Capstone Design Conference 2022
June 6–8, 2022 ▶ Dallas, Texas

Assessment of "Effective" Communication in Design Courses

Rachel E. Horenstein[1], Goncalo Martins[1] and Peter J. Laz[1]
[1]*University of Denver*

Communication is a critical component of preparing engineering students to enter the workforce. The requisite skills include communication to technical and non-technical audiences, which is reflected in ABET's student outcomes. The aims of this paper are to: (1) present methodologies for measuring "effective" communication competency, (2) share observations of areas in which engineering students struggle, and (3) identify potential teaching strategies to support the development of student communication skills. The design experiences and assessment process are used as a framework to evaluate and discuss the development of students with a multi-dimensional communication competency.

Keywords: communication competency, design experience, technical and non-technical audiences

Corresponding Author: Rachel Horenstein, rachel.horenstein@du.edu

Motivation

Communication competency is well-recognized within the engineering profession as a critical trait for a successful career. This competency is so critical that the ability to communicate effectively is explicitly included by the Accreditation Board for Engineering and Technology (ABET) as a desired student outcome for engineering programs.[1] While communication competency is not unique to engineering, its significance in this profession is amplified by the role of engineers in high-impact, high-profile arenas (e.g., public health and safety).[2] Despite exposure to opportunities in academic settings to become proficient communicators, evidence suggests that most engineers lack communication skills that meet professional standards.[3] To better understand why students are not achieving competency in "effective" communication, it is helpful to understand how engineers define "effective" communication.

In a survey of 162 engineers and engineering managers, more than 60% of respondents ranked communication as the most essential skill required to be an effective engineer.[4] Survey results also revealed three overarching themes that encompass how engineers define "effective" communication: "big picture" awareness, willingness to engage, and being a good listener.[4] These identified themes support the importance of recognizing that communication is multi-dimensional (e.g., oral, written, listening, visual, intercultural, interdisciplinary) and addressing this complexity in our pedagogy.

Accordingly, the aims of this paper are to: (1) present methodologies for measuring "effective" communication competency, (2) share observations of areas in which engineering students struggle, and (3) identify potential teaching strategies to support the development of student communication skills. The program assessment process at the University of Denver (DU) demonstrates and provides a framework for a multi-dimensional approach to evaluating "effective" communication competency.

Design Courses at the University of Denver

Interdisciplinary Student Teams

All undergraduate engineering students at DU participate in two design experiences. The first, entitled Integration, is a two-quarter course series taken during the junior year. The second, entitled Engineering Design, is a year-long capstone design course series taken during the senior year. In both experiences, interdisciplinary student teams comprised of all engineering majors (electrical, computer, mechanical) work together to tackle design problems. A major difference between Integration and Engineering Design is the source of the design problem. In Integration, the course instructor provides the design problem and every student team works on solving the same problem. In Engineering Design, students identify, formulate, and solve unique design problems provided by external sponsors (e.g., industry, academic researchers) and work closely with their sponsor throughout the design process.

Student Communication of the Design Process

One emphasis deeply embedded in the design course curriculum is clear communication of the design process through multiple modes of communication. Required documents and the written and visual communications contained therein are summarized in Table 1. Students submit multiple iterations of documentation at various stages of the design process (e.g., requirements, conceptual designs, data to support design decisions, project planning, etc.) and to various stakeholders (course instructors, faculty advisors, project sponsors). These iterations provide an opportunity for students to hone effective written and visual communication skills. Interestingly, students often overlook the importance of visual communication forms (e.g., drawings, diagrams, etc.) and do not recognize the value of visual aids in written and oral communication. Visual communication competency is essential for effective non-verbal communication of content[5] and for an individual's ability to process, store and retrieve information.[6] Iterative development of visuals helps students better understand their projects and accurately identify scope, requirements, functionality, etc. To incentivize students to focus on visual content, presentations were evaluated for well-designed and organized visual materials to effectively communicate ideas. Despite an emphasis on visual communication forms, faculty observations reveal that many students are resistant to devote time to developing and improving this form of communication. Interestingly, these are typically the same students who struggle to propose creative design solutions.

In the 2021-2022 academic year, Engineering Design instructors piloted a System Diagram/Concept of Operations (CONOPs) Workshop. Teams prepared 3 power point slides: (1) project introduction, (2) CONOPs diagram, and (3) system diagram. Slide 1 was intended to provide practice for presenting 2-minute project pitches at the end-of-year symposium. Students were told to use only their CONOPs and system diagrams to explain the purpose of their system from the user's perspective and their system, subsystems, components, and the interactions between them. Teams were given 10 minutes to present to their peers; instructors suggested spending 4-5 minutes on each diagram. After watching another team's presentation, students completed a four-question survey:

1. In layperson's terms, quickly summarize what you learned about this project.
2. Identify 3 strengths (total) of the brief project introduction, system diagram, and/or CONOPs diagram.

After seeing the brief project introduction, system diagram and CONOPs diagram…

3. What questions do you still have about the following topics? *(Students were asked to identify questions related to at least two topics from a provided list)*
4. What are you thinking about your own project? *(Students were prompted to identify aspects of their own project pitch and/or diagram(s) that they were proud of or that could be improved)*

Verbal student feedback on the workshop was overall positive, with many students reporting that reflection on their own project (survey question 4) was the most valuable part of the workshop.

Table 1. Documentation content

Document	Communication
Requirements Document	*Written*: motivation/technical foundation for the design problem, clear, complete, and verifiable requirements. *Visual*: concept of operation (CONOPs) diagram.
Design Document	*Written:* design process (high-level design concepts to specific details), engineering analyses, design alternatives, justification for design decisions, fabrication plans, impact of design. *Visual:* system diagram, functional decomposition, requirements traceability, decision matrices, fabrication drawings.
Verification Document	*Written:* verification procedures/results to demonstrate the system meets the requirements. *Visual:* requirements traceability matrix, verification summary table.
Project Management Plan	*Written:* projected schedule of tasks, team charter. *Visual:* team organizational chart, project schedule, proposed/realized expenditures table, risk assessment table(s).

Program Assessment

For the purposes of program assessment, communication skills are evaluated in both design courses since junior/senior year is when student performance nears the standards for the engineering profession. In the 2020-2021 academic year, the format of assignments and rubrics used in the junior and senior year design courses was standardized to promote consistency and communicate expectations. This standardized approach provides the ability to longitudinally track assessment data within a single cohort for a more comprehensive view of whether student skills improve as students approach graduation. To demonstrate student achievement of "effective" communication, the abilities to effectively communicate in written documents, in oral design review presentations, and orally to a range of audiences are evaluated.

The ability to effectively communicate in written documents is assessed using an "overall quality of documentation" score in the junior and senior design courses at the Final Design Review. To impress upon students the importance of written communication, this team score accounts for 10% of the design review grade. Written documents are evaluated for two criteria: (1) written content, organization, and audience; and (2) engineering format and language. The expectations are that: (1) content is organized, clear, concise, and tailored to the audience, and presented information logically leads to and supports the presented conclusions; and (2) content exhibits formatting and language consistent with that used by professional engineers (e.g., formatting of figures, tables, and references, engineering language, formal grammar). Collected data show that 83.8% of seniors and 54.8% of juniors demonstrated the ability to effectively communicate in written documents (defined by an "overall quality of documentation" score ≥ 80%, n=62/cohort).

The *ability to effectively communicate in oral design review presentations* is evaluated with a presentation score that incorporates multiple communication forms. In Engineering Design, course instructors evaluate student oral communication skills using a team score. In contrast, Integration instructors evaluate oral communication skills using an individual score.

The three criteria (and corresponding expectations) used to determine a team score are: (1) *presentation content, organization, & audience* (Includes organized, clear, and concise content that is tailored to the audience (background, vocabulary, etc.). Presents information that logically leads to/supports the presented conclusions.); (2) *visual content* (Uses well-designed and organized visual materials to effectively communicate ideas.); (3) *preparation & time management* (Team is well prepared and manages the available time to present appropriate content and facilitate discussion. All team members contribute to the presentation, and the team appropriately addresses questions.)

The three criteria (and corresponding expectations) used to determine an individual score are: (1) *presentation delivery* (The individual presents in a professional manner, contributes to the presentation, and appropriately addresses questions.); (2) *presentation content & contribution to design* (The individual presents key pieces of individual engineering work that relate to a design decision; describes his/her/their design process, the key results, and the impact of the work on a specific design decision; demonstrates in-depth knowledge of the design(s); demonstrates that data/analysis were used to support individual contributions); (3) *preparation & time management* (The individual is well prepared and effectively manages the available time to present the desired content and facilitate discussion.)

Data from the 2020-2021 academic calendar year revealed that 100% of seniors and 80.6% of juniors (n=62/cohort) demonstrated the ability to effectively communicate in oral design review presentations (defined as a presentation score ≥ 80%).

Understanding the "Big Picture"

Communication skills characteristic of a successful engineering professional extend beyond technical proficiency and include the ability to communicate a technical narrative to experts and non-experts alike (i.e., a range of audiences). Many engineering graduates consider the ability to effectively communicate with people outside of their area of expertise essential for their jobs[4], suggesting that engineers who can identify/ communicate the "big picture" have an advantage over their coworkers.

One aspect of broader impact thinking is a social, political and business awareness of the large scope of professions that interact with engineers[4]. Because of DU's partnership with industry sponsors, students in the Engineering Design course have a unique opportunity to develop business awareness (i.e., how to treat a customer, write an email, answer/ask questions, etc.). Honing this skillset is important since interactions between engineers and customers can influence whether a business relationship succeeds or fails.[4]

In addition to technical communication of their design, DU engineering students are tasked with demonstrating social and/or political awareness via a written essay on the broader impact of their chosen designs. This essay also addresses ethical and professional responsibilities that relate to the project's scope. Students must reflect on their obligations as engineers to consider a multitude of factors when designing solutions (e.g., global, cultural, social, environmental, economic). They also must demonstrate an ethical and professional responsibility to make informed judgments with considerations of broader impacts. Essay grades are incorporated into program assessment, but are not discussed here since they are not used for communication assessment.

Understanding the Audience

Competency in "audience awareness" includes the ability to effectively interact with individuals that are outside of one's own area of expertise. The "ability to appropriately tailor content to an audience" is already included in the assessment score for effective communication in oral design reviews. Two additional measures that DU uses to measure audience awareness are: (1) audience perception of students' ability to communicate effectively in a presentation to the general public and (2) student self-perception of the ability to communicate effectively with project advisors and DU staff. Data collected are used to evaluate student ability to effectively communicate orally to a range of audiences.

The ability to communicate effectively in a presentation to the public is measured by surveys of attendees of team oral presentations and poster sessions during the end-of-year Senior Design Symposium. The attendees represent a large range in audience, including project sponsors, Industry Advisory Board members, university faculty and staff. Attendees are asked to complete a survey about the teams' 2-minute oral project pitches and subsequent open team visits during a poster session (Table 2). This survey was first introduced in the 2020-2021 academic year. Responders included 6 IAB members, 20 DU faculty, 11 DU staff, and 1 alumnus. The intent is to grow the number of non-faculty responders to account for most of the survey participants. The ability to communicate effectively with sponsors, vendors, faculty, and staff is measured by an end-of-year student survey, also piloted in 2020-2021 (Table 3). Questions were answered on a 1-5 scale (1 = not confident/effective; 5 = very confident/effective). 38 students completed the survey. Most students reported feeling confident and effective in their communication (defined as a response rating ≥4). Survey data from the public demonstrate some agreement with these student perceptions. While almost all students met or exceeded expectations, improving the ability to effectively answer questions is a potential focus for teaching improvement.

Table 2. Audience perception of communication skills.

Survey Questions	% of students meeting or exceeding
Did the 2-minute pitch clearly communicate the goals, details, and outcomes of the project?	97.3% (37 responses)
Did the team clearly communicate the goals, details, and outcomes of the project during your team visit?	97.2% (36 responses)
Was the student team able to answer your questions?	72.2% (36 responses)

Table 3. Student self-assessment of communication skills.

Survey Questions	% of students that felt confident and effective
When communicating with sponsors or external vendors…	
Did you feel confident/prepared?	92.1%
Were you able to communicate your needs, ideas, and technical concepts effectively?	94.7%
When communicating with advisors and DU staff…	
Did you feel confident/prepared?	94.7%
Were you able to communicate your needs, ideas, and technical concepts effectively?	92.1%

Potential Areas for Future Work

Faculty observations include that some students are resistant to incorporating and/or defensive towards instructor feedback during formal design review presentations. This behavior falls within the realm of "effective listening", which is a contributor to overall effectiveness of communication. Finding means to measure students' ability to listen to others and receive feedback, traits that result in better work performance and end results, could be interesting for student and program assessment purposes. For example, creating an assignment or allocating points to incentivize students to take notes during these presentations could prove useful.

"Effective" communication includes a willingness to engage in informal interactions with others[4], but this trait is hard to measure. DU currently uses the CATME Peer Evaluation survey (www.CATME.org)[7–9] to measure students' ability to function on a team. The survey results reflect a combination of five teamwork dimensions. One of these dimensions, "Interacting with Teammates", measures students' ability to: (1) ask for/show interest in teammates' ideas and contributions; (2) make sure teammates stay informed and understand each other; (3) provide encouragement or enthusiasm to the team; and (4) ask teammates for feedback and use their suggestions to improve. Isolating data for this dimension could be a useful method for measuring "willingness to engage".

References

1. Criteria for Accrediting Engineering Programs, 2019 – 2020 | ABET. www.abet.org
2. Werner N, et al. "Speak Up!" A program for teaching communication skills to summer undergraduate researchers. *ASEE Annual Conference*, 2017.
3. de Souza Almeida LM, et al. Understanding industry's expectations of engineering communication skills. *ASEE Annual Conference*, 2019.
4. Nicometo C, et al. "More than just engineers": how practicing engineers define and value communication skills on the job. *ASEE Annual Conference*, 2010.
5. Pudlowski ZJ. An aptitude test and associated research on basic electrical circuits. In: Visual Communication via Drawings and Diagrams. Sydney, 1993:75-91.
6. Riemer MJ. Communication skills for the 21st century engineer. *Glob J Eng Educ.* 2007;11(1):89-100.
7. Loignon A, et al. Facilitating peer evaluation in team contexts: the impact of frame-of-reference rater training. *Acad Manag Learn Educ*. 2017;16(4):562-578.
8. Ohland M, et al. The comprehensive assessment of team member effectiveness: Development of a behaviorally anchored rating scale for self and peer evaluation. *Acad Manag Learn Educ*. 2012;11(4):609-630.
9. Loughry M, et al. Development of a theory-based assessment of team member effectiveness. *Educ Psychol Meas.* 2007;67:505-524.