors' exposition of skills necessary for effective interpersonal communication and their interpretation of course objectives.

MAPPING COMMUNICATION SKILLS TO BLOOM'S TAXONOMY

The collection of topical learning objectives in Table 1 represents a range of skills that span all levels of Bloom's revised taxonomy. To evaluate the progression of skill development in the curriculum, the authors have mapped the skill level required for each sub-objective in each of the communication-intensive courses in the Rowan engineering curriculum. To do so, the authors have paired levels of Bloom's revised taxonomy based on the skill-level required as R/U: remembering and understanding; A/A: applying and analysing; E/C: evaluating and creating.

In some cases, the mapping of a course objective in this framework was straightforward. For example, a learning objective from the common Sophomore Engineering Clinic I syllabus reads, *During the course, Rowan engineering students will develop information literacy and research-based writing skills by using the library's engineering databases and the internet to select best sources.* To achieve this objective, the students must *remember* how to access and search the library's databases, *apply* that skill to find reference information, and *evaluate* the quality of their search results to select the best sources. In other cases, the mapping required more interpretation and input from the authors who have taught the course(s) previously to determine the expected competencies within the stated objectives. In discussions regarding this mapping, it became clear that competency at various levels of Bloom's revised taxonomy was also inferred within objectives of compound skills without being explicitly stated in the course syllabus. For example, an objective of Freshman Engineering Clinic I is to *communicate effectively about laboratory work with a specific audience both orally and in writing.* Students in this course have not had formal instruction regarding oral presentation message construction, yet they are asked to create and deliver technical presentations, which implies an expectation for competency in *creating* an appropriate message. Table 1 shows the complete mapping for all of the communication-intensive courses in the Rowan engineering curriculum. The authors' objectives are to use this map to identify gaps or jumps in expectations throughout the existing curriculum, and to identify opportunities to better align course objectives to facilitate the development of communication skills throughout the curriculum.

DISCUSSION

While it has been established definitively that communication skills are critical for engineering graduates, the specific communication skills that should be covered, and those that are already covered, in the engineering curriculum to meet the needs of practicing engineers have been poorly defined. In an effort to identify important communication-based skills that are taught and practiced within the common engineering curriculum in Rowan University's Henry M. Rowan College of Engineering, the authors have developed a longitudinal analysis of communication-intensive courses. Through an assessment of course syllabi, they identified a set of communication skills and objectives covered in the curriculum and, then, mapped the course objectives related to these skills to Bloom's revised taxonomy to identify gaps or jumps in expectations. The results of this mapping are shown in Table 1.

Table 1: The four categories of communication-based topical learning objectives and associated sub-objectives identified in the communication-intensive courses in the Rowan engineering curriculum.

	Comp I			FEC			SEC			Jr/Sr Clinic		
	R/U	A/A	E/C	R/U	A/A	E/C	R/U	A/A	E/C	R/U	A/A	E/C
Rhetorical awareness												
<i>Audience analysis</i>	X	X		X			X	X	X	X	X	(I)
<i>Identification of appropriate form</i>	X			X			X	X		(I)	X	
<i>Community expectations and situational awareness</i>	X	X						X		X	X	
<i>Information literacy</i>	X	X	X	X	X	X	X	X	X	X	X	X
Writing												
<i>Genre knowledge</i>	X						X	X		X	X	
<i>Conventions in technical writing styles</i>				X			X	X		X	X	
<i>Presentation of data</i>				X	X		X	X	X	X	X	X
<i>Writing mechanics/competencies</i>	X	X	X	X			X	X	X			
<i>Collaborative writing</i>				X	X		X	X	X	(I)	(I)	
<i>Synthesis of the writing process</i>	X	X	X		X		(I)	X	X	X	X	X
Oral presentations												
<i>Speech purposes</i>				X			X	X		X	X	
<i>Message construction</i>						(I)	X	X		X	X	X
<i>Real time audience analysis and adaptation</i>							X	X	X	X	X	
<i>Organisational format</i>					(I)		X	(I)		X	X	X
<i>Reasoning and critical thinking</i>							(I)	X	X	X	X	X
<i>Research and source credibility</i>					(I)		X	X	X	X	X	X
<i>Visual/audio aid design and use</i>						(I)	X	X	(I)	X	X	X
<i>Delivery practices</i>				X	X		X	X		(I)	(I)	
Interpersonal communication												
<i>Verbal and nonverbal competence</i>				X	X		X			(I)	(I)	
<i>Roles and relationships: dyadic and teams</i>				X	X		X	X		X	X	(I)
<i>Messages and meanings</i>							X	(I)				
<i>Active listening</i>							(I)	(I)		X	X	(I)
<i>Conflict management and resolution</i>				X			(I)			(I)	X	
<i>Meanings of power and influence</i>							(I)					

Please note: the expectations for each item are mapped for College Composition I (Comp I) and each level of Engineering Clinic (FEC = Freshman Engineering Clinic; SEC = Sophomore Engineering Clinic, and Jr/Sr Clinic = Junior/Senior Engineering Clinic) to paired levels of the revised Bloom's Taxonomy based on the level of competency expected of students in these courses. An *X* indicates explicit expectations in the course syllabus, as interpreted by the authors, whereas (*I*) indicates an inferred or implicit skill based on compound skill development explicitly stated in the course syllabus. R/U = Remembering/Understanding; A/A = Applying/Analysing; E/C = Evaluating/Creating.

The analysis revealed several interesting facets of the way communication skills are taught and utilised within the curriculum. First, while effective teamwork is explicitly included in the learning objectives of most classes investigated, the course objectives rarely include any explicit instruction in or assessment of the interpersonal communication skills required for effective teamwork. While the authors' experience suggests that many sections of these courses include formal or informal evaluation of teamwork and team dynamics, the interpersonal communication skills required for these collaborations is rarely stated or taught explicitly. This raises questions of where and when students should receive instruction in interpersonal communication and in what form. These questions are outside of the scope of the current analysis, but warrant additional discussion and investigation.

One of the goals in developing this framework was to identify gaps or jumps in expectations. One example of this is a gap in the rhetorical awareness category in identifying the appropriate form of communication. For the most part, in the communication-intensive courses, students are taught about different types of reports and presentations and, then, they are given practice writing or presenting in that form. The authors have classified this as *remembering*, *understanding* and *applying* the skill of form identification. They posit that the higher-level cognitive objectives of *evaluating* and *creating* in this skill would only be achieved if students were given an open-ended assignment with few parameters where they would be responsible for evaluating the situation and requirements and selecting the correct form. This is challenging to implement in a classroom setting, so an alternative idea is to ask students to re-purpose a submitted assignment in light of new situational information into one of a different form or to identify situations in which an alternative form would be required.

Next, there is considerable variation among the identified skills in terms of the level of competency required within a course and across the curriculum. This is not surprising given the different complexity of the skills. However, what this framework cannot illustrate is elevating expectations within a skill. For example, informational literacy is of paramount importance in effective communication of technical content. In early courses, students are asked to *remember* and *understand* the procedures for finding reference material, *apply* this skill by collecting references for an assignment and *evaluate* the results of their search to determine which are the best references for their task. This spans all three paired categories of Bloom's revised objectives. In later courses, the expectations for informational literacy change. For example, in Junior/Senior Engineering Clinic, students are typically faced with an open-ended question and asked to find, read and synthesise primary literature to support their design or research decisions. While this task still requires all three paired categories of Bloom's revised objectives, the rigor and complexity is considerably greater because there is not a known answer or clear path to the information. Thus, although each course examined has explicit expectations in all three paired categories for informational literacy, one must be careful not to use this type of analysis to remove instruction that is necessary for advanced applications.

It is important to emphasise that the mapping was based on stated course objectives, and may not reflect the entire content of any given class. For example, there is an emphasis on peer review of writing and speaking in Sophomore Engineering Clinic I and II that requires competency in evaluating many of the sub-objectives listed in Table 1. In most cases, the course objectives related to peer review do not include indicators that these skills are part of the peer review process explicitly. Therefore, while the students might be asked to evaluate, the mapping would not reflect that level of competency. Furthermore, the skills and objectives listed in Table 1 reflect what is present in the courses, not what the authors think *should* be included in the curriculum. The authors do, however, think that this compilation provides a good starting point for future discussions, analysis and assessment of communication-based objectives throughout the engineering curriculum and that this framework can be applied easily to programmes in other universities.

SUMMARY AND CONCLUSIONS

Here, the authors have developed a framework for the longitudinal evaluation of communication-based professional skills in the Rowan University Henry M. Rowan College of Engineering curriculum. From published surveys of employers and recent graduates and established objectives for first-year collegiate writing courses, four major categories of communication skills were identified to be critical for engineering graduates: rhetorical awareness, writing, oral presentations and interpersonal communication. The course and learning objectives for each of the communication-intensive courses in the Rowan engineering curriculum guided the identification of sub-objectives in each of these categories. Then, the course and learning objectives from each course were mapped to the revised Bloom's taxonomy.

The authors aim to use this map to identify gaps or jumps in expectations throughout the existing curriculum and, then, to identify opportunities to better align course objectives with the development of communication skills. The framework is easily transferrable to other universities for similar longitudinal analysis and curricular design and provides a scaffold for future work in the assessment of these communication-based objectives throughout the curriculum.

REFERENCES

1. Engineering Accreditation Commission, Engineering Criteria 2000, ABET, Inc. Baltimore, MD (1998).
2. Shuman, L.J., Besterfield-Sacre, M. and McGourty, J., The ABET *professional skills* - can they be taught? can they be assessed? *J. of Engng. Educ.*, 94, 1, 41-45 (2006).
3. Sageev, P. and Romanowski, C.J., A message from recent engineering graduates in the workplace: results of a survey on technical communication skills. *J. of Engng. Educ.*, 90, 4, 685-693 (2001).
4. Vest, D., Long, M. and Anderson, T., Electrical engineers' perception of communication training and their recommendation for curricular change: results of a national survey. *IEEE Trans. on Professional Communication*, 39, 1, 38-42 (1996).
5. Anderson, L.W., Krathwohl, D. R. and Bloom, B.S., *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. Allyn & Bacon (2001).
6. Council of Writing Program Administrators, WPA Outcomes Statement for First-Year Composition (2014). 16 February 2015, http://wpacouncil.org/files/WPA%20Outcomes%20Statement%20Adopted%20Revisions%5B1%5D_0.pdf
7. Dorland, D. and Mosto, P., The Engineering Clinics at Rowan University: a unique experience. *Proc. 17th Inter. Cong. of Chemical and Process Engng, (CHISA 2006)*, Prague, Czech Republic (2006).
8. Chandrupatla, T.R., Dusseau, R., Schmalzel, J. and Slater, C., Development of multifunctional laboratories in a new engineering school. *Proc. American Society for Engng. Educ. Conf.*, Washington DC, United States (1996).
9. Farrell, S., Jahan, K., Hesketh, R.P., Newell, J.A. and Savelski, M.J., Introducing freshman engineering students to chemical product design. *Inter. Conf. on Engng. Educ.*, Manchester, United Kingdom (2002).
10. Bauer, S.K., Mcfarland, A.R., Staehle, M.M. and Jahan, K., Weaving sustainability into undergraduate engineering education through innovative pedagogical methods: a student's perspective. *Proc. American Society for Engng. Educ.*, San Antonio, United States (2012).
11. Farrell, S. and Vernengo, J., A controlled drug-delivery experiment using alginate beads. *Chemical Engng. Educ.*, 46, 2, 97-109 (2012).
12. Farrell, S. and Cavanagh, E., Biodiesel production, characterization, and performance: a hands-on project for first-year students. *Educ. for Chemical Engineers*, 9, 2, e21-e31 (2014).
13. Riddell, W., Courtney, J., Constans, E., Dahm, K., Harvey, R. and von Lockette, P., The connections between engineering design and technical writing in an integrated instructional setting. *Design Principles and Practices*, 2, 4 (2008).
14. Dahm, K., Riddell, W., Constans, E., Courtney, J., Farrell, S., Harvey, R., Jansson, P. and von Lockette, P., Implementing the converging-diverging model of design in a sequence of sophomore projects. *Advances in Engng. Educ.*, 1, 3 (2009).
15. Riddell, W., Courtney, J., Constans, E., Dahm, K., Harvey, R. and von Lockette, P., Making communication matter: integrating instruction, projects and assignments to teach writing and design, *Advances in Engng. Educ.*, 2, 2 (2010).
16. Riddell, W., Simone, M., Farrell, S. and Jansson, P.M., Communication in a project based learning design course. *Proc. American Society for Engng. Educ. Conf.*, Pittsburgh, United States (2008).
17. Gillespie, J., Bhatia, K., Jansson, P. and Riddell, W., Rowan University's Clean Energy Program. *Proc. American Society for Engng. Educ. Conf.*, Pittsburgh, United States (2008).
18. Dym, C.L., Agogino, A.M., Eris, O., Frey, D.D. and Leifer, L., Engineering design thinking, teaching and learning. *J. of Engng. Educ.*, 94, 1, 103-120 (2006).
19. Katz, S.M., The entry-level engineer: problems in transition from student to professional. *J. of Engng. Educ.*, 82, 3, 171-174 (1993).
20. Nicometo, C., Anderson, K., Nathans-Kelly, T., Courter, S. and McGlamery, T., *More than just engineers* - how engineers define and value communication skills on the job. *Proc. American Society for Engng. Educ. Conf.*, Louisville, United States (2010).
21. Donnell, J.A., Aller, B.M., Alley, M.A. and Kedrowicz, A.A., Why industry says that engineering graduates have poor communication skills: what the literature says. *Proc. American Society for Engng. Educ. Conf.*, Vancouver, Canada (2011).

BIOGRAPHIES



Mary M. Staehle is an Assistant Professor of Chemical and Biomedical Engineering at Rowan University. Before joining the faculty at Rowan in 2010, Dr Staehle worked at the Daniel Baugh Institute for Functional Genomics and Computational Biology at Thomas Jefferson University and received her PhD in chemical engineering from the University of Delaware. She also holds a BS in Biomedical Engineering from Johns Hopkins University. In the Rowan Engineering Clinic sequence, Dr Staehle has taught Freshman Engineering Clinic I and II, Sophomore Engineering Clinic II and all four semesters of Junior/Senior Engineering Clinic.



Amy R. Reed is an Assistant Professor of Writing Arts at Rowan University, where she teaches upper level technical writing courses in addition to Sophomore Engineering Clinic I. Prior to joining the Rowan faculty in 2012, she earned her PhD in Rhetoric and Writing from Virginia Tech where she worked as a graduate assistant in the Engineering Communication Program. She also holds an MA in English from the University of Dayton and a BS in Biology and a BA in English from The Ohio State University. Dr Reed's primary research areas are in technical and professional writing and medical rhetoric.



Harriet Sharlow Benavidez holds a BA in Education from Purdue University and an MA in Communication from the University of Hawaii. Benavidez has over 30 years of teaching and training experience in government, non-profit and corporate sectors. She has been teaching at Rowan University since 1992. Benavidez teaches public speaking, interpersonal communication and public speaking for engineering students as part of Sophomore Engineering Clinic II. She serves as the Coordinator for communication studies faculty who team-teach this course with engineering faculty.



William T. Riddell is an Associate Professor of Civil and Environmental Engineering at Rowan University. He is currently the Sophomore Engineering Clinic Coordinator for the College of Engineering. Prior to coming to Rowan, he worked at the John A. Volpe National Transportation Systems Center and was a National Research Council Postdoctoral Fellow in residence in the Mechanics of Materials Branch at NASA Langley. His research interests include fracture mechanics and fatigue, sustainability and design education.