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Engineering Communication and Engineering Criteria 2000: Assessing the Impact Through Papers Presented at the ASEE Annual Conference

Dr. Kathryn A. Neeley, University of Virginia

Kathryn Neeley is Associate Professor of Science, Technology, and Society in the Engineering & Society Department of the School of Engineering and Applied Science. She has served twice as chair of the Liberal Education/Engineering & Society Division of ASEE and received the Sterling Olmsted Award for outstanding contributions to engineering education. i She is co-chair (with Judith Norback) of the Communication Across Divisions initiative, an effort to coordinate the efforts of all ASEE members who are researching and teaching engineering communication. That initiative is part of a broader effort to encourage a systems approach to engineering communication, that is, across the four years of an engineering curriculum and across institutions.

Mr. Michael Alley, Pennsylvania State University

Michael Alley is a professor of teaching for engineering communications at Pennsylvania State University. He is the author of The Craft of Scientific Writing (Springer, 2018) and The Craft of Scientific Presentations (Springer-Verlag, 2013). He is also founder of the popular websites Writing as an Engineer or Scientist (www.craftofscientificwriting.com) and the Assertion-Evidence Approach (www.assertion-evidence.com).

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Optimism and energy (with a pinch of anxiety) characterized the Liberal Education Division (LED)[1] at the beginning of a new millennium. The enormously influential Accreditation Board for Engineering and Technology (ABET) put forward a radically redesigned process and new criteria for accreditation, which came to be known as "EC2000." The new process focused on educational outcomes rather than credit hours, and the outcomes included a significant number of abilities that the humanities and social sciences (HSS) are essential for developing, including "an ability to communicate effectively." This paper reports on an ambitious (and perhaps foolhardy) work-in-progress that aims to trace the history and evolution of engineering communication over the last 20 years, using papers published in the proceedings of the ASEE Annual Conference as evidence.

The last 20 years are worth analyzing because the implementation of the EC2000 criteria had the potential to transform the way the non-technical (professional) competencies, including engineering communication, are valued and taught within engineering education. The study reported here builds on work by Neeley and Norback (2016) and Neeley, Norback, Bennett, and Laugelli (2020) that analyzes all of the papers on communication published in 2015 and 2019, respectively. That work captures moments in time—what might be called "snapshots"—of engineering communication. The current study expands that approach by focusing on three years (2000, 2010, and 2020) and complements notable attempts (for example, Kynell, 1996 and 1999; Reave 2004; and Read and Michaud, 2018) to go beyond a single institution or instructional strategy to provide a more comprehensive view of engineering communication pedagogy and research.

Because progress—or lack thereof—can best be assessed by looking at the goals that motivated EC2000, we begin by describing how the new criteria and process reflected several different communities' aspirations for the "engineer of the 21st century." Next, we introduce our methodology for analyzing the papers published in the ASEE proceedings as a way to study how the engineering education community has thought about communication over the past 20 years. After identifying trends and themes in each of the 3 years analyzed in this study, we sketch a preliminary history of engineering communication pedagogy and research in ASEE from 2000-2020.

In brief, our initial findings suggest that (1) interest in engineering communication grew in tandem with the implementation of EC2000; (2) momentum built gradually between 2000 and 2010 and more rapidly between 2010 and 2020; (3) meaningful integration of communication into engineering curricula is possible but often not achieved at the level of a curriculum considered as a whole; and (4) the awareness of published research on engineering communication as reflected in the reference lists of the papers increased over the 20 year period, but few papers include a substantial literature review. We discovered that—despite substantial intellectual pedagogical advancements and the delivery of copious amounts of high-quality

[1] The Liberal Education division (LED) is now called the "Liberal Education/Engineering and Society" division (LEES). The name change reflects a desire to emphasize the connection between liberal education broadly defined and what LE has to offer to engineering education. The transition to the new name occurred during the period treated in this study. Throughout the remainder of the paper, we use the current name and its associated acronym, LEES.

instruction by individual instructors—much of the work on engineering communication engages in what might be called “rediscovering the wheel,” that is, independently discovering one’s own strategies when many possibilities are readily available in the published research on engineering communication.

Why EC2000 Generated Optimism, Energy, and (Just a Hint of) Anxiety

To understand why EC2000 generated optimism and energy, it helps to appreciate how the new approach differed from the one that preceded it. The difference was not, as is often asserted in papers on engineering communication, a new recognition of the importance of professional competencies in engineering. Drawing on a historical perspective to establish how EC2000 *could* transform engineering education, Gravander (2004) reminded his readers that “from the outset, engineering education has recognized that the liberal arts contribute to engineers’ ability to practice engineering. . . .[and] engineering curricula have long included *courses* [emphasis added] directed toward preparing engineers to cope with the non-technical aspects of engineering practice” (pp. 4-5).

Gravander goes on to identify a series of reports commissioned by ASEE to study the role of the liberal arts in engineering education between 1918 and 1968. These reports established the “second stem” model that dominated engineering curricula before EC2000 and envision engineering education as consisting of a “main stem” of technical courses and a “second stem” of courses drawn from the humanities and social sciences (Gravander, p. 5). For accreditation purposes, second stem courses had to be “pure” HSS courses; courses that developed “skills,” including communication, did not count. EC2000, then, offered the opportunity to break out of the second stem model in which the HSS and communication had been isolated from the rest of engineering education.

Thus, in contrast to the accreditation process that preceded it, EC2000 implied an integrated approach that could deliver on the potential of the HSS to contribute to engineering education. A report commissioned by ABET to assess the impact of the EC2000 redesign described the motivation for change: “For most of the second half of the 20th century, ABET’s accreditation criteria dictated all major elements of an accredited engineering program, including program curricula, faculty, and facilities. In the mid-1990s, however, the engineering community collectively began to question the validity of such rigid accreditation requirements” (Lattuca, Terenzini, and Fredericks, 2006, p. 1).

The new criteria were designed to allow flexibility and promote pedagogical and curricular innovation. Perhaps most significantly, they incorporated a much more fully articulated vision of the professional competencies that engineering education should develop. (Table 1 lists the outcomes to which the HSS can contribute and elaborates on them in a way that makes their HSS content more explicit.) The anxiety arose from a lack of familiarity and comfort with outcomes-based assessment among LED members and a recognition of the many obstacles that stood in the way of the curricular integration that the new criteria implied. As things turned out, outcomes-based assessment was much less of a problem than the cultural and structural obstacles that stood in the way of integration.

Table 1. Outcomes Articulated in EC2000 That Fall Outside of Engineering as Traditionally Understood and Taught

ABET Criterion 3 Outcomes and Assessment *The description of each outcome as provided by ABET appears in bold type. The elaboration that follows interprets the outcome as it can be developed in the humanities and social sciences.*
(d) **an ability to function on multi-disciplinary teams**: appreciate perspectives that differ from your own and integrate your individual expertise and views with those of other people of both technical and non-technical backgrounds
(e) **an ability to identify, formulate, and solve engineering problems**: identify, formulate, articulate, and solve engineering problems; think critically about and reflect on the processes of problem definition, engineering design, and project management
(f) **an understanding of professional and ethical responsibility**: understand professional and ethical responsibilities as they apply to both particular engineering projects and to the engineering profession as a whole
(g) **an ability to communicate effectively** with both expert and non-expert audiences
(h) **the broad education necessary to understand the impact of engineering solutions in a global and societal context:** understand the impact of engineering solutions in a global and social context and use that understanding in the formulation of engineering problems, solutions, and designs
(i) **a recognition of the need for, and ability to engage in, lifelong learning:** the development of the research and analytical skills necessary to engage in lifelong learning and understand why it is necessary
(j) **a knowledge of contemporary issues**: recognize and analyze the role that technology and engineering play in important contemporary issues and use a knowledge of social and historical context to put contemporary issues in perspective
ABET Criterion 4 Outcomes and Assessment **As part of the major design experience, consider and integrate economic, sustainability, ethical, political, health and safety and sociopolitical issues into the design, implementation, and management of technological systems**: systematically explore the full range of non-technical issues that are part of the problem addressed by the project and might arise in the design, implementation, and management of technological systems that make up the context of the project

These outcomes provide a fairly detailed description of what engineering graduates should get out of their education, but they do not explain either the motivation behind the new approach or the means by which the outcomes could be achieved. To understand motivation and means, we turn to three different communities: thought leaders in engineering education, LEES, and technical communication. Collectively, these three communities articulated both what the new system should achieve and how it could be achieved. Thus, they provide a set of criteria and categories for assessing both the impact of EC2000 on engineering communication and the extent to which engineering communication pedagogy has progressed over the last 20 years.

"The Engineer of 2020": Thought Leaders in Engineering Education Make the Case for Transformation and Integration

While the LEES community was generally enthusiastic about the new criteria, the impetus for changing the accreditation process in a way that could transform engineering education came from elsewhere: thought leaders in engineering. The aspirations of the thought leaders achieved one of their most clear and full expressions in *The Engineer of 2020: Visions of Engineering in a New Century* (2004), a report from the National Academy of Engineering (NAE). Although the EC2000 criteria and the attributes of the engineer of 2020 were apparently developed by separate groups and organizational processes, they converge nicely. *The Engineer of 2020* identifies the traits needed by the engineers of the future, and the EC2000 criteria establish a set of goals for engineering education that would prepare engineering graduates for leadership roles.

The Engineer of 2020 report was written by what the NAE website characterizes as "a group of distinguished educators and practicing engineers from diverse backgrounds." The group systematically projected possible future scenarios, "based on current scientific and technological trends," as the basis for establishing the roles that engineers could and should play in those possible futures. The working group then used these scenarios to identify "the ideal attributes of the engineer of 2020" and describe "ways to improve the training of engineers to prepare them for addressing the complex technical, social, and ethical questions raised by emerging technologies."

The Engineer of 2020 casts engineers in the role of change agents and leaders in both the private and public sector and focuses on the opportunities that lay ahead: "The years between the present and 2020 offer engineering the opportunity to strengthen its leadership role in society and to define an engineering career as one of the most influential and valuable in society and one that is attractive for the best and the brightest" (p. 48). Realizing these aspirations, the report's authors continued, would require the engagement of both "engineering educators and practicing engineers" in the redesign of "engineering curricula and related educational programs to prepare today's engineers for the careers of the future, with due recognition of the rapid pace of change in the world and its intrinsic lack of predictability" (p. 51).

Although *The Engineer of 2020* does not specifically treat the role of the liberal arts in engineering education, the new vision that is articulated suggested what Gravander (2004) described as "a fundamental reconceptualization of the role of the liberal arts in engineering education. . .possible. . .only recently because of a revolutionary transformation of engineering education that is being driven by new accreditation criteria that became effective in 2000" (p. 3). Subsequent experience would show that "revolutionary transformation" was far from predetermined. It was nonetheless apparent that achieving the new vision would require transformation of engineering education.

The LEES Community Establishes Integration as an Ideal

Many publications articulate the aspirations and hopes of the LEES community at the time of the launch of EC2000. We focus here on ideals articulated in *Liberal Education in Twenty-First Century Engineering* (2004), a collection of papers and articles organized by LEES members that also included the perspectives of engineers who were not participants in LEES but were committed to the transformational potential of the new criteria. This volume offers as close as we have gotten to a comprehensive vision of the curricular possibilities of the new approach to accreditation. It also specifies (at least by implication) criteria according to which LEES members would evaluate the success (or lack thereof) of EC2000.

Liberal Education in Twenty-First Century Engineering treats outcomes other than communication and puts EC2000 in the context of earlier attempts to define the role of liberal education within engineering education, including Florman's *The Civilized Engineer* (1968) and Gianniny's "A Century of ASEE and Liberal Education" (1995). We focus here on three chapters that deal with effective communication instruction for engineers and reflect three different institutional contexts: N. C. State (Miller), MIT (Perelman), and the University of Virginia (Neeley). It is important to note that all three of these chapters situate engineering communication as a humanistic pursuit that permeates engineering education.

Like other communication specialists addressing an audience of engineers and engineering students, Miller focuses on classical rhetoric's emphasis on "practical communication tasks" and "the integration of communication into the student's work in a variety of courses" (p. 42). Drawing on an understanding that communication proficiencies "need to be developed through sustained and systematic processes" (p. 69), Perelman describes the rationale for and essential features of a communication-intensive undergraduate curriculum in engineering. Perelman recognizes the demands that communication-intensive curricula place on faculty and administrators when he describes the creation of such curricula as "a delicate political and philosophical process" that will require "defining and redefining the roles and responsibilities of all faculty at science- and engineering-based universities" (p. 78-79). Neeley reminds us that EC2000 is not the first attempt to revolutionize engineering education and identifies characteristic ways of thinking about engineering communication instruction that will need to be overcome to achieve integration.

Taken together, the discussions of engineering communication in *Liberal Education for Twenty-First Century Engineering* articulate three foundational perspectives for transforming the teaching of engineering communication in response to EC2000.

First, we need an **integrated view** that does not separate communication from engineering work, "a view of communication that makes it not only a result that can be graded or assessed but also, and more important, a medium of interaction that facilitates other activities, a strategic and situated process, and an evidentiary record of social and intellectual effort" (Miller, p. 44).

Second, a more robust engineering communication approach requires an understanding of **communication as both a field of expertise and an interdisciplinary enterprise**. This more robust approach abandons the impoverished view of communication reflected in the vocabulary of "skills" and "technical writing" as a description of the proficiencies that engineers need for success in practice. Neeley argues that we will need to "[g]o beyond generalizations and ready explanations to inquire into the changes in the organization of engineering work and the broader cultural changes that have led to renewed interest in the communication abilities of engineers" (p. 56).

Third, achieving the goals established by EC2000 will require engineering educators to design **curricula, not just courses**, and "students should receive instruction and feedback in writing and speaking during each undergraduate year; and that responsibility should be distributed across the entire . . .curriculum" (Perelman, p. 65).

The Technical Communication Community Adds Specificity to the Evaluation Criteria by Distinguishing Among Different Models of Integration

In the same year as *Liberal Education for Twenty-First Century Engineering* was published, Reave (2004) published a survey of technical communication instruction at top-ranked U.S. and Canadian programs. Although several organizations and journals are devoted to technical communication, we highlight Reave's paper because it takes an approach that is valuable but seldom pursued: going beyond a single course, intervention, or institution. Taken together, *Liberal Education for Twenty-First Century Engineering* and "Technical Communication Instruction in Engineering Schools: A Survey of Top-Ranked U.S. and Canadian Programs" allow us to develop a reasonably comprehensive view of the aspirations and hopes of both the LEES and the technical communication communities.

Reave focuses on the "initiatives that engineering schools are taking to improve communication instruction for their students, including required courses in technical communication, integrated instruction, elective courses, and engineering communication centers" (p. 452). Reave's formulation of integrated instruction goes beyond the ideal of integration as articulated by the LEES community by specifying that integration requires engaging communication experts in instruction and building communication instruction into core engineering courses. Like all taxonomies that attempt to categorize modes of developing professional competencies in engineering, Reave's modes of delivery constitute more of a spectrum than a set of distinct entities and are not entirely logically consistent. The value of Reave's study for our purposes lies in the breadth and number of programs that she analyzed.

Reave makes two astute observations that capture crucial distinctions with respect to engineering communication. First, "**requiring performance is not the same thing as *providing instruction*** [emphasis added]" (p. 464). Making this distinction means that administrators cannot "claim that technical communication is being taught through integrated instruction. . .[just because] students are doing some writing and speaking in a course." Second, most engineering schools seem to assume that they must choose between stand-alone and integrated instruction when in reality "this restriction is a classic logical fallacy—some schools use both approaches together, and others, unfortunately, use neither. The most comprehensive approach is to **use stand-alone and integrated instruction to provide concentrated attention as well as continued practice within the discipline"** [emphasis added] (p. 473).

One of Reave's greatest contributions is highlighting the many ways in which all forms of apparent integration are not equal. Reave expresses the heart of the distinction between authentic and inauthentic integration succinctly: "A solid engineering communication program can be built only by experts who are motivated to deliver excellence in communication instruction" (p. 470). Inauthentic versions of integration, in contrast, are those in which the idea that "everyone should teach writing [is misinterpreted as meaning that] anyone can teach writing" (p. 470), test scores are treated as evidence of technical communication competency, and any course in which students read or write qualifies as communication instruction. These observations form the basis for distinguishing "authentic" and "inauthentic" integration as summarized in Table 2. The five conceptual models of engineering communication instruction that Reave identifies are listed below from most to least potential for authentic integration.

Table 2. Differences Between Authentic and Inauthentic Integration as Reave Defines Them

Conceptual Model of Integrated Communication Instruction	**Authentic Version**	**Inauthentic Version**
1. partnership	"true partnership" exists when faculty from communication and engineering collaborate on instructional design, delivery, and evaluation (p. 464)	• failing to acknowledge the expertise gap between communication faculty and engineering faculty • assuming that good writing is good writing in any discipline
2. team teaching *(partnership on a larger scale)*	"a whole team of communication faculty and instructors works with a team of engineering faculty and assistants" (pp. 464-465)	students and engineering faculty in team-taught courses view the technical topic as the primary focus and "see communication or writing as a skill set with a "handmaiden status"' (Shwom cited by Reave, p. 472)
3. communication across the curriculum (CAC)	• "In an engineering school, true CAC instruction means that instruction is distributed throughout the student's course work" (p. 466) • These programs "keep communication consistently in the foreground, showing its relevance to engineering practice" (p. 467)	• implicitly signaling that communication is peripheral by requiring one or two courses at the introductory level + senior capstone reports • treating technical communication as "a basic skill such as literacy" (p. 468)
4. communication modules in technical courses	"separate, usually one-credit, modules added on to engineering courses" usually an optional extension requested by engineering faculty" (p. 465)	assuming that instruction in management or leadership can substitute for focused communication instruction
5. expert feedback *barely qualifies as integration*	communication experts evaluate papers and reports and may meet individually with students but do no classroom teaching	graders with minimal expertise in communication focus on grammar and mechanics

Developing a Comprehensive View: Methods and Methodological Complications

Given that EC2000 was designed to transform all of engineering education, evaluating the impact of EC2000 on engineering communication instruction requires a body of evidence with a reasonable claim to being comprehensive or at least representative. The design of our study assumes that the body of papers published in the proceedings of the ASEE annual conference provides one example of such evidence. Even when we limit the scope to the period from 2000 until 2020, there is a daunting number of papers to consider (approximately 500).

Given this volume, we sampled the papers at equivalent time intervals of ten years between our samples. For each of the 3 years (2000, 2010, and 2020), we used the search function in the PEER repository to identify papers dealing with engineering communication. Specifically, we conducted a title search for "communication *or* writing *or* speaking *or* presentations" and then examined the papers individually to determine whether they serve one or more of four functions:

(1) develop or assess the communication abilities of engineering students,
(2) assess student attitudes and experiences in communication courses,
(3) analyze pedagogical strategies or curriculum design processes for teaching engineering students to communicate, or
(4) provide fundamental understanding of engineering writing and speaking.

The search function in PEER makes it possible to identify trends across the divisions of ASEE and over time, but this function is far from perfect. A strategy like the title search we used produces results that are much more manageable than those for an open search for "communication" or "technical writing" but also yields results that are not relevant for understanding how engineering communication pedagogy has evolved between 2000 and 2020. We excluded as not relevant:

- papers on "community,"
- topics that obviously were not communication (faculty salaries, for example),
- "communications" as that term is used in electrical and computer engineering,
- choosing the right technology (hardware and software) for an educational enterprise other than engineering communication,
- papers on writing or speaking used simply as a means to understand another aspect of engineering education—for example, the effect of a global experience, and
- papers about courses designed for non-engineering student groups.

A few of the papers in our study were not returned by the title search described above, but came to our attention in other ways, such as work on research projects other than this one.

In our preliminary analysis of the papers, we focused on evidence in the categories articulated by the various stakeholder groups we analyzed above:

- an integrated view that does not separate communication from engineering work
- understanding communication as both a distinctive field of expertise and an interdisciplinary enterprise
- designing curricula, not just courses
- recognizing various degrees and modes of integration

Trends and Themes

We hope that what we have presented so far provides a sense of the amount of work that was required to define the scope of our study and to identify and catalogue the papers. This paper is very much a "work-in-progress," but there are some trends that have emerged.

2000 Papers: Responding to EC2000, Establishing the Intellectual and Organizational Foundations for Integration

In 2000, there were 14 papers relevant to the purposes of our study. One theme that ran across all of the papers was EC2000, typically formulated as "a new national focus on outcomes by engineering educators, industry mentors, and ABET evaluators, [that means that] communication skills and teamwork have become a much more prominent part of the engineering curriculum" (Anderson, p. 1) As we mentioned earlier, the history of liberal education as a part of engineering education demonstrates that the truly new dimensions of EC2000 were not the focus on non-technical outcomes, but rather the outcomes-based approach itself and the significantly more detailed description of the professional competencies in the list of outcomes.

Approximately half of the papers demonstrate a heightened awareness of the opportunities for students to practice communication in informal contexts such as community service projects, laboratory courses, team projects, and classrooms—but without apparent emphasis on actually teaching students how to communicate. For example, Newell's "The Business Meeting: An Alternative to the Classic Design Presentation" treats engineering communication as situated in a particular context that provides the communicators with a clearly identified audience, well-defined goals, and a set of conventions about how the communication should be structured. That paper does not, however, go beyond describing the assignment to specify the component communication competencies that should be exemplified in the alternative format. Other papers offer advice for taking advantage of technical capabilities in presentations (high-tech presentations and grading of written work).

In contrast to the papers that focus on awareness and opportunity, several other papers provide clear evidence that the intellectual foundations, basic collaborative arrangements, and pedagogical tools already existed to make integrated instruction not just possible but also successful. "Using Multi-Disciplinary Teams to Teach Communication to Engineers, Or Practicing What We Preach" (Anderson, Kelso, Yarnoff, Shwom, and Hirsch) describes "a design and communication course (Engineering Design and Communication) for engineering freshmen based on a cross-disciplinary approach and taught by multidisciplinary teams" (p. 1). This course design and others like it take advantage of three distinctive affordances of interdisciplinary team teaching: (1) the intellectual and practical similarities between design and communication, (2) demonstrating through the participation of faculty from the engineering disciplines "that engineers value—and depend on—communication," (p. 1) and (3) enacting interdisciplinary integration and collaboration through authentic team teaching that demonstrates the investment of all faculty members in the teaching of the course.

Gribb and Alford's "Using Writing to Improve Retention: Communications Assignments in a Freshman Year Experience Course for Engineers" describes a similar course design with an emphasis on "the relevance of science and math to the challenging and creative work of engineering" (p. 1) and a series of writing, speaking, reading, and listening assignments designed collaboratively by writing professionals and engineering faculty. "Team Teaching Technical

Topics: An Innovative Approach to Instruction in an Introductory Civil Engineering Course" (Camp, Palazolo, and Phillips) describes the "radical redesign" that transformed a disconnected sequence of three civil engineering introductory courses (surveying, computer usage, and programming) into an integrated three-course sequence that is team taught by faculty from writing studies and civil engineering.

The most fully realized example of authentic integration in the 2000 papers is "Improving the Engineering and Writing Interface: An Assessment of a Team-Taught Integrated Course" (Johnson *et. al*) authored by a team of faculty from the College of Communication and the College of Engineering at Rowan University, a new engineering school established in southern New Jersey by a donation of $100,000,000 from industrialist Henry Rowan. The integration of communication and engineering is part of all four years of the engineering curriculum through a a "multidisciplinary, project-oriented Engineering Clinic sequence" modeled after the medical school concept. The Engineering Clinics are taught at all four levels of the curriculum, and every student—in all engineering majors—participates in them. The paper itself focuses on Sophomore Engineering Clinic I, "which integrates the engineering clinic with a specialized version of the required second semester composition course" (p. 2).

As a new engineering school that is not weighted down by 100+ years of traditional curricular design, Rowan is in an ideal position to create an innovative, comprehensive, and integrated approach to engineering communication. The small size of the Rowan student body (15-35 students in each entering class and 66-140 students total) undoubtedly makes integration easier, but this paper demonstrates strategies for engineering-communication collaboration that can be applied in any context. It is also worth noting that, unlike several of the innovative programs that have emerged over the years, the program at Rowan is still going strong.

2010 Papers: Greater Awareness of Published Research and Building on the Intellectual and Organizational Foundations of Integration

In 2010, although the total number of papers that fell into our categories did not increase significantly (17 in 2010 vs. 14 in 2000), awareness of published research did increase. In 2000, the average number of references was 6.4, but in 2010, the average number was 13.6, which is more than a 100 percent increase. Whereas the median number of references in 2000 was 4.5 and the mode was 1, the median number of references for 2010 was 10 and the mode was 7. In essence, almost every paper in 2010 attempted to bring in a range of sources, whereas almost half of the papers in 2000 had only one to three citations. The number of references is, of course, only a crude measure of awareness of published research. That said, the increase suggests that ASEE authors writing on engineering communication were beginning to move beyond discovering the topic and becoming part of a scholarly community. It also reflects another significant change since 2000: the increasing number of engineering faculty who identify engineering education as one of their research areas.

The 2010 papers provide ample evidence that the transformative practices identified above were fully developed and being implemented successfully. Two papers exemplify what can be achieved in interdisciplinary collaborations that combine engineering disciplinary expertise with expertise in communication, engineering education, and areas such as management and social psychology.

“Infusing Communication Skills in an Engineering Curriculum” by Eichorn *et al.* describes the design of and rationale for engineering communication instruction in a new electrical and computer engineering program. This new program incorporates the full range of transformative practices outlined above: team teaching in true partnership, an integrated approach to communication, and designing curricula not just courses. The design team included faculty from the institution’s School of Communication, Media, and the Arts along with faculty from computer science and senior leadership in electrical and computer engineering. The paper highlights the multifaceted nature of engineering communication and the value of embedding communication instruction in organizational and intellectual contexts: “This point of view takes an approach that is not always embraced by communication specialists in the engineering community” (p. 6).

The DeFranco, Deek, and Sangwan paper, “Promoting Effective Communication in Global Engineering Projects,” reports on research (an extensive literature review and survey) designed to inform engineering communication instruction. Although the paper responds directly to increasing numbers of engineering projects undertaken by teams “across different sites in different geographic locations and across different time zones” (p. 1), it is also concerned with “the development of critical Systems Engineering behaviors” (p. 1) required for designing any large-scale, complex sociotechnical system. All three authors hold PhDs in computer and information science but also have expertise in areas such as group cognition, collaborative learning, and industrial practice. Thus, they qualify as integrative individuals, that is, people with interdisciplinary expertise. Their paper exemplifies another good practice in the design of engineering communication pedagogy: conducting a substantial literature review that makes it possible to define their pedagogical goals more precisely and avoid “reinventing the wheel,” that is, spending time developing strategies that have already been successfully developed somewhere else.

2020 Papers: Increased Attention to Integration, Expertise, Interdisciplinarity, and Curricula (vs. Courses)

In 2020, 11 of the 34 papers yielded by our search were excluded as not relevant. The remaining 22 papers showed more extensive development and application of at least one of the transformative practices identified in *Liberal Education for Twenty-First Century Engineering:* (1) integrated view of communication and engineering, (2) communication as both a field of expertise and an interdisciplinary enterprise, and (3) designing curricula, not just courses.

In a paper from the University of New Haven (“A Partnership Model for Integrating Technical Communication Habits Throughout Undergraduate Engineering Courses”), Horvat and Randi focus on teaching communication in the Department of Chemical Engineering: This paper demonstrated the first *Liberal Education* theme through its focus on the value that arises when faculty from different disciplines (one chemical engineering, the other writing) collaborate. Here, the authors abided by the definition of “authentic collaboration,” as given by Reave (2004). Moreover, because this teaching occurred over two semesters and was part of a college-wide initiative to integrate writing into all four years, the paper demonstrated the third theme of designing curricula, not just courses.

The theme of designing curricula was seen in another 2020 paper that was also from the University of New Haven. Titled “A Three-Course Laboratory Sequence in Mechanical

Engineering as a Framework for Writing," this paper by Carnasciali *et al.* arose from the same college-wide initiative as the Horvat and Randi work. The University of New Haven was not alone in attempting to integrate communication throughout the curriculum. A similar scope was seen in two other 2020 papers—one by Bauer from Southern Methodist University ("Integrating Writing Throughout the Engineering Curriculum") and the other by McCollum, Pfluger, and Butkus at the United States Military Academy ("Technical Communications in an Environmental Engineering Curriculum").

The University of Illinois paper by Kovanen *et al.* ("Implementing Writing-as-Process in Engineering Education") reported on a fully realized example of treating communication as both a field of expertise and an interdisciplinary enterprise. This paper describes an interdisciplinary collaboration of seven authors from various writing disciplines and three authors from engineering or science and focuses in depth on an important area of writing pedagogy: writing as process. This paper was not the first such collaboration to come out the University of Illinois.

Another trend was a greater awareness of published research. Table 3 summarizes the quantitative results of our analysis, including the number of references for each of the three years. While the number of citations by itself does not necessarily reflect the quality of a literature review, it does provide insight into the expectations that authors assume for the rigor of the publication. As seen in the table, both the number of papers and the average number of references increased each year. Although the average for 2020 was aided by the 62 references for one paper (Kovanen *et al.* 2020), the increases in both median number of references and the mode for references reflect a general increase in depth for the literature reviews of that year's set of papers. Such an increase is not surprising, given ASEE's push in the last twenty years to increase the rigor in reviews of papers. What is important, though, is that engineering communication papers have responded in a significant way to that impetus.

Table 3. Summary of Quantitative Results

Year	**Number of Papers on Communication**	**Average Number of References**	**Median Number of References**	**Mode for References**
2000	14	6.4	4.5	1
2010	17	13.6	10	7
2020	22	18.0	13.5	10

The contrast between the 2020 paper by Horvat and Randi and the 2000 paper by Gribb and Alford captures the change that occurred over 20 years. Both papers focus on the benefits of collaboration between writing faculty and engineering faculty; however, while the works cited for the 2000 paper consisted of 3 sources, the 2020 paper had 29 citations. In addition to sources motivating the work, the literature review by Horvat and Randi spanned the subjects of best practices in writing instruction, writing across the disciplines, and integrating writing partnerships.

The papers published in 2020 also suggest another trend: the diffusion of the scholarly discourse on engineering communication within ASEE. Although LEES has the most papers involving engineering communication, such papers also arise from a host of divisions. For instance, during 2020, papers arose in the following divisions: LEES (8), Educational Research and Methods (2), Materials (2), Mechanical Engineering, First-Year Programs, Multidisciplinary Engineering, Environmental Engineering, Electrical and Computer Engineering, Cooperative and Experiential Education, Engineering Libraries, Experimentation and Laboratory-Oriented Studies, Graduate Studies, Student, and Faculty Development. This expansion reflects the increasing levels of engagement of engineering faculty in communication instruction, but it also contributes to fragmenting the discourse on engineering communication and making it more difficult for authors to be aware of other scholars working on the same topic.

Closing Observations: Where Do We Stand and Where Do We Go from Here?

The preliminary analysis reported here suggests that the implementation of EC2000 increased interest in communication within ASEE and expanded the community of scholars who teach and research engineering communication. Within this expanded community, multidisciplinary collaborations have become increasingly common and made it possible to achieve authentic integration of communication instruction that connects communication with engineering work and learning, recognizes communication as both an area of specialization and an interdisciplinary enterprise, and engages in the design of entire curricula (not just courses). Not surprisingly, some of the most successful efforts at integration have occurred in new engineering schools and programs, particularly those that receive industry or alumni funding. In sum, we have the intellectual foundations and pedagogical strategies required to realize the integrated vision of EC2000, but we do not seem to have the structures and institutional commitments that are needed for engineering communication to flourish as an integral part of engineering curricula, especially those with long histories and large student bodies.

Several factors explain why the hoped-for transformation did not occur pervasively. Engineering faculty—including the department chairs and deans who make decisions about funding—were not significantly represented in the stakeholder groups that advocated for the changes embodied in EC2000 and may not be aware of the possibilities of integrating communication into the engineering curriculum. Although many engineering faculty share the aspirations reflected in *The Engineer of 2020*, the incentive structures within which they operate and the priority most institutions place on investing in research discourage significant investments in communication instruction. Lastly, and perhaps most significantly, the accreditation process and criteria changed, but the accreditors themselves remained essentially the same.

Another major challenge is the conditions under which many instructors of engineering communication work. They typically have heavy teaching and grading loads and no funding for traveling to conferences or conducting systematic research. These structural problems manifest themselves in the recurring pattern we have called here "rediscovering the wheel." In such cases, an engineering college, department, or course begins teaching engineering students how to write and speak as engineers. Building its program or course on resources at hand, the instructor or instructors discover a number of strategies that improve the instruction and then write a paper detailing those improvements. The paper is presented at ASEE and little, if anything, changes outside that particular college, department, or course.

What would deepen such a contribution would be an analysis of the strategies in the context of what other schools have done. As things currently stand, we are not consolidating knowledge, applying best practices, and taking advantage of the research that others have done to the extent that we could—nor are we supporting newcomers to engineering communication as well as we could. The study reported here is a step in the direction of creating a network of people interested in engineering communication across divisions of ASEE. We welcome collaborators in this effort.

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9. Horvat, K., & Randi, J. (2020, June), A Partnership Model for Integrating Technical Communication Habits Throughout Undergraduate Engineering Courses. Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual Online. 10.18260/1-2—34029.
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Appendix: Papers Included in This Study

2000 Papers

Anderson, J. C., & Kelso, D., & Yarnoff, C., & Shwom, B., & Hirsch, P. (2000, June), Using Multi Disciplinary Teams To Teach Communication To Engineers, Or "Practicing What We Preach" Paper presented at 2000 Annual Conference, St. Louis, Missouri. 10.18260/1-2--8815.

Davis, M. T. (2000, June), Technical Communication: Partner In Abet Accreditation And Assessment Paper presented at 2000 Annual Conference, St. Louis, Missouri. 10.18260/1-2--8764.

Gohmann, E. (2000, June), Opportunities To Teach Teamwork, Collaboration, And Interpersonal Communications In Mechanical Engineering Technology Courses Paper presented at 2000 Annual Conference, St. Louis, Missouri. 10.18260/1-2--8609.

Gribb, M. M., & Alford, E. M. (2000, June), Using Writing To Improve Retention: Communications Assignments In A Freshman Year Experience Course For Engineers Paper presented at 2000 Annual Conference, St. Louis, Missouri. 10.18260/1-2--8826.

Jack, H. (2000, June), High Tech Presentations The Easy Way Paper presented at 2000 Annual Conference, St. Louis, Missouri. 10.18260/1-2--8425.

Jalkio, J. A. (2000, June), Incorporating Design, Communications, Teamwork, And Modeling In A Controls Laboratory Experience Paper presented at 2000 Annual Conference, St. Louis, Missouri. 10.18260/1-2--8448.

Johnson, F. S., & Sun, C. C., & Marchese, A. J., & Newell, H. L., & Schmalzel, J. L., & Harvey, R., & Ramachandran, R., & von Lockette, P., & Dahm, K. (2000, June), Improving The Engineering And Writing Interface: An Assessment Of A Team Taught Integrated Course Paper presented at 2000 Annual Conference, St. Louis, Missouri. 10.18260/1-2--8445.

Kenny, W., & Myers, K., & Cornell, H. (2000, June), An Investigation Of The Communication Culture Of An Introductory Chemical Engineering Class Paper presented at 2000 Annual Conference, St. Louis, Missouri. 10.18260/1-2--8518.

Miller, D. J. (2000, June), The Student Consultant: Enhancing Communication Skills In The Undergraduate Laboratory Paper presented at 2000 Annual Conference, St. Louis, Missouri. 10.18260/1-2--8714.

Newell, J. A. (2000, June), The Business Meeting An Alternative To The Classic Design Presentation Paper presented at 2000 Annual Conference, St. Louis, Missouri. 10.18260/1-2--8193.

Nicklow, J. W. (2000, June), Technical Writing In An Undergraduate Design Course Paper presented at 2000 Annual Conference, St. Louis, Missouri. 10.18260/1-2--8765.

Ordonez, R., & Benavidez, H., & Marchese, A. J., & Newell, J. A., & Schmalzel, J. L., & Sukumaran, B., & Ramachandran, R., & Haynes, J. (2000, June), A Pedagogical Concept Of Integrating Multidisciplinary Design And Technical Communication Paper presented at 2000 Annual Conference, St. Louis, Missouri. 10.18260/1-2--8621.

Pinkus, R. A., & Simmons, C. A. (2000, June), Professional Writing Seminar For Engineering Students: A Pilot Project And Evaluation Paper presented at 2000 Annual Conference, St. Louis, Missouri. 10.18260/1-2--8638.

Switzer, S. L., & Ray, C. S. (2000, June), Improving Written Communication Skills In University Engineering / Technology Programs: The Grading Nightmare Paper presented at 2000 Annual Conference, St. Louis, Missouri. 10.18260/1-2--8446.

2010 Papers

Alley, M., & Garner, J., & Zappe, S. (2010, June), Projected Words Per Minute: A Window Into The Potential Effectiveness Of Presentation Slides Paper presented at 2010 Annual Conference & Exposition, Louisville, Kentucky. 10.18260/1-2--16059.

Alvarez, E., & Saville, S., & Mefford, O. T., & DesJardins, J. (2010, June), The Use Of Conference Preparatory Principles And Practices (Writing And Presentation Skills) To Teach Interdisciplinary Laboratory Courses Paper presented at 2010 Annual Conference & Exposition, Louisville, Kentucky. 10.18260/1-2--16632.

Atwood, S., & Patten, E., & Pruitt, L. (2010, June), Outreach Teaching, Communication, And Interpersonal Skills Encourage Women And May Facilitate Their Recruitment And Retention In The Engineering Curriculum Paper presented at 2010 Annual Conference & Exposition, Louisville, Kentucky. 10.18260/1-2--15641.

BouSaba, N. N., & Conrad, J., & Gehrig, B., & Hoch, D., & Heybruck, W., & Kane, M., & Schmidt, P., & Sharer, D., & Patterson, S. (2010, June), Successes Of An Early Conceptual Design Presentation For Senior Design Projects Paper presented at 2010 Annual Conference & Exposition, Louisville, Kentucky. 10.18260/1-2--16384.

DeFranco, J., & Deek, F., & Sangwan, R. (2010, June), Promoting Effective Communication In Global Engineering Projects Paper presented at 2010 Annual Conference & Exposition, Louisville, Kentucky. 10.18260/1-2--15645.

Eichhorn, K., & Thompson, C., & Vampola, D., & Messere, F., & Manseur, R. (2010, June), Infusing Communication Skills In An Engineering Curriculum Paper presented at 2010 Annual Conference & Exposition, Louisville, Kentucky. 10.18260/1-2--15778.

Epstein, A., & Easton, J., & Murthy, R., & Davidson, E., & de Bruijn, J., & Hayse, T., & Hens, E., & Lloyd, M. (2010, June), Helping Engineering And Science Students Find Their Voice: Radio Production As A Way To Enhance Students' Communication Skills And Their Competence At Placing Engineering And Science In A Broader Societal Context Paper presented at 2010 Annual Conference & Exposition, Louisville, Kentucky. 10.18260/1-2--16230.

Estell, J. K., & Reid, K., & Laird, L. (2010, June), Cheeseburger, Fries, And A Coke: It's About The Presentation Paper presented at 2010 Annual Conference & Exposition, Louisville, Kentucky. 10.18260/1-2--15706.

Hsieh, S., & Sun, A. (2010, June), Communication Needs In Collaborative Automated System Design Paper presented at 2010 Annual Conference & Exposition, Louisville, Kentucky. 10.18260/1-2--15963.

Larkin, T. (2010, June), The "Write" Path To Effective Student Understanding In Physics Paper presented at 2010 Annual Conference & Exposition, Louisville, Kentucky. 10.18260/1-2--16430.

Lockwood, S., & Caswell, D., & Eggermont, M. (2010, June), The Challenge Of Consistent Grading In Real World, Open Ended Design With Multiple And Multi Disciplinary Instruction Paper presented at 2010 Annual Conference & Exposition, Louisville, Kentucky. 10.18260/1-2--16642.

Nicometo, C., & Anderson, K., & Nathans-Kelly, T., & Courter, S., & McGlamery, T. (2010, June), “More Than Just Engineers” How Engineers Define And Value Communication Skills On The Job. Paper presented at 2010 Annual Conference & Exposition, Louisville, Kentucky. 10.18260/1-2--16018.

Richards, B., & Milanovic, I. (2010, June), Partnership Between Engineering And Professional Writing Paper presented at 2010 Annual Conference & Exposition, Louisville, Kentucky. 10.18260/1-2--15926.

Ross, P. (2010, June), Space Exploration: Science, Engineering, And Social Impact In A Freshman Technical Communication Course Paper presented at 2010 Annual Conference & Exposition, Louisville, Kentucky. 10.18260/1-2--16712.

Sinnreich-Levi, D., & Metz, S., & Silverstein, D. (2010, June), Improving The Ability Of Engineering Students To Communicate To Non Technical Audiences Paper presented at 2010 Annual Conference & Exposition, Louisville, Kentucky. 10.18260/1-2--16078.

Utschig, T., & Norback, J. (2010, June), Refinement And Initial Testing Of An Engineering Student Presentation Scoring System Paper presented at 2010 Annual Conference & Exposition, Louisville, Kentucky. 10.18260/1-2--16824.

Waggenspack, W., & Liggett, S., & Hull, W., & Bowles, D., & Sears, S., & Thomas, D., & Davis, P. (2010, June), Incorporating Visual Communications Assignments To Enrich Education In All Engineering Disciplines Paper presented at 2010 Annual Conference & Exposition, Louisville, Kentucky. 10.18260/1-2--16090.

2020 Papers

Alley, M., & Garner, J. K., & Pigeon, K. (2020, June), WIP: Online Tutorials to Help Undergraduates Bridge the Gap Between General Writing and Engineering Writing Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—35563.

Briliyanti, A., & Rojewski, J. W., & Colbry, D. J. L., & Luchini-Colbry, K. (2020, June), STEMAmbassadors: Developing Communications, Teamwork, and Leadership Skills for Graduate Students Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—35207.

Bauer, D. H. (2020, June), WIP: Integrating Writing Throughout the Engineering Curriculum Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—35548.

Carnasciali, M., & Dieckman, E. A., & Orabi, I. I., & Daniels, S. D. (2020, June), A Three-course Laboratory Sequence in Mechanical Engineering as a Framework for Writing in the Discipline Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—34077.

Cosoroaba, E. (2020, June), Helping Students Write It Right: Instilling Good Report-writing Habits in a Linear Circuit Lab Course Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—34723.

Cress, J. A., & Thomas, P. W. (2020, June), Imbedding Industry Expectations for Professional Communication into Undergraduate Engineering Curricula Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—34749.

Eggleston, A. G., & Rabb, R. J. (2020, June), Student Success Impacts in Communication and Professional Networking Contexts Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—35241.

Genau, A. (2020, June), Teaching Report Writing in Undergraduate Labs Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—35279.

Godavari, S. N., & Parker, A. E. (2020, June), Lifelong Learning in an Engineering Communication Course Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—34927.

Hendricks, D. G. (2020, June), WIP: Reflection to Promote Development of Presentation Skills in a Technical Communication Course Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—35566.

Horvat, K., & Randi, J. (2020, June), A Partnership Model for Integrating Technical Communication Habits Throughout Undergraduate Engineering Courses Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2--34029.

Jamshidi, R., & Wright, K., & Slaboch, P. E. (2020, June), Enhancement of Students' Technical Writing through a Combination of Classroom Activities Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—34567.

Kim, D., & Lynch, J. D. (2020, June), Perspectives and Practices of Undergraduate/Graduate Teaching Assistants on Writing Pedagogical Knowledge and Lab Report Evaluation in Engineering Laboratory Courses Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—35052.

Kovanen, B., & Ware, R., & Mericle, M., & Turnipseed, N., & Coleman, J. P., & Elliott, C. M., & Popovics, J. S., & Cooper, S. L., & Gallagher, J. R., & Prior, P., & Zilles, J. L. (2020, June), Implementing Writing-as-Process in Engineering Education Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—34786.

Lisa Bosman, Purdue University-Main Campus, West Lafayette (College of Engineering); Erin J. McCave, University of Houston; Molly H Goldstein, University of Illinois at Urbana - Champaign; Kelli L. Chelberg, College of Menominee Nation.

May, V. V., & Macaulay, D. A. (2020, June), The Way Things Work: Sketching and Building to Improve Visual Communication and Spatial Reasoning Skills Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—35382.

McCollum, C. J., & Pfluger, A. R., & Butkus, M. A. (2020, June), Technical Communications in an Environmental Engineering Curriculum: A Framework for Analysis and Continual Improvement Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—35287.

Neeley, K. A., & Norback, J. S., & Bennett, C., & Laugelli, B. J. (2020, June), Communication Across Divisions: Trends Emerging from the 2019 Annual Conference of ASEE and Some Possibilities for Strategic Action Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—34304.

Summers, S., & Bercich, R., & Cornwell, P., & Kawano, D. T., & Mayhew, J. E., & Moseley, S. (2020, June), The Impact of Scaffolded Writing Instruction on Followup Course Assignments Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—35332.

Wallwey, C., & Wilson, T. G., & Egyed, A. J., & Vick, O., & Parke, M. (2020, June), Exposing First-year Engineering Students to Research-based Technical Communication Through the Use of a Nanotech Project Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—34651.

Wilson, S. A., & Kaufmann, R. (2020, June), Communication Expectations to Industry Realities Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—34305.

Wilson, S. A., & Kaufmann, R. (2020, June), Learning to Talk the Talk – Preparing Students for Success during Internships through Communication Workshops Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—34904.

Zhao, Z., & Brunhaver, S. R. (2020, June), Investigating the Relationship Between Self-efficacy and Perceived Importance of Communication Skills Among Engineering Students Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line . 10.18260/1-2—34881.