Exploring the role of engineering judgment in engineer identity formation through student technical reports

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Abstract— **The engineering disciplines are rigorous in their application of scientific principles, and these principles are the ones most directly addressed in undergraduate engineering classrooms. However, engineers are also called to make decisions that implicitly account for complex criteria, including the welfare of those who use or are impacted by the systems engineers design and the economic needs of their employers. As a result, engineering is an art that requires practitioners to routinely navigate difficult tradeoffs that require professional judgments. These judgments include economic, ethical, social, and value-based dimensions. These dimensions can be conflicting, increasing the complexity of practice and foregrounding the prominence of judgment. And often, these judgements need to be explained to colleagues, managers, and clients through a range of written documents. Yet little work to date has investigated the relationship between the writing engineering students do and the development of engineering judgement, particularly in terms of how these facets intersect in students developing engineering identities . Therefore, the overall goal of this project is to elucidate the interactions between how students' identification with the engineering profession impacts the way they convey engineering judgments to different audiences.**

Keywords—engineer identity, identity production, engineering judgment, professional communication

I. INTRODUCTION

This work in progress explores how teaching writing skills to engineers intersects with engineer identity formation, using engineering judgement as a focal point. The study begins with the observation that in professional practice engineers must demonstrate sound judgments that balance complex, competing objectives or constraints. Engineers must articulate and justify those judgments through a variety of communication mechanisms, including writing. Yet little research has investigated the relationship between the writing engineering students do and the development of engineer identities, particularly in terms of judgment.

To address this gap, our research investigates how students produce engineer identities in written artifacts through which they expect to be recognized as engineers. We ask: "How do students interact with the writing process, and particularly the need to articulate and justify engineering judgments, to produce engineer identities, and how do their identities shape the ways in which they articulate their engineering judgements?

This work in progress is the first part of a two-phase qualitative case study in project-based undergraduate Systems Engineering courses that uses semi-structured interviews and analyses of student writing to explore how engineering identity production influences the way engineering judgments are reflected in student writing, and how writing in terms shapes engineering identity. The second phase of this work in progress will involve the design of assignments that foster engineering identity production in writing. We draw from scholarship on academic literacy in writing studies research, together with identity frameworks from engineering education research [1]–[3], exploring the ways students learn to think, act, write, and speak as professionals as they learn different conventions for writing.

This paper presents the study design and initial data from student interviews and written products. In semi-structured interviews, students describe their process of drafting and revising written documents, with prompts focusing on approaches to—and engineering judgments for—problem formulation and calculation/computation, and engineering judgments for communicating findings in writings. The goal is to identify the concepts, categories, and frames students use to make communication choices that align with understandings of "engineering writing," and how choices intersect with student perceptions of engineering identity.

II. BACKGROUND

A. Writing Instruction and Engineering Education

Despite the criticality of writing and communication skills in engineering practice, the relationship between writing education

and engineering identity formation has not previously been studied, and in fact, even among working professionals, communication tasks are perceived as "not engineering" (e.g., [4]). The study of writing in engineering education is an active area of research inquiry, but these inquiries focus on genre studies [5], [6], instruction in technical communications [7], writing-to-learn science, technology, engineering, and mathematics topics [8]–[13], student metacognition and metacognitive practices [14]–[16]. Writing in engineering education research has consisted mostly of descriptive case studies, and educators have hesitated to incorporate writing to learn activities in their classrooms because no framework exists to integrate the research findings with practice [12], even though scholars have argued that learning to engineer is embodied in the acquisition of a discursive identity [17].

Two landmark studies in engineering writing inform the direction of our research. First, in her seminal study, Winsor [3] conducted case study research investigating the ways that four engineering students learned to "write like engineers" during their five-year undergraduate education. The subjects of this research were students in an engineering program that integrated industrial work experience with classroom education in alternating terms. Therefore, this study was able to produce insights into how students learned writing from the classroom, what aspects of classroom learning transferred to the workplace, and how students learned writing skills in the workplace. Winsor found that the students' affinity towards the engineering profession led them to construct a view of "engineering writing" that guided how they approached their writing assignments. One example of this is the subjects' views that engineering writing is arhetorical (a finding echoed in Leydens' later research on faculty [18]). That is, engineers should not write persuasively, their goal should be to present the data—which will speak for itself. Of the four case studies, only two subjects' views on the rhetorical, i.e., persuasive, nature of engineering writing and communication changed. Three other characteristics marked student-held views on "engineering writing": i.) engineering writing is boring and inept, i.e., engineering writing is intended for instrumentality and not entertainment; ii.) engineers write for engineers; and, iii.) appropriate standards for engineering writing are learned at work ([3], p.87-88). Winsor's findings suggest that the type of professional identity students develop and aim to convey has implications both for their view of what constitutes "engineering writing" and how such writing should be employed in communication tasks.

More recently, Poe, Lerner, and Craig [2] studied the intersection of communications and technical instruction at the undergraduate and graduate levels in writing across the curriculum. Their investigation evaluated the ways that: i.) the communications taught were socially situated in the needs of the technical community the students' trajectories would place them in; and, ii.) the artifacts of the communications taught by the technical (i.e., engineering and science) professors were partially determined by the identities social roles required and the engineering or science identities that needed to be produced for the tasks at hand. The study was a mixed-methods multi-year observational study that combined surveys, interviews, and ethnographic methods.

B. Engineering Identity

There are several lines of research that have formed within the engineering education community, and there are several thematic lines that emerge: discursive engineering identity research, quantitative measurement of engineering identity, influences of professional or extra-curricular experiences on engineering identity, and intersectionality, race, and gender studies in engineering education. Our work in progress draws most heavily from the discursive identity stream within this community. Discursive engineering identity research is probably the largest sub area of research, and its development largely proceeds from the seminal work of Gee [19]. The discursive engineering identity stream argues, loosely, that learning involves taking on the discourse of a community— whether that community is a professional community of practice or an affinity group. For example, Allie et al. [17] argue that successful engineering learning involves developing a discursive identity as a member of the engineering community, and argue that engineering education should make more explicit key aspects of engineering discourse that engineering students may be vaguely aware of. Allie et al. [17] suggest that successful learning in engineering will involve a student's personal identification with the profession of engineering.

Eliot et al. [20] build on the centrality of personal identification with the profession. Their study takes a constructivist approach to understanding how students situate their knowledge, interests, and sense of self within the broader context of professional engineering. Eliot et al. [20] emphasize that the construction of professional identity should be an explicit goal of engineering education programs, and not only a phenomenon that occurs as a result of undergoing an engineering education curriculum. They concluded that students constructed "possible selves" that represented their potential future professional identities on the basis of what they believed was expected of them. Their perspectives are closely related to the discursive identity lens of Gee [19] and the identity productions of Tonso [21], [22]. In addition, their findings seemed to be corroborated by the work of Groen et al. [23] and Groen and McNair [24]. In summary, discursive engineering identity research focuses on identity as mastery of disciplinary discourse practices [25], [26]. This sub-field of engineering identity research suggests that literacy and identity are co-constructed.

C. Summary

In our work in progress, we posit that the written artifacts students produce are sites of identity production in which authors present themselves as competent engineers, and sites of identity consumption, in which readers who are part of the discourse community students hope to join– colleagues, managers, clients, or other stakeholders in engineering work - evaluate and accept or reject that presentation.

To frame our study, we first draw on Gee's analytic lens [19], which is comprised of four ways to view identity: nature-identity—a state perceived as inherent in one's nature; institution-identity—a position authorized by authorities within institutions; discourse-identity—an individual trait recognized in the discourse/dialogue of/with 'rational' individuals; and affinity-identity—experiences shared in the practice of 'affinity

groups.' This lens enables us to explore students' identities as produced in and through their writing (discourse identity), but also in the context of their sense of self (nature identity), their social interactions (affinity identities), and their institutional positions (as students and as engineering majors). This framework provides a broad lens with which we can explore students' perceptions of their engineering identities.

To complement this lens, Tonso's anthropological approach complements Gee's framework by highlighting the ways in which engineering identities are framed by cultural practices and knowledge about campus engineer identities learned through practice and participation in work and life on campus [21], [22]. In doing so, it provides a mechanism to attend to not only students' perceptions, but the courses in which the study is situated as well as the broader departmental and campus climate. Her study argues that engineer identities were produced through a complex process that "bound up thinking about oneself as an engineer, performing an engineer self, and ultimately being thought of as an engineer." In other words, students produce engineer identities in writing as they navigate the interplay between their perceptions of themselves, their future profession, and the broader external perceptions of the profession.

Finally, Lea and Street's academic literacies framework provides the means to focus specifically on the relationship between student writing and student identity [27], [28]. This framework focuses on the links between learning the language of a discipline and its ways of making and constructing arguments and constructing a professional identity in the discipline. In other words, writing like an engineer signals engineering identity and enables students to persuade through the knowledge and professional authority within that identity. In doing so, it provides a lens to explore students' texts, along with the interview and field note date, as enactments of engineering identity.

III. RESEARCH DESIGN

A. Theoretical Frameworks

This work in progress is part of a constructivist thematic analysis investigating the ways student writers produce engineering identities through their written work. This work is grounded in three interconnected frameworks: Gee's use of identity as an analytic lens [19] forms our primary framework while Tonso's identity production theory [22], [29] and Lea and Street's academic literacy approach [27], [28] provide complementary frameworks that allow us to link identity to writing instruction.

B. Study Details

This work in progress is part of a two-phase qualitative study: an exploratory phase investigated via instrumental case study; and a subsequent intervention designed to enhance the production of engineering identities through writing. Phase 1 uses semi- structured interviews and analyses of student work to explore engineering identity production in writing, and Phase 2 uses those results to design and study assignments intended to more effectively foster engineering identity production in writing. Phase 1 involves a set of pilot interviews that will be used to refine the research design and support the development of a more robust set of qualitative research protocols to be used

to complete. The research design described in this paper corresponds to this pilot phase.

In this pilot phase, we will conduct semi-structured interviews with two fourth-year undergraduate students currently enrolled in a systems engineering capstone course at a large private mid-Atlantic university. Recruitment of study participants is ongoing, and is taking place using e-mail and other electronic communications via the current senior project instructors.

At each interview, students will be requested to bring: i.) an example of a past writing sample that the student believes represents good engineering writing; and, ii.) writing samples related to their present research project at different stages of the project that could help to show how they have made engineering judgment choices in writing.

The interview questions will investigate students' responses to the ideas: "What is Engineering and Writing?" and "How are Engineering Judgments and Process Expressed in Writing?" Questions that explore the first idea include items such as:

- What are your experiences with writing?

- In our recruitment materials, we'd asked you to bring along a recent piece of your writing that you felt represented a good technical or engineering writing sample.

    o What was the purpose of this writing? What was this writing intended to achieve (beyond getting a particular grade)?

    o How will did your writing achieve this purpose?

- Based on your experience(s) and understanding, could you describe what characterizes good technical or engineering writing?

    o In what ways does/doesn't your writing sample meet these criteria?

- More broadly, what role does writing play in engineering work?

- How well prepared do you feel to do the type of writing you expect to do when you start working?

Questions that explore the second idea include items such as:

- Please describe your current project and its overall goals.

- What is the purpose of this document in the scope of your project? What is your writing supposed to do? What do you think it does?

- In your writing sample, please show where you would expect the reader to know your objectives. Could you use your writing sample to explain what your writing "does"?

- Do you remember what you did "as an engineer" to obtain your results? How do you communicate what you did in your writing?

o Can you point to specific choices in your writing that reflect what you did?

- Could you describe, generally, the process you used to complete this assignment?

The questions exploring engineering and writing are intended to understand students' backgrounds with writing, then build on this understanding to explore how students understand the role of writing in engineering practice. The questions exploring judgement and writing are intended to explore the choices students express in their writing about their judgements, as well as the processes used to construct both the judgements and the written document. The data collected during these interviews will be analyzed using thematic analysis, using NVivo 12 software to obtain codes and thematic maps of our data.

IV. Final Considerations

Ultimately, research findings of this work in progress will develop writing-based interventions in engineering education, producing reproducible frameworks for incorporating writing instruction that support undergraduates in bridging the gap between their student and professional experiences. These findings will enable educators to employ pedagogical strategies that will support student development of engineer identities.

Acknowledgement

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