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Building a Communication-Integrated Curriculum in Materials Science

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Abstract
With the need to meet ABET outcomes around professional skills, such as communication and teamwork, engineering programs have long explored approaches to ensure their graduates are able to participate in the workplace in ways that employers demand. While approaches vary and success depends on a number of factors, research demonstrates that an integrated approach to professional skill development is the most impactful for student learning. How can an engineering program build an integrated approach that provides meaningful communication education?

This paper shares the experiences from faculty in the Micron School of Materials Science and Engineering (MSMSE) at Boise State University that has created an integrated approach to communication and is working toward creating a cohesive culture around communication and professional skill development. This program started small: a technical communication faculty from the Department of Writing Studies at Boise State was recruited to work with a materials science faculty managing the Materials Teaching Lab and teaching junior- and senior-level project courses. The focus of the program was primarily on bolstering written skills, but in recent years has expanded to consider professional skills more broadly, including working on diverse teams and supporting equity and inclusion through writing and collaboration.

The goal of this paper is to share where the program is currently and the next steps to expand efforts to continue to support student learning. Starting in 2022, the integrated communication education has been expanded to the sophomore lab to create a three-course sequence focused on communication and professional skill development. This scaffolding and multi-year focus allows faculty to build student confidence in their ability to work as technical professionals after they graduate. By the time undergraduates reach their senior capstone, they are more fully prepared to take on complex communication situations within challenging team projects. Future efforts focus on more consistently scaffolding writing throughout the full materials science program and engaging a larger set of faculty around these areas. The paper will share findings of how these efforts have supported student learning and explore how faculty can address areas that still need support. Overall, this collaboration has not only allowed the materials science program to fully meet ABET outcomes but also understand the ways communication support enables graduates to develop engineering identities and move into the next phase with the skills they need to be successful.

Introduction

Driven by ABET Student Outcomes and industry needs, engineering programs aim to provide students the opportunity to develop communication and teamwork skills alongside the technical proficiencies needed to be successful in engineering [1]. Ideally, engineering graduates are able to transition into industry or graduate school with the skills, dispositions, and knowledge to navigate communication and collaboration effectively [2]. In addition to the technical skills needed to solve engineering problems, employers seek candidates who can communicate effectively, who are able to manage projects, and who can generate innovation solutions [3]. However, employers have indicated that gaps exist in engineering training, with entry-level engineers often unable to communicate in the ways employers expect, especially on diverse

teams [4]. This gap in training means that individuals struggle to transition into workplace contexts and have barriers to success and promotion.

To address these gaps, engineering programs strive to provide sufficient opportunities for graduates to develop the communication skills and teamwork skills that will support their work as professionals. Programs approach this problem in a range of ways, from requiring coursework outside of the program to integrating communication skills into a degree program to engaging in project-based learning and other high-impact practices or some combination of these approaches, as summarized in the literature review below. These approaches are dependent on a range of factors, and what works at one institutional context may not be effective at another.

In this paper, we detail one integrated approach that involves a partnership between the two co-authors, Jenn Mallette, a technical communication instructor/researcher housed in the Department of Writing Studies, and Harold Ackler, a materials science instructor. After a literature review, we detail the nature of our partnership, including the ways the partnership and approach continues to shift and adapt to the changing nature of engineering education and student needs in the materials science program. We share successes as well as areas we continue to build capacity within, with some takeaways for programs working in similar partnerships or seeking to build integrated communication and teamwork curriculum.

Overview of scholarship on integration

Learning to communicate effectively in engineering is a process of learning to understand the disciplinary conventions and genres used in engineering contexts. As such, this communication education is most likely to be impactful when it takes place in an integrated, scaffolded way [5]. Instructors cannot simply rely on providing lists of rules or rigid templates to follow; novice communicators must understand the reasons behind rules and see templates as guidelines [6]. In other words, the challenge for many communicators is moving beyond following rules to developing the metacognition to understand why these guidelines matter and how templates are aligned with the genres that allow them to participate as active members of an engineering discourse community.

In engineering education, however, the trend is to outsource communication training to programs outside of engineering coursework, such as first year writing or a standalone technical communication course. In one survey, Reave found that 50% of engineering programs require an external technical writing courses, while only 33% integrate writing into engineering curriculum [5] This approach often relies on individual faculty in engineering programs to incorporate writing into their courses, or heavily burdens the senior capstone requirements with preparing students to learn and practice writing in engineering. In these engineering courses, writing is often assigned without explicit writing instruction, leading faculty to feel frustrated with students' ability to generate writing aligned with their expectations and engineering communication conventions. In part, this approach emerges because of the many challenges of integrating writing into engineering coursework and curriculum in a sustained and scaffolded way, including the need for instructors trained in both writing pedagogy and engineering communication and the ever-packed engineering curriculum.

Furthermore, a study by Conrad [6] has demonstrated the misalignment between how students think they should communicate as engineers and how practitioners implement communication effectively. The disconnect is, in part, a sign that students are still developing knowledge in engineering communication. However, this difference may also be a result of how they are taught to write as students; for instance, Conrad found that students are more likely to use longer, more complex sentences because they thought their goal was to sound intelligent, while practitioners focused on shorter sentences that would more clearly communicate their content [6]. Longer, complex sentences and vocabulary choices indicate that many students are thinking of what is acceptable and possibly more rewarded in an academic setting versus what is most effective at accomplishing engineering goals.

This example highlights the benefits of more fully-integrated instruction that focuses on building students' skills and knowledge of engineering-specific communication practices within engineering courses. Integrated models take on a number of forms, from one writing-specific course or a few courses with writing requirements to more fully integrated approaches [7]. For the more fully integrated models, programs might use a Writing Across the Curriculum (WAC) approach, where writing is deliberately embedded in a range of courses and levels and faculty are provided support and professional development for teaching and assessing the writing students produce [7]. Some universities have communication programs housed within the engineering college to support writing intensive courses, such as the University of Michigan [8]. Other programs have engineering communication centers that support students with their engineering-specific writing assignments and faculty to integrate writing, such as Virginia Tech [9] and (at one point) Carnegie Mellon's Global Communication Center, which has been moved to be part of their larger Student Academic Success Center [10].

Other engineering programs might partner with English, technical communication, writing studies, and/or communication programs to call on writing and teaching expertise. A more minimal partnership might involve pairing engineering students with technical communication editing students [11]. Alternately, some approaches involve creating cross-disciplinary teams to collaborate on client-based projects, thus offering students the opportunity to learn from peers in a range of disciplines while working for a real client to solve a specific, real-world problem [7]. These partnerships can involve an instructor based in a technical communication program designing and teaching a one-credit course that is cross-listed with a specific lab course, as one of this paper's authors does at their institution. This course was designed in collaboration with a specific engineering program's needs and taught by faculty trained in engineering communication and technical communication. Other models might involve deeper partnerships, such as Ford's integration into her university's mechanical engineering program as first a partner and then later through a joint appointment [12-13] This approach allows Ford to be seen as a member of both the technical communication and mechanical engineering departments and to bring her expertise in to inform her work with mechanical engineering students. [12-13].

Overall, these different approaches each have benefits. The variety of models also indicate that any approach should be developed based on a specific context–a Writing Across the Curriculum model, for instance, is more likely to succeed when there is sustained support for WAC from both instructional faculty as a grassroots initiative and from administrators through financial resources and pushes for larger university-wide efforts [14]. Thus, a model that works in one

university and program context may not be able to be exported fully to another. In the rest of this paper, we discuss a specific partnership informed by these approaches but is also deeply context-dependent. After we discuss the model, we offer recommendations for programs who are seeking to create integrated writing instruction within their own institutions.

Approach to integration in one program

At Boise State, we work to integrate communication skills instruction and feedback into project-based courses in materials science and engineering. Harold teaches sophomore and junior lab courses as well as the senior capstone courses. This multiyear sequence provides the opportunity to build a progression of technical education integrated with communication and professional skills education. The laboratory courses are built with multi-week modules designed to mimic engineering projects one might experience working in industry, drawn from Harold's personal experiences in multiple companies. Most modules are staged in progressive phases of development, with communication assignments (e.g. memos, reports) accompanying many stages using genres appropriate for the given project phase. In almost all modules students are role playing in the lab's make-believe company, which is managed by Harold, doing work for make-believe clients.

Prior to this faculty position, Harold had accumulated over 13 years of experience working in industry. There, he learned through trial and error how important communication and professional skills are to the success of a technical professional's career. So, when he began designing and teaching laboratory and project-based courses, he understood how they are an ideal environment to simulate the settings and activities found in engineering workplaces, including communication and professional skills.

Thus, he and the materials science program wanted to incorporate a strong focus on communication in the lab courses. The program director invited Jenn to collaborate, offering a course buyout to her department for her to do this work. Since Fall 2017, Jenn has been integrated as a member of the teaching team for the junior and senior courses, engaging directly with students throughout each semester through classroom instruction and writing feedback. In 2022, she has also begun supporting the sophomore lab course indirectly, working with Harold to develop a set of class activities to teach preliminary technical writing skills and a set of assignments to accompany the lab modules

Throughout all courses, the workplace skills students may learn from each module and assignment are explained in class when the assignment is introduced, in the lab during each project, as well as in the assignments. These are both technical skills, such as compiling and analyzing data, and communication skills. Students also learn that communicating with others about their technical work is an integral part of engineering. Together, we aim to show how being a good communicator is as much a part of engineering identity as being good at math and science.

One approach we use is to set aside time during class for most assignments to allow students to work with their teams on the written assignments with assistance from Harold, if they need it. Another intended outcome of in-class writing time is it demonstrates that writing and technical communication is integral to engineering, rather than something extra they just have to do. "If

you can't communicate your work effectively, it's like it never even happened," is what they are told. However, instead of just assuming students will make time to do the writing and produce at the level expected, we work to explicitly name the writing work and make space for it, including requiring students to submit multiple drafts of projects and incorporate feedback during revision processes.

This process of explicit instruction on writing concepts, paired with drafting/revising processes, formative feedback, and feedback from both faculty members, allows students a range of opportunities to learn and to apply what they're learning. As our collaboration has evolved, we have gotten better at thinking more deliberately about how to scaffold specific skills and layer on expectations. Our goal with each revision is to identify areas where we see students struggling with a concept and provide direct instruction and feedback to support their learning.

With the goal of continuous improvement in mind, as well as a desire to focus more on using writing to support student success, we applied for a grant supporting pedagogical projects. In summer 2022, we were awarded a small grant from Boise State's Center for Teaching and Learning to focus on student success. This project allowed Jenn to think about how to apply findings from a study on equity, writing, and collaboration to teaching these students. The grant was also an opportunity to think about more broadly integrating and scaffolding writing across the materials science curriculum, beginning with a lab course at the sophomore level.

As part of this work, we revisited writing assignments to assess how clearly they were able to communicate assignment goals, tasks, and success criteria. We then revised these assignments, using a transparent assignment framework [15]. The goals of the transparent assignment framework are to clarify the "hidden curriculum" for students, making implicit ideas of success more explicit, ensuring all elements are transparent to all students, rather than assuming students have the knowledge to complete assignments successfully or the skills to figure out how to approach the work.

For example, Harold had created thorough instructions for the proposal and report template that the seniors were using for their projects–but it meant students were unclear on the goals and expectations for each individual draft. Instead of having all the information about expectations be in the template, we shifted approaches and created a transparent assignment sheet for each draft (three over the course of the semester) that stressed the communication and technical goals, highlighted deadlines, and outlined the evaluation elements for each draft. We then both reviewed each draft assignment in class with students, with Jenn incorporating this review into the focus of the communication instruction. We observed that the student teams seemed less confused about the goals for each draft than in the past and seemed to understand what they should be focusing on more so than in past semesters. They reported understanding the assignments well.

Transparent assignments are one method that has allowed us to refocus our instruction on equity in the classroom–these assignments have been shown to reduce barriers for students, particularly the populations of students more vulnerable to leaving the university. In addition, we also thought about how to explicitly talk about bias in writing and on teams, though this part of the project is still in development. One finding from Jenn's research, however, is that we can do a

better job of framing our effective teaching practices as explicitly aimed to reduce inequities in the classroom. The other finding is that we can train students to intervene when they see biases emerging in teamwork and around writing (especially the ways that women are impacted by patterns of bias around writing). We hope to continue exploring what works to support students and improve equity.

Program successes

Overall, these efforts have supported student learning. One key goal of this work is that all students have the chance to learn and practice effective communication skills, rather than relying on mentors or individual experiences. We have thus reframed these efforts as supportive of student success and focused on preparing graduates to be able to more easily transition into workplace expectations. In Jenn's research of transitions from university to the workplace [16], she found that alumni used some of the communication skills and professional skills training they gained in these project courses. This education was something they fell back on when they were faced with a new communication situation, and the participants in this study frequently mentioned their project experiences as formative for preparing them for the workplace.

In another study, she found that when participants were asked if and where they received direct instruction on effective collaboration, once again, they pointed to senior capstone as one of the only spaces where this instruction happened–and they also often cited their senior capstone team experiences as one of the best experiences with collaboration in their education. These projects were meaningful and relevant to their goals and offered opportunities to apply the vast range of their education and training to do experimental work and create effective writing for audiences beyond their course instructors. Part of this is the power of the applied project courses, but the other is reflective of the community built within these project courses, as well as the preparation the students received.

This feedback from past students indicates our work supports their writing in the manner intended. However, we currently lack detailed, quantitative data for a more thorough assessment. A multiyear, post-graduation survey of alumni will provide the information we need to more rigorously evaluate how students are using the communication and professional skills they have learned in this program. Most students in each of the last five cohorts have agreed to participate, so over the next year one or more surveys will be designed and implemented. Our goal is that these surveys will provide feedback on what strategies supported graduates as well as what we should consider adding in the future.

Next steps for the program

The MSMSE has committed to continuing to support this collaboration to ensure Jenn has the time to continue to be embedded. However, this currently is a year-to-year agreement. Thus, one goal is to craft a more permanent agreement in coordination with academic leaders across the departments/colleges. This agreement could be a formal affiliation, so she is affiliated with the materials science program to formalize the arrangement; another idea is to create a joint appointment, much like Ford has at her institution [12-13]. The goal is for Jenn to be able to contribute more fully and to potentially offer broader support around communication to other programs in the college.

Within the broader program, curriculum revisions have been underway. In these revisions, program faculty have expressed interest in a 1-credit writing course to serve as a corequisite with the lab courses. The benefit of this approach is that the writing would be explicitly housed in a course while still being linked to and embedded in the project courses. In addition, having Jenn teach this 1-credit class would mean it would be visible in her workload. The challenges that have prevented the program from taking this next step, however, are that the department wants to ensure the approach would be sustainable and would be able to be taught by someone with a writing studies background.

Other next steps are to complete the integration of communication skills into the sophomore labs, work that was begun in Fall 2022 with the grant work. This would require program faculty to agree to maintain written assignments in the class and the integration of course materials around writing that would need to be developed and shared with the broader program. We also hope to continue to engage with program faculty to find opportunities to build on this scaffolding in other courses to give students more opportunities to learn and apply what they receive in the project courses.

Finally, these efforts are being reframed as supporting student success, particularly students who are seen as more likely to leave the university without a degree as well as underrepresented and minoritized students. Thus, future work will more explicitly highlight how communication instruction can and should support equity and inclusion in the program. While we have begun highlighting the areas where bias can emerge on teams and in connection to writing, we recognize students need more opportunities to understand these patterns of bias and how they can directly intervene. Our goal is that we can use these approaches to not only ensure all students are given ample opportunity to develop the professional skills they need for success in engineering, but that all students have positive experiences that allow them to experience a sense of belonging.

Recommendations for programs

We outline our experience here to show one approach for supporting student writing in engineering. As we demonstrate, however, this is an ever-evolving partnership, and one that has required sustained support and communication. This approach would not be feasible if the materials science program was not supporting Jenn through a course release or buy-out, meaning that she has the time in her week to work with students. As such, if programs are considering approaches, they have to think about what will work within their own contexts and what is feasible. Here, we offer some recommendations to consider.

Identify what is feasible

Every institution is different and has different levels of resources. What is feasible at our institution may not work in other places. As a first step, programs seeking this level of collaboration and integration will need to determine what resources are available and who might be willing to support these efforts. What instructors would be able to work with an engineering program to support writing and communication? Can the program offer funding to the communication faculty who are able to collaborate? What ways can programs partner with other departments/programs to set the groundwork for these partnerships? Can they partially fund or

completely fund a new hire? Is a joint appointment feasible? These are all context-dependent questions to answer to determine how to begin and build a partnership.

Think in the long term

The kind of integrated collaboration we've built here did not happen overnight–it took some time to build and requires continued support. The materials science program is committed to continuing this partnership for the long term, and currently, they are working to move beyond a year-to-year memorandum of understanding between departments/colleges and toward something more sustainable. Programs should consider the long term when determining approaches and plan ways to ensure the partnership is able to be sustained over time.

People who learn together

Another recommendation is to consider how the partners can learn from each other–this collaboration works best when faculty are open to exchanging ideas and learning from each other, and learning from student experiences. Jenn spends significant time interacting not just with the primary materials science instructor, Harold, but also with other faculty in the program. This collaboration is often represented by an exchange, where she is invited to participate in program meetings, offer workshops, and engage with ABET accreditation. However, Jenn also learns from program faculty to better understand the discipline and the needs of the students, and she has been able to advance her research agenda through this collaboration. This exchange and focus on continuous improvement ensures that the partnership is meaningful for all stakeholders, which ultimately benefits the students.

Assess and revise

Finally, the approaches and projects should be evaluated on a regular basis with the goal of revising approaches. Every semester, we try something new based on what students ask for, what they seem to be struggling with, and what Jenn is finding in research about effective practices. Our current focus on increasing opportunities for student success emerges from professional development, deeper understanding of equity in engineering education, and funding from a grant aimed at improving student success in the classroom. We anticipate our approaches will continue to develop with each iteration.

Conclusion

We see the impact of our approach on student learning–alumni have shared the ways they have applied what they learned about writing and professional skills in their workplaces. Thus, we know that this work is effective at supporting the communication development of these writers and ensuring they have opportunities to practice skills they need for beyond the university. However, without continued support from various academic leaders and coordination among programs, this partnership may not be able to continue. For us, next steps are to find ways to convince academic leaders that this work is worth the resources it uses. One way would be to amplify the ways it supports students and also may improve student success and retention. Ultimately, this partnership is valuable, but it must be more visible to the range of stakeholders beyond the students we support in the classroom to ensure its continuation.

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