Creating Communicative Self-Efficacy through Integrating and Innovating Engineering Communication Instruction

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Abstract

Cornell University's Sibley School of Mechanical and Aerospace Engineering and the College of Engineering's Engineering Communications Program (ECP) have developed a sophomore to senior, communication-across-the-curriculum plan, called the "MAE/ECP Initiative," to meet the needs of students, faculty, the college, and industry alike in their quest to heighten the pre-professional skills of graduating students. At its core, the partnership encourages the students' development of *communicative self-efficacy* in meeting the complex communicative demands related to performing technical work in mechanical and aerospace engineering. This paper discusses the pedagogical framework, the research paradigm, the foundational concepts (engineering communication: communicative practice, context, communicative design, and engineering identity), communication modalities (written, oral, visual, electronic) and outcomes (including ABET alignments) as collected by our two years of student survey data. The incredible success of Year1's quantitative findings are outlined in full. For example, in response to our communicative self-efficacy survey, the scores across all communicative modalities increased substantially (changing from low-medium to mid-high range) for all the students taking the pilot. In addition, on 17 of the 23 items on the survey, 80% of the pilot students scored in the high range. We believe that it safe to claim that the pilot has had a profound and very positive impact on students' reported communicative self-efficacy in MAE engineering contexts.

Introduction

Communication is ubiquitous in the lives of professional engineers. With a number of surveys suggesting that engineers spend between 40 and 60 percent (and more) of their workday engaged in communicative activities[1-4], not only is the importance of communication apparent, but it can no longer be separated from the practice of engineering as the misleading hard skills vs soft skills, technical skills vs professional skills dichotomy asserts. However, given the escalating demands for "work-ready" undergraduates and the resulting heavy workload of engineering faculty and students, adding direct and recurring communications instruction to the engineering curriculum represents a significant challenge.

In response to this challenge, a few schools and colleges of engineering are attempting integrate communication instruction into and across their existing engineering curriculum by fostering "partnerships," e.g., teaching partnerships and course partnerships, with communication professionals[5]. Such integration facilitates students learning communication as "socially situated [technical ***and*** professional] practice"[6], while also reducing somewhat the workload and supplementing the relevant expertise of engineering faculty. The Sibley School of Mechanical and Aerospace Engineering (MAE) and the Engineering Communications Program (ECP) in the College of Engineering at Cornell University are actively facilitating the formation of such partnerships.

The MAE/ECP Engineering Communications Initiative

Since the Technical Writing Requirement was adopted by the College in 1987, Cornell's Sibley School of Mechanical and Aerospace Engineering (MAE) has required that its majors fulfill it through a senior level capstone course taught by departmental faculty and graduate teaching assistants. As a lab-based course, that capstone focuses primarily on report writing and designing visuals. While the instructors have been successful at empowering students to produce well-written reports and well-designed visuals, the recurring results of departmental surveys of stakeholders (e.g., students, alumni, industry representatives) suggested that MAE needed to do something more to prepare students for workplace and research communication needs.

In the early fall of 2015 and as a beginning step in their attempt to do more, representatives of MAE and the Engineering Communications Program (ECP) identified a number of important needs, corresponding with outcomes, that together we expect our new partnerships, similar to those described above, will serve. Those needs are

- communication instruction that begins earlier in the MAE curriculum and is more theoretically consistent, constant, and coordinated across the curriculum
- communication instruction that is focused on foundational communication concepts and multiple modalities – written, oral, visual, electronic (WOVE) – making what students learn about communication and do as communicators transferable
- communication instruction that empowers students as participants in their chosen field through, for example, iterative revision, peer response and reflection, to be continually ready to learn to learn how and to teach each other

Rather quickly it became clear that to be able to realize these needs, we needed to create a new MAE communications curriculum and design a research program for assessment. This new curriculum and the adjoining research program is known as the ***MAE/ECP Engineering Communications Initiative***.

There are three key components to the initiative:

1. Creating a pilot partner course, ENGRC 2250, ***Communication for Mechanical Engineering Design*** at the sophomore level to be taught in conjunction with MAE 2250, ***Mechanical Synthesis.***
2. Coordinating and supporting through teaching partnerships communication instruction in select junior and senior level MAE courses.
3. Designing a two-to-five-year educational research project with the objective of assessing students' improved ability to communicate. This research should provide both quantitative (most important) and qualitative evidence of the success (or not) of that course and should be useful for continuing assessment into students' third and fourth years and beyond graduation.

Our plan allowed us to teach ENGRC 2250 during the spring 2016 and 2017 semesters to a self-selecting subset, 20+ students, of MAE undergraduates also enrolled in MAE 2250. At the same time, we conducted quantitative *and* qualitative educational research, commonly referred to as

mixed methods research. As well, in the academic years of 2015-2016 and 2016-2017 (and possibly again in spring 2017-2018), we worked with faculty in the junior and senior level MAE courses to determine how we might best coordinate and support teaching communication in their courses as well. In addition, ECP will provided MAE faculty with the findings of that educational research. Of particular interest are our findings in response to our focal research question:

How well can we facilitate the development of communicative self-efficacy (CSE)?

Depending upon those findings, then, a decision will be made concerning full curricular implementation. However, even at this early juncture, we believe that the MAE/ECP Engineering Communications Initiative, if implemented, is innovative in a number of ways:

1. It offers a deliberate and purposeful horizontal and vertical, theoretically consistent, and constant curriculum for providing communication instruction that will serve as a model for other schools and colleges of engineering.
2. The Initiative anticipates and enables learning post-graduate technical and professional communication by empowering students with foundational communication concepts and providing them experience applying those concepts within the multiple modalities (WOVE) and across many genres.
3. The plan proposes a model process for near- and long-term assessment through locally-situated and emergent educational research.

Research paradigm, self-efficacy, design, and methods

In order to assess the new MAE engineering communications curriculum and specifically to answer the above focal research question, we selected a research paradigm, design and method that seemed most appropriate. It should be apparent from the above that MAE and ECP are taking action – creating a new engineering communications course and curriculum. Consequently, we selected a pragmatist paradigm. Our aim was to produce *useful knowledge* used "to guide behavior that produces anticipated outcomes"[7]. The design was an explanatory, sequential mixed methods design. The critical question related to this design is "In what ways do the qualitative data explain the quantitative results?"[8]. And finally, because different methods have different strengths, we choose to use a survey instrument to collect quantitative data and interviews primarily to collect qualitative data[7].

Our focal research question became more detailed as we progressed. Now, our frame is this: *How well can we facilitate in MAE undergraduate engineering students the development of communicative self-efficacy (CSE) through ENGRC 2250 and then foster its continuing development through select junior and senior level courses in the MAE curriculum in a way that transfers to and enables technical and professional communicative practice?* CSE became the way that we choose to operationalize and test improvement in students' ability to communicate.

Simply put, using *self-efficacy* as a measuring stick for success is a well-established practice in engineering education. Self-efficacy tools measure how well subjects (in this case, students) rate themselves as having positive behaviors; and positive behaviors translate into higher-performing

practices. In ASEE Proceedings alone, there are over 1400 references to self-efficacy in student engineering practice. So, it is both an established and apparently quite useful construct. Self-efficacy, as a theoretical tool put into practice, is a critical element of Social Cognitive Theory[9]. It "refers to beliefs in one's capabilities to organize and execute those courses of action required to produce given attainments"[10], or a "person's awareness of their ability to accomplish a goal" [11].

There are four kinds of experiences that contribute positively to self-efficacy: 1) mastery experiences, 2) vicarious experiences, 3) verbal or social persuasions, 4) and psychological states. It has proven to be a powerful predictor of achievement in areas that range from the more general – learning, academic achievement, retention, mathematics – to the more specific – computing[11], engineering design[12], engineering modeling[13], even tinkering[14] just to name a few. Implementing it requires development of a survey instrument, which, although not easy, is more flexible and therefore applicable as well as less time- and labor-intensive than alternatives for assessing communicative performance[15]. Consequently, and along with other possible contributions, our research has the opportunity to offer a model for the development of other similarly focused instruments.

MAE students enrolled in ENGRC 2250 took two surveys-- Early Term Survey and End of Term Survey--in order to determine the impact of the pilot course. Both survey instruments were exactly the same. In addition, we will encourage those students to take that survey again (and again) as they progress through their junior and senior years in order to determine if there will be a continuing impact.

We also distributed the survey across the MAE curriculum at the start of the term, encouraging as many students with a declared MAE major as possible to participate. The results from those sophomores, juniors and seniors who have not taken the course serve as a comparison to provide perspective. Indeed, we hope eventually to offer the survey to MAE graduates employed in professional engineering positions.

Foundational concepts of the Initiative

Following the guidelines suggested by Bandura[15], the development of the survey instrument has been based upon two of the needs or outcomes mentioned earlier: 1) the foundational communication concepts and 2) the multiple modalities (WOVE) for performing communicative activities. The instrument itself contained seven items seeking demographic information and twenty-three items seeking response to these two needs. The scale for response was 0-100. The foundational concepts are described below:

1. **Communicative Practice:** When we communicate, we perform specific activities. All communication is a "doing" or it has a purpose, even purposes.
2. **Communicative Context:** Communicative practice cannot be separated from context nor the context from practice. All communication is context-bound.

3. **Communicative Design:** Communication is all about the particulars of design or structure and organization.
4. **Communicative Identity:** Communication creates identity, not only the identity of the one initiating communicative interaction, but also the identity or identities the one or ones being communicated with.

We intend that these four foundational concepts serve as a basis for understanding what seemingly different ways of communicating actually all have in common. Our survey question set can be found in Appendix A. As well, at this site (https://tinyurl.com/engrc2250), readers can find more details about our course setup, assignments, and ABET alignments.

WOVE: Actionable and socially constructed modes

There are additional constructs: WOVE is the acronym for the written, oral, visual and electronic modes of communication. As such, it is an emerging area of interest and research in engineering communication and communication instruction[5]. It "recognizes that writing and speaking do not occur in a vacuum but are often embedded in dynamic, multimodal [texts and] contexts"[6]. For the purposes of engineering communication and providing communication instruction to our students, we identified those modes of communication most relevant to the fields of mechanical and aerospace engineering. And, narrowing it even further, we focused on the particular genres and those modes most important for undergraduate and sophomore level students enrolled in the MAE 2250 partner course.

However, rarely do the WOVE modes occur in isolation in the relevant genres. Lab reports almost always include visuals: graphs, tables, charts, sketches. Visuals include captions, which is specialized writing that describes the important information in the visual. Presentations certainly include speech, but routinely also include visuals and writing. In fact, almost all the genres associated with communication in the sciences and engineering are multimodal. Even communication in project teams is multimodal: speech, of course, but that communication also involves email exchanges, texts (as in texting) and more.

So, our aim in ENGRC 2250 was not only to encourage the students to develop facility with each of the isolated modes, but also to consider how they might combine different modes into a single document in ways that acknowledge each mode's affordances or potentialities and constraints or challenges. As well, we wanted to explore each mode's potentialities as it contributes in a positive way to the ensemble that is the communicative performance. Again, in our survey (Appendix A), questions 4, 5, 6, and 7 address the mode of writing. Questions 8, 9, and 10 address oral modality. Questions 11, 12, 13, and 14 address the visual modes. Questions 15 and 16 address the electronic mode. Questions 19, 20, 21, and 22 address modes used in communication in teams.

Finally, we collaborated with the Cornell University Survey Research Institute (SRI) both to distribute our communicative self-efficacy survey online to MAE undergraduates and to assist us in analyzing the results. Our survey and this process has been fully evaluated and approved by our university's IRB.

Before presenting the results of quantitative research following the first pilot, let's summarize. The Mechanical and Aerospace Engineering (MAE) program at Cornell University wanted to do something more to prepare undergraduates for professional communicative practice. We proposed creating a pilot partner communications course to be taught to self-selecting MAE sophomore students. In addition, we proposed coordinating and supporting teaching partnerships with faculty in select junior and senior level courses. We proposed designing a two-to-five year mixed methods educational research project to assess the results. (See Appendix B for a diagram of that research project.) And finally, as a critical component of that proposal, we operationalized the ability to communicate as communicative self-efficacy. To date, we have completed the first pilot and are beginning the second. We have begun meeting and coordinating with MAE faculty teaching designated junior and senior MAE courses. And, we have completed the first year of our multi-year research project.

Results of the Early Term Survey for communicative self-efficacy

Herein, we will be presenting the results of early term survey distribution. As mentioned above, the survey did contain seven questions asking for demographic information. But for the reasons of focus and length, we will not be presenting that information in this paper with one exception – that of academic level. The reason for including academic level is to offer a kind of "snapshot" of the current state of *communicative self-efficacy* (CSE) among participating undergraduate students in MAE. Also, for the purposes of simplifying the presentation of the results, we have collected students into two groups: "ENGRC 2250 Course Students" or those enrolled in the pilot and "MAE Anonymous Students" or other sophomore (but not enrolled in the Communications course), junior and senior level MAE students. Later in this work, we will present the results from our end of term survey with those course students.

Our extensive data set (Tables 1-14) is provided fully in Appendix B. The total number of responses, *N*, ranged from 239 to 245 – not all the students responded to all the questions. In our study's tables, numbers in the "ENGRC 2250" columns represent sophomore-level students who were taking MAE 2250 and ENGRC 2250 concurrently. In the "Anonymous MAE Students" column, we report responses from declared MAE majors from several courses; none of these respondents were in ENGRC 2250. (Tables are in Appendix B.)

Now, and briefly, as a preview of our data, we offer these take-aways:

- Combining the responses of both the course students and anonymous students the average mean score ranged from the lowest, 67.5 for "giving effective talks and presentations" and the highest, 83.4 for "can communicate effectively in teams."
- Results suggest that CSE increases as disciplinary or field experience increases; that is, seniors exhibit higher self-efficacy than juniors and juniors more than sophomores (Tables 1 and 2).
- It appears that progressively larger percentages of the undergraduate student population locate themselves in the high range (Table 2).

- Results can lead us to surmise that students understand the modes as real constructs with high reliability scores across the relevant survey items – the only exception being electronic communication. See Table 3.
- We observed a pattern of development for those modes or dimensions that is parallel to that of individual items (Tables 4 and 6).
- Our anecdotal observations were reinforced-- that students understand that their ability to communicate and their ability to communicate using various modes is a learned experience that increases with academic level and is enhanced through opportunities to practice (Tables 7 and 8).

Table 1, titled "Descriptive Statistics of CSE Items by Academic Level," reports communicative self-efficacy according to academic level. There are a few items of note:

- First, the overall CSE ratings by all the students taking the survey were relatively high.
- Second, given the range of mean scores, the ratings demonstrated some spread, i.e., standard deviation. Again, there seemed to be greater spread in the responses of course students than in anonymous students, and that spread tended to tighten with progressing academic level.
- Third, those ratings generally increased with academic level – juniors rated themselves higher than sophomores and seniors higher than juniors or sophomores.

Next, Table 2, "Table 2. Percentage of Students Indicating Low, Medium, and High CSE for Items by Academic Level, Early Term Survey," records the percentages of students in the low, medium, and high ranges. Not only do the mean scores go up, but the percentages of students who locate themselves in the high range also increases. Then, Table 3, "Question Topics Included and Reliability of Dimensions of CSE," reports scale reliabilities or how well items within each dimension go along with one another and address a similar construct.

In addition, we also grouped certain survey items together into six dimensions generally correspondent with modalities and related constructs (see Table 4). Those dimensions are: **D1** or general CSE, **D2** or writing self-efficacy, **D3** or presenting/speaking self-efficacy, **D4** or visual CSE, **D5** or electronic CSE and **D6** or CSE in small groups/teams. Table 4 reports these results according to academic level. Again, the take-away is that the means scores increase with academic level.

Figure 1, below, displays average dimension scores computed as the average of scores to all items within a dimension and their standard errors with error bars [SD4]. Also, in an effort to understand how the dimensions relate to one another, correlations (Pearson *r*s) between pairs of dimensions were also examined. Table 5 shows the correlations between dimensions. As one might expect, the general dimension displayed the highest correlations with the other dimensions and the electronic dimension demonstrated the lowest (again something that we might want to consider investigating further). Table 6 shows the percentage of students in low, medium, and high CSE for dimensions.

The percentages for students' responses to individual items is similar to the students' responses when related by dimensions. Course students often report lower CSE for dimensions than other non-course sophomores, juniors slightly higher, as a rule, than sophomores, and seniors higher than course students, sophomores and juniors.

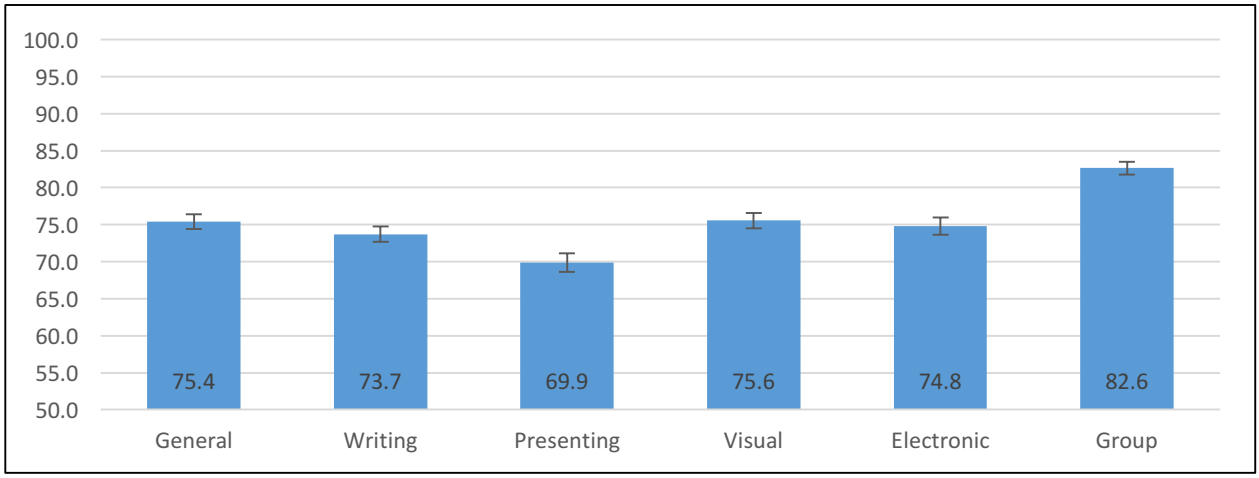

Figure 1: Average and Standard Error of Dimension Scores. Communication self-efficacy in small groups/teams was the highest score, while presenting/ speaking self-efficacy was the lowest. The error bars indicate the standard error of the mean, a measure of the spread in the possible means.

Finally, Tables 7 and 8 report summaries of ANOVAs for individual survey items and for dimensions. (ANOVA means "ANalysis Of VAriance, which is a statistical method for making comparisons simultaneously between 2+ means. ANOVA methods give values and results that can be analyzed to determine if there is a significant relationship between variables.) For both Tables 7 and 8, F ratios are large, observed p values are consistently below an alpha level of .005, effect sizes estimates (Partial η^2) are consistently over .5 and power is almost always 1.0. Considered together, these tables support the idea that academic level is a salient variable.

Preliminary thoughts

So, what have we learned from our initial snapshot? We are very satisfied with the usefulness of this instrument in providing us with a picture of the understanding that MAE undergraduates students have of their ability to communicate in an engineering context. Specifically, the scores suggest students understand that their ability to communicate, as operationalized by CSE, is a learned experience--a developing competence in a particular discipline or field. The scores also suggest they understand that practice or opportunities to practice communicating within a disciplinary or field context is both relevant and necessary to that development. And finally, students' scores reveal that as they progress through the curriculum and with added experience and practice, they come to believe more powerfully in their capabilities to perform and realize goals through various communicative actions, and to do so in ways that allow them to participate as disciplinary or field members.

Douglas and Purzer[16] claim, "validity is not a property of an instrument," but rather it is revealed in its usefulness in providing evidence of the meaning and relevance of the resulting scores. We propose that our survey results provide evidence for how MAE undergraduates understand their

ability to communicate and how they understand that that ability develops with experience and practice.

Results of the End of Term Survey for communicative self-efficacy (ENGRC 2250 students only)

Here we present the results of our follow-up or second distribution of the survey to the students in the communication course (ENGRC 2250). Let us give some brief background in order to avoid confusion.

Twenty students enrolled in the first pilot ENGRC 2250 course (AY 15-16). Of those twenty, one student did not complete the survey at the end of the semester. Another claimed that he/she was a junior. Consequently, the total number of course students counted as responding to the first distribution was 18 (see Table 1). In representations of the first distribution in the data that follows, notice that that number increases to 19. The student who identified as a junior was later added to the totals. Finally, despite repeated requests, we failed to get two ENGRC 2250 students to respond. So, the total number of students responding to the second survey distribution is only 16 versus `18 from the start of the term.

Again, and briefly, let us preview of our follow-up data findings:

- Briefly stated, the students reported demonstrable improvement. Table 9, "Descriptive Statistics of CSE Items for Early Term Survey and End of Term Survey at Time Points (ENGRC 2250 Students Only)," and Table 10, "Descriptive Statistics of CSE Dimensions at Early Term and End of Term Time Points," reveal large increases in the mean CSE scores both for individual items and across the various dimensions or modalities. Since the time points for the baseline and the follow-up surveys are the beginning and the end of the ENGRC 2250 course, we attribute that increase to the course.
- Tables 11 and 12 confirm that attribution.
- Table 13, "Percentage of Respondents Indicating Levels of CSE for Items at Time Points," and Table 14, "Percentage of Respondents Indicating Levels of CSE for Dimensions at Time Points," reveal that not only did the CSE scores increasing dramatically, but also there was an increase in the number of students ranking themselves in the highest categories – both for individual items and for the dimensions or modalities.

In looking at our results, two things are clear:

1. Mean scores were consistently higher for both individual items and dimensions at the End of Term Survey versus the Early Term Survey. To illustrate: for item 8, "give effective talks/presentations," the mean of the Early Term Survey scores was 55.4. For the same item 8, the mean of the follow-up scores was 91.7. For the dimension score relating to "presenting/speaking self-efficacy," the mean of the baseline scores was 55.6. The mean of the follow-up scores was again 91.7.
2. The variation in scores as measured by the standard deviation is consistently lower in the follow-up. The narrowing of the standard deviation may be related to

the small sample size. However, it may also suggest that the course had a similar and considerable impact on most of the students enrolled. The increases in CSE across academic levels in the baseline survey could be described as *incremental*, especially from the sophomore to the junior years; *increases in CSE for course students could be described as substantial, changing from the medium-low range to the mid-high range.*

Table 9 shows both Early Term and End of Term responses to the individual items of the course students. Table 10 shows the both responses for the dimensions.

In order to detect direct change in CSE from baseline to follow-up, scores for course students at each time point were compared with ANOVA. Tables 11 and 12 show that the results of analyses on each individual item, as well as dimension scores. These results clearly suggest that respondents reported meaningfully higher self-efficacy after completing the course.

These tables clearly convey that changes in CSE are significant. In particular, and in relation to the two time points or the Early/End responses to the survey, F ratios are large, observed p values are consistently below an alpha level of .005, effect sizes estimates (Partial η^2) are consistently over .5 and power is almost always 1.0. The only caveat that should be drawn to this data is that it is based on a relatively small sample, and it will be important to replicate these patterns and their associated sizes or intensities in future distributions of the survey.

Yet another method of examining change in scores across time points, item and dimension scores were again categorized into groups indicating low, medium and high CSE. The percentage of respondents reporting these levels of CSE for each item is shown in Table 13 and the percentage for each dimension is shown in Table 14.

In the Early Term data, 39.2% of responses indicated low CSE, 38.0% indicated medium CSE and only 22.8% indicated high CSE. Within the results for End of Term, only 0.5% of responses indicated low, 18.0% indicated medium, and 81.5% indicated high CSE. Similarly, no dimension scores at follow-up were in the low CSE range and the lowest percentage in the high CSE range was 81.3%.

Most interesting here is that the presenting/speaking dimension (D3) exhibited the greatest percent of dimension scores indicating low CSE at Early Term, and the greatest percent of dimension scores indicating high CSE in the End of Term results.

Program adoption advice

We have been asked more than a few times how this Initiative's communications curriculum might port to other programs or colleges. To begin, it is important to acknowledge the current curricular context and to understand that any new communications curriculum should adapt (and can be adapted) to that context. With that in mind, we have three specific suggestions.

First, before beginning preliminary curricular planning, all the partners involved need to identify potential funding, e.g., development funds or the reallocation of tuition dollars. Accounting for

long term workloads and labor availability are best done once there is a firm financial framework and therefore foundation in place. If a similar survey/study is to be part of the plan, funding for the dissemination, gathering, and analysis should also be factored in.

Second, the goal must be clear. Why would an engineering department want to imbue its curriculum with more communication skills? Is it ABET driven? Is it driven by alumni surveys? Is it an internal goal, identified by faculty or students or administration? Understanding what compels the adoption of such an initiative is important to its sustained vitality and the ways in which outcomes will be analyzed and valued.

Third, both the engineering partners and the communication partners should begin to identify the courses and instructors that would be at the core of the effort. As for the communication teaching, does your institution have specialized technical or engineering communication instructors? We strongly advise the use of these specialized instructors to address the needs of engineering/technical writing and presenting. The MAE/ECP Initiative landed on an early strong course that was required for all sophomores as its starting point, with re-enforced communication elements reappearing in the junior and senior years. In this phase, begin to speak with engineering faculty whose individual classes might be good candidates for strong communication infusion.

Finally, collaboration along with a mutual curiosity and respect for the partners' differing expertise and potential contributions are key. The established partnerships, and there will be many, must function as a genuine partnership.

Conclusion and Next Steps

As we began this project, the question was this: What more can we do to prepare students for the professional practice of communication in engineering? Currently, our data is both preliminary and incomplete, as we are not yet presenting the results of our extensive qualitative research. However**,** if we accept that the ability to communicate can be operationalized by *communicative self-efficacy* (CSE), then what more we can do is to create a partner course that begins earlier in the curriculum and that dramatically accelerates and enhances undergraduate students' development, a development that is already occurring. Clearly, we are interested to learn if course students' CSE will continue to increase, remain the same or perhaps even decrease. Importantly, we can "track" course students in a way that will allow us to discover that.

In the next semesters, we want to take advantage of students' improved ability as they progress through the MAE curriculum. By creating teaching partnerships with faculty offering select junior and senior level courses, we can certainly reinforce "lessons learned" and potentially enhance learning by building on students' prior experience and practice. However, we can also reduce engineering faculty workload and supplement their expertise by either teaching ourselves in those courses (most likely a single assignment) or by training interested faculty and/or TA graduate students to be more efficient and effective communication instructors. Finally, we claim that our approach to near- and long-term assessment will enable not only MAE but also other engineering schools and departments to offer concrete learning outcomes and produce actual data to support those outcomes.

There is much yet to learn. We are looking forward to the insights that that data most certainly will provide. Still, we believe that we have made a promising start toward planning and implementing an alternative communications curriculum that empowers students to actually be "work-ready" as communicators when they begin their professional engineering careers. And, while we must be careful with our inferences so early in the research process and from such a small sample size, we believe that it is at least safe to suggest that the pilot ENGRC 2250 has had ***a profound and very positive impact on students' reported communicative self-efficacy in engineering contexts***.

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Appendix A: Survey Instrument

Construct	Construct Operationalized	Survey Item
General Communicative Self-Efficacy	Confidence Engaging in Effective Communicative Practice	1. I am confident that I can effectively express and represent my expertise in technical and professional communication contexts.
Awareness of Communicative Design	Confidence Understanding the Importance of "Design" in Relation to Communicative Practice	2. I am confident in my ability to choose the best words, select an appropriate sentence structure for communication in technical and professional contexts. 3. I am confident that I can structure well organized communication in technical and professional contexts.
Written Modality	Confidence Preparing and Performing an Effective Technical and Professional Text	4. I am confident preparing a final document and adhering to given conventions, specifications, and/or requirements in technical and professional contexts. 5. I am confident writing a first draft. 6. I am confident revising beyond simple editing. 7. I am confident accurately finding, referencing, and citing sources.
Oral Modality	Confidence Preparing and Performing Technical and Professional Presentations	8. I am confident that I can give technical and professional talks and presentations. 9. I am confident using slideware strategically in order to enhance understanding. 10. I am confident responding to questions, leading discussion, and providing a second closing.
Visual Modality	Confidence Preparing and Performing Data and Non-data Visuals	11. I am confident that I can design data visuals, e.g., charts, tables, graphs in ways that facilitate the understanding and interpretation of technical information. 12. I am confident that I can design non-data visuals, e.g., diagrams, drawings, illustrations, pictures, 3D CAD renditions in ways that facilitate understanding and interpretation of technical information. 13. I am confident creating captions that interpret data and non-data visuals while also following the conventions for labeling, titling and citing. 14. I am confident integrating data and non-data visuals into a text in ways that facilitate the understanding and interpretation of technical information.

Construct	**Construct Operationalized**	15. **Survey Item**
Electronic Modality	Confidence Preparing and Performing Communicative Practice Using Electronic Technologies	16. I am confident that I can explore, both as a consumer and as a producer, new media forms or genres, e.g., video (YouTube) and video chat, web pages, podcasts, blogs. 17. I am confident that I can use electronic communication such as email, texts and instant messaging along with other forms of social networking media in ways that are appropriate and purposeful in technical and professional contexts.
Awareness of Communicative Practice	Confidence Understanding the "Purposefulness" of Communicative Practice	18. I am confident that I can communicate in ways that "get work done" in both technical and professional contexts.
Awareness of Communicative Context	Confidence Understanding the "Situated Nature" of Communicative Practice	19. I am confident that I can select, adapt and present technical information for multiple audiences, e.g., instructors, colleagues and peers, clients, and supervisors and/or managers.
Concomitant Communicative Practice	Confidence Preparing and Performing in Teams	20. I am confident that I can communicate effectively in teams. 21. I am confident communicating in ways that support project aims/goals. 22. I am confident communicating in ways that facilitate developing productive relationships with other team members. 23. I am confident communicating in ways that allow me to adopt various roles, e.g., follower, leader, expert, facilitator, learner, in team projects
Awareness of Communicative Identity	Confidence Understanding "Persona" in Communicative Practice	24. I am confident I can be perceived as a knowledgeable and capable communicator in technical and professional contexts.

Appendix B: Data Tables

Table 1. Descriptive Statistics of CSE Items by Academic Level, Early Term Survey

Item No.	ENGRC 2250 Course Students (n=18), all sophomores			Anonymous MAE Students (n=218)								
				Sophomores			Juniors			Seniors		
	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.	n
1	62.3	18.5	18	70.1	19.8	90	72.2	17.2	82	78.7	15.5	46
2	63.6	18.4	18	67.5	23.2	93	69.6	19.4	82	77.3	18.4	48
3	59.6	18.7	18	68.3	20.6	93	72.4	17.9	82	79.7	17.1	48
4	61.7	21.9	18	69.4	22.8	93	73.3	22.0	83	84.2	12.2	48
5	73.8	16.4	18	80.3	18.3	93	77.7	18.5	83	86.1	12.5	48
6	65.3	22.9	18	74.7	21.7	93	74.8	21.8	83	82.5	15.2	48
7	59.0	24.7	18	72.1	23.1	93	72.9	22.3	83	77.8	14.8	48
8	55.9	25.0	17	65.3	21.8	93	65.7	21.5	82	78.5	18.1	48
9	59.0	27.5	18	74.1	18.1	93	70.7	22.8	83	84.0	15.3	48
10	59.4	20.4	17	68.5	21.1	93	66.0	24.3	83	78.3	17.5	48
11	58.7	23.1	18	75.3	18.4	93	78.6	18.6	83	83.0	17.2	48
12	53.3	25.4	18	75.0	19.4	94	80.1	19.8	83	82.5	17.6	47
13	58.3	26.1	18	73.4	18.1	93	75.5	20.6	83	84.6	13.7	47
14	54.1	25.1	18	70.7	17.4	93	76.1	17.3	83	83.8	14.1	47
15	63.0	20.6	18	68.8	24.1	93	71.8	20.4	83	77.8	16.4	48
16	65.7	27.1	18	78.4	20.3	93	78.9	20.4	83	83.7	15.7	48
17	71.2	17.0	18	77.0	18.4	93	79.4	16.9	82	84.7	12.6	48
18	58.9	21.2	18	71.4	18.7	93	73.8	18.0	82	83.2	14.0	48
19	74.9	16.8	18	82.3	15.1	93	83.1	13.2	83	88.9	9.8	48
20	75.1	15.4	18	82.7	13.8	93	82.1	13.5	83	87.3	11.0	48
21	77.7	13.1	18	82.1	14.6	93	80.1	16.2	81	86.9	11.7	48
22	76.7	17.5	18	81.6	15.3	93	81.7	15.3	81	87.1	11.7	48
23	65.7	24.6	18	74.6	20.5	93	77.6	16.6	83	82.8	16.3	48

Notes:
--Values in this table exclude the respondent indicating an academic level of First-Year, the one that did not report an academic level, and the Course student that indicated Junior level.
-- In order to more easily identify any patterns that emerged, we arbitrarily labelled low CSE as 0-60, medium CSE as 60-80 and high CSE as 80-100. Only course students had a mean below 60 on any of the items, and then it was relatively close to 60.

Table 2. Percentage of Students Indicating Low, Medium, and High CSE for Items by Academic Level, Early Term Survey

Item No.	ENGRC 2250 Course Students (n=18), all sophomores			Anonymous MAE Students (n=218)								
				Sophomores			Juniors			Seniors		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
1	38.9%	50.0%	11.1%	30.0%	40.0%	30.0%	20.5%	47.0%	32.5%	8.7%	37.0%	54.3%
2	44.4%	44.4%	11.1%	36.6%	29.0%	34.4%	31.3%	33.7%	34.9%	16.7%	31.3%	52.1%
3	50.0%	33.3%	16.7%	31.2%	41.9%	26.9%	22.%	41.0%	36.1%	14.6%	22.9%	62.5%
4	61.1%	22.2%	16.7%	32.3%	26.9%	40.9%	21.4%	34.5%	44.0%	6.3%	27.1%	66.7%
5	22.2%	44.4%	33.3%	11.8%	29.0%	59.1%	15.5%	32.1%	52.4%	4.2%	31.3%	64.6%
6	33.3%	38.9%	27.8%	20.4%	29.0%	50.5%	22.6%	32.1%	45.2%	6.3%	35.4%	58.3%
7	38.9%	44.4%	16.7%	25.8%	30.1%	44.1%	21.4%	33.3%	45.2%	12.5%	50.0%	37.5%
8	52.9%	29.4%	17.6%	39.8%	36.6%	23.7%	37.3%	39.8%	22.9%	18.8%	29.2%	52.1%
9	50.0%	27.8%	22.2%	20.4%	44.1%	35.5%	34.5%	22.6%	42.9%	6.3%	27.1%	66.7%
10	52.9%	29.4%	17.6%	32.3%	36.6%	31.2%	42.9%	23.8%	33.3%	12.5%	37.5%	50.0%
11	50.0%	33.3%	16.7%	19.4%	38.7%	41.9%	16.7%	23.8%	59.5%	8.3%	27.1%	64.6%
12	61.1%	27.8%	11.1%	22.3%	31.9%	45.7%	16.7%	20.2%	63.1%	10.6%	31.9%	57.4%
13	50.0%	27.8%	22.2%	23.7%	38.7%	37.6%	20.2%	32.1%	47.6%	6.4%	27.7%	66.0%
14	61.1%	22.2%	16.7%	22.6%	49.5%	28.0%	15.5%	40.5%	44.0%	6.4%	31.9%	61.7%
15	33.3%	50.0%	16.7%	35.5%	28.0%	36.6%	27.4%	31.0%	41.7%	8.3%	52.1%	39.6%
16	33.3%	33.3%	33.3%	18.3%	31.2%	50.5%	11.9%	28.6%	59.5%	10.4%	25.0%	64.6%
17	27.8%	44.4%	27.8%	17.2%	35.5%	47.3%	8.4%	41.0%	50.6%	6.3%	25.0%	68.8%
18	50.0%	33.3%	16.7%	22.6%	43.0%	34.4%	26.5%	36.1%	37.3%	6.3%	27.1%	66.7%
19	11.1%	50.0%	38.9%	6.5%	34.4%	59.1%	9.5%	22.6%	67.9%	2.1%	20.8%	77.1%
20	16.7%	44.4%	38.9%	5.4%	35.5%	59.1%	8.3%	29.8%	61.9%	2.1%	22.9%	75.0%
21	5.6%	61.1%	33.3%	6.5%	31.2%	62.4%	12.2%	29.3%	58.5%	4.2%	25.0%	70.8%
22	11.1%	38.9%	50.0%	8.6%	34.4%	57.0%	11.0%	28.0%	61.0%	2.1%	29.2%	68.8%
23	33.3%	33.3%	33.3%	2.04%	34.4%	45.2%	14.5%	33.7%	51.8%	12.5%	22.9%	64.6%

Notes: Values in this table exclude one [SD1] respondent indicating an academic level of First-Year, one that did not report an academic level, and one ENGRC 2250 Course student that indicated Junior level. Percentages are valid responses; that is, they do not include missing responses as part of the 100%.

Table 3. Question Topics Included and Reliability of Dimensions of CSE

Dimension	Survey Topic Questions	Reliability
D1. General Communication Self-Efficacy	1, 17, 18, 23	.87
D2. Writing Self-Efficacy	2, 3, 4, 5, 6, 7	.86
D3. Presenting/Speaking Self-Efficacy	8, 9, 10	.89
D4. Visual Communication Self-Efficacy	11, 12, 13, 14	.88
D5. Electronic Communication Self-Efficacy	15, 16	.64
D6. Self-Efficacy Communicating in Small Groups/Teams	19, 20, 21, 22	.92

Table 4. Descriptive Statistics of Dimension by Academic Level

Dimension	ENGRC 2250 Course Students (n=18)			Anonymous MAE Students (n=223)								
				Sophomores			Juniors			Seniors		
	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.	n
D1	64.5	17.2	18	73.3	16.6	93	75.7	13.5	83	82.4	12.8	48
D2	63.8	14.4	18	72.0	16.0	93	73.5	16.3	83	81.3	11.2	48
D3	56.3	24.1	18	69.3	17.6	93	67.3	21.0	83	80.3	15.6	48
D4	56.1	22.5	18	73.3	15.1	93	77.5	16.1	83	83.2	12.9	48
D5	64.3	19.3	18	73.6	18.9	93	75.3	17.4	83	80.7	14.4	48
D6	76.1	14.6	18	82.1	13.1	93	81.7	13.0	83	87.6	10.2	48

Note: Values in this table exclude the respondent indicating an academic level of First-Year, the one that did not report an academic level and the Course student that indicated Junior level.

Table 5. Correlations between Dimensions of CSE

Dimension	D1	D2	D3	D4	D5
D1	-				
D2	.65	-			
D3	.71	.62	-		
D4	.63	.70	.60	-	
D5	.55	.58	.43	.60	-
D6	.67	.52	.52	.57	.52

Note: All correlations are statistically significant at the .001 level.

Table 6. Percentage of Students Indicating Low, Medium, and High CSE for Dimensions by Academic Level, Early Term Survey

Item No.	ENGRC 2250 Course Students (n=18)			Anonymous MAE Students (n=223)								
				Sophomores			Juniors			Seniors		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
D1	38.9%	44.4%	16.7%	18.3%	45.2%	36.6%	13.1%	45.2%	41.7%	4.2%	31.3%	64.6%
D2	33.3%	55.6%	11.1%	21.5%	41.9%	36.6%	20.2%	41.7%	38.1%	4.2%	35.4%	60.4%
D3	61.1%	16.7%	22.2%	31.2%	39.8%	29.0%	35.7%	33.3%	31.0%	12.5%	31.3%	56.3%
D4	55.6%	27.8%	16.7%	16.0%	55.3%	28.7%	14.3%	35.7%	50.0%	4.2%	35.4%	60.4%
D5	44.4%	33.3%	22.2%	22.6%	38.7%	38.7%	19.0%	33.3%	47.6%	8.3%	35.4%	56.3%
D6	11.1%	44.4%	44.4%	4.3%	34.4%	61.3%	9.5%	26.2%	64.3%	0.0%	27.1%	72.9%

Notes: Values in this table exclude the respondent indicating an academic level of First-Year, the one that did not report an academic level and the Course student that indicated Junior level. Percentages are for valid responses, that is, they do not include missing responses as part of the total 100%.

Table 7. Summary of ANOVAs for Items by Academic Level

Item No.	*F* ratio	Observed *p*	Partial η^2	Power
1	4.87	.008	.040	.799
2	4.31	.015	.035	.745
3	7.70	.001	.061	.947
4	9.98	<.001	.077	.984
5	3.80	.024	.031	.688
6	3.51	.031	.028	.651
7	2.21	.112	.018	.449
8	8.37	<.001	.066	.962
9	7.75	.001	.061	.948
10	5.79	.003	.046	.867
11	5.61	.004	.045	.856
12	6.55	.002	.052	.906
13	8.18	<.001	.064	.958
14	13.73	<.001	.103	.998
15	3.68	.027	.030	.673
16	2.22	.111	.018	.449
17	4.50	.012	.036	.765
18	9.75	<.001	.075	.982
19	5.43	.005	.043	.843
20	3.50	.032	.028	.650
21	3.61	.029	.029	.664
22	3.25	.041	.027	.615
23	4.55	.012	.037	.770

Notes: These analyses did not include the respondent indicating an Academic Level of "First-Year" and the one that did not indicate an Academic Level.

Table 8. Summary of ANOVAs for Dimensions by Academic Level

Dimension	*F* ratio	Observed *p*	Partial η^2	Power
General	8.34	<.001	.065	.962
Writing	8.02	<.001	.063	.955
Presenting	8.93	<.001	.069	.972
Visual	11.21	<.001	.085	.992
Electronic	4.02	.019	.032	.714
Group	4.67	.010	.037	.782

Notes: These analyses did not include the respondent indicating an Academic Level of "First-Year" and the one that did not indicate an Academic Level.

Table 9. Descriptive Statistics of CSE Items for Early Term Survey and End of Term Survey at Time Points (ENGRC 2250 Students Only)

Item No.	Early Term Survey			End of Term Survey		
	Mean	S.D.	N	Mean	S.D.	N
1	63.2	18.8	19	89.8	7.2	15
2	62.9	18.1	19	85.9	8.8	16
3	59.1	18.3	19	86.8	8.5	16
4	61.2	21.4	19	89.2	9.3	16
5	74.4	16.2	19	94.9	6.5	16
6	63.6	23.5	19	89.4	8.1	16
7	59.3	24.1	19	86.9	11.9	16
8	55.4	24.4	18	91.7	8.0	16
9	58.3	27.0	19	92.4	8.4	16
10	58.1	20.5	18	91.1	8.3	16
11	59.2	22.6	19	85.9	10.4	16
12	53.7	24.8	19	89.1	12.2	16
13	57.6	25.6	19	88.5	9.5	16
14	54.2	24.4	19	90.8	8.6	16
15	62.4	20.2	19	86.9	12.4	16
16	65.9	26.3	19	89.3	11.7	16
17	71.1	16.6	19	90.6	9.1	16
18	59.0	20.6	19	87.7	8.6	16
19	74.7	16.4	19	91.6	9.6	16
20	74.8	15.0	19	91.5	8.7	16
21	77.2	12.9	19	90.4	11.6	16
22	76.6	17.0	19	89.9	12.0	16
23	65.7	24.6	18	90.6	10.0	16

Note: Values in this table include all respondents responding to that item at that time point, hence differing sample sizes at each time point.

Table 10. Descriptive Statistics of CSE Dimensions at Early Term Survey and End of Term Survey Time Points(ENGRC 2250 Students Only)

Item No.	Early Term Survey			End of Term Survey		
	Mean	S.D.	N	Mean	S.D.	N
D1	64.7	16.7	19	89.4	7.5	16
D2	63.4	14.1	19	88.8	6.8	16
D3	55.6	23.6	19	91.7	6.6	16
D4	56.2	21.9	19	88.5	9.2	16
D5	64.1	18.8	19	88.1	10.1	16
D6	75.8	14.3	19	90.8	10.3	16

Table 11. Summary of ANOVAs for Items Across Time Points

Item No.	*F* ratio	Observed *p*	Partial η^2	Power
1	34.2	<.001	.710	1.0
2	62.2	<.001	.806	1.0
3	67.2	<.001	.818	1.0
4	24.2	<.001	.618	.996
5	26.8	<.001	.641	.998
6	36.6	<.001	.710	1.0
7	29.1	<.001	.660	.999
8	90.7	<.001	.866	1.0
9	38.2	<.001	.718	1.0
10	63.0	<.001	.818	1.0
11	40.0	<.001	.726	1.0
12	41.5	<.001	.734	1.0
13	32.5	<.001	.684	1.0
14	47.8	<.001	.761	1.0
15	26.2	<.001	.636	.998
16	13.0	.003	.465	.921
17	34.0	<.001	.694	1.0
18	36.8	<.001	.710	1.0
19	26.8	<.001	.641	.998
20	32.8	<.001	.686	1.0
21	28.5	<.001	.655	.999
22	22.4	<.001	.599	.993
23	18.3	.001	.567	.978

Table 12. Summary of ANOVAs for Dimensions Across Time Points

Dimension	*F* ratio	Observed *p*	Partial η^2	Power
General	45.3	<.001	.751	1.0
Written	104.2	<.001	.874	1.0
Oral	60.4	<.001	.801	1.0
Visual	54.6	<.001	.784	1.0
Electronic	26.0	<.001	.634	.997
Group	36.9	<.001	.711	1.0

Table 13. Percentage of Respondents Indicating Levels of CSE for Items at Time Points (ENGRC 2250 Students Only)

Item No.	Early Term Survey			End of Term Survey		
	Low	Med	High	Low	Med	High
1	36.8%	52.6%	10.5%	0.0%	12.5%	81.3%
2	47.4%	42.1%	10.5%	0.0%	18.8%	81.3%
3	52.6%	31.6%	15.8%	0.0%	18.8%	81.3%
4	63.2%	21.1%	15..8%	0.0%	12.5%	87.5%
5	21.1%	42.1%	36.8%	0.0%	6.3%	93.8%
6	36.8%	36.8%	26.3%	0.0%	18.8%	81.3%
7	36.8%	47.4%	15.8%	0.0%	37.5%	62.5%
8	52.6%	26.3%	15.8%	0.0%	12.5%	87.5%
9	52.6%	26.3%	21.1%	0.0%	12.5%	87.5%
10	52.6%	26.3%	15.8%	0.0%	6.3%	93.8%
11	47.4%	36.8%	15.8%	0.0%	25.0%	75.0%
12	57.9%	31.6%	10.5%	0.0%	18.8%	81.3%
13	52.6%	26.3%	21.1%	0.0%	18.8%	81.3%
14	63.2%	21.1%	15.8%	0.0%	18.8%	81.3%
15	36.8%	47.4%	15.8%	0.0%	31.3%	68.8%
16	31.6%	36.8%	31.6%	0.0%	25.0%	75.0%
17	26.3%	47.4%	26.3%	0.0%	25.0%	75.0%
18	52.6%	31.6%	15.8%	0.0%	25.0%	75.0%
19	10.5%	52.6%	36.8%	0.0%	6.3%	93.8%
20	15.8%	47.4%	36.8%	0.0%	18.8%	81.3%
21	5.3%	63.2%	31.6%	6.3%	12.5%	81.3%
22	10.5%	42.1%	47.4%	6.3%	12.5%	81.3%
23	31.6%	31.6%	31.6%	0.0%	18.8%	81.3%

Notes: Percentages at Early Term include valid (i.e., non-missing) responses from the 19 students that completed the survey, whereas percentages at End of Term include valid responses from the 16 students that completed the survey. Thus, in some cases, the total of percentages within Early or End may not sum to 100%.

Table 14. Percentage of Respondents Indicating Levels of CSE for Dimensions at Time Points (ENGRC 2250 Students Only)

Dimension No.	Early Term Survey			End of Term Survey		
	Low	Med	High	Low	Med	High
D1	36.8%	47.4%	15.8%	0.0%	18.8%	81.3%
D2	36.8%	52.6%	10.5%	0.0%	18.8%	81.3%
D3	63.2%	15.8%	21.1%	0.0%	6.3%	93.8%
D4	57.9%	26.3%	15.8%	0.0%	12.5%	87.5%
D5	42.1%	36.8%	21.1%	0.0%	18.8%	81.3%
D6	10.5%	47.4%	42.1%	0.0%	18.8%	81.3%

Notes: Percentages at Early Term Survey include dimension scores for the 19 students that completed the survey, whereas percentages at End of Term Survey include dimension scores for the 16 students that completed the survey. Due to rounding, the total of percentages within Early Term or End of Term may not sum to 100%.