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The WRI2TES Project: Writing Research Initiating Identity Transformation in Engineering Students

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Abstract

The NSF Research Initiation in Engineering Formation (RIEF) project described in this paper is grounded in our understanding of the realities of professional practices. Engineers must be able to construct and participate in sound judgments that balance complex, competing objectives or constraints, and they must simultaneously produce recognizable engineering identities that enable them to articulate and justify those judgments to others through a variety of communication mechanisms, including writing. Consequently, the objective of our project isto investigate the ways students produce engineer identities in written artifacts through which they expect to be recognized as engineers. We divided the project into two phases: Phase 1 involving semi-structured interviews designed to conceptualize the engineering judgment process using thematic analysis; Phase 2 involving the design and dissemination of pedagogical approaches based on our results. This paper primarily reports the preliminary results of Phase 1. This project is an instrumental case study using semi-structured artifact-based interviews as the primary data source. Our semi-structured interviews are designed to focus on the ways students construct engineering judgments and produce engineer identities through their written projects. Course documents (including assignments and related material) as well as reflective field notes and analytic memos are used to provide additional contextual data. The data from this project provide a foundation for an understanding of engineering judgment that conceptualizes students as decision makers who participate in acts of engineering judgment. These judgments may be constructed individually, or constructed jointly through the interactions of multiple individuals working in teams to navigate ambiguity, uncertainty, and conflicting objectives. Moreover, our project situates engineering judgment as an interplay among several interdependent cognitive processes, and shows how the theories of identity as in interpretive lens, academic literacies, identity production, and naturalistic decision making can help to explain how undergraduate students come to view themselves as professionals capable of participating in acts of engineering judgment.

Overview

In practice, engineers must navigate a tension between professional loyalty to their technical community, and their professional and economic allegiances to their firms. Consequently, it is natural for engineering practitioners to continually negotiate multiple, potentially conflicting identities. These identities may intersect most consequentially in the myriad decision making situations faced as engineers scope projects or problems, design solutions, communicate recommendations, or identify new markets or opportunities for technologies The engineering disciplines are manifestly 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 we design and the economic needs of their employers.

As a result, in many ways 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. Each of these dimensions could be conflicting, increasing the complexity of practice and foregrounding the prominence of judgment. The result,

as Dorothy Winsor observes, is that engineering is information work requiring skill in persuasive communication [1]. Such information work means that engineers not only must develop engineering judgment, but must also develop engineering identities that will enable them to recognize for themselves the centrality of such judgments to engineering work and to be recognized by others as experts capable of making such judgments. As engineers progress in their professional capacities, they will inevitably need to communicate their judgments to engineers, non-specialists, clients, and a variety of others. One key goal in all such interactions will be to convey themselves as competent professionals; either as an insider when in the company of other engineers, or as an authoritative expert when in the company of those seeking their advice. The art of engineering, in short, is tightly bound to the negotiation of engineering identity.

The NSF Research Initiation in Engineering Formation project described in this paper is grounded in our understanding of the realities of professional practices: engineers must be able to practice engineering as art and develop sound judgments that balance complex, competing objectives or constraints, and they must simultaneously produce recognizable engineering identities that enable them to articulate and justify those judgments to others through a variety of communication mechanisms, including writing. Consequently, the originally proposed objective of our project was to investigate the ways students produce engineer identities in written artifacts through which they expect to be recognized as engineers.

To investigate this question, we have foregrounded the role of engineering judgment in our research. Engineering judgment is a range of cognitive processes that are possessed both by individuals and by groups, and so our research is directed towards a theorizing of engineering judgment at the intersection of cognitive processes, academic literacies, identity theories, and identity production.

In asking the research question: "How do students interact with the writing process, and particularly the need to articulate and justify engineering judgments, to produce engineer identities?", our research explores the related processes of:

i) engineering judgment practiced by undergraduate systems engineering students; and
ii) communication of engineering judgments in systems engineering students' writing.

In our original proposal we divided the project into two phases: Phase 1 involving semi-structured interviews designed to conceptualize the engineering judgment process using thematic analysis; Phase 2 involving the design and dissemination of pedagogical approaches based on our results. This paper primarily reports the preliminary results of Phase 1. Our research team is in the process of completing Phase 1 and moving to Phase 2 in ongoing work.

Theoretical Frameworks

Our project is a constructivist thematic analysis investigating the ways student writers participate in and construct engineering judgments while they produce engineering identities through their written work. According to Chism et al. [2], constructivism examines the meanings individuals create to describe the world around them. Constructivism assumes meaning is socially constructed through interaction of individuals with the world and their own particular viewpoints and experiences. Our study is grounded in three interconnected frameworks: Gee's use of identity as an analytic lens [3], Tonso's identity production theory [4], and Lea and Street's academic literacy approach [5].

Gee's analytic lens is comprised of four ways to view identity: nature-identity—a state developed from forces in 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. 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. 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 argued 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 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. 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.

By integrating these three frameworks, our team has explored how students approach the various engineering judgments required to construct their written arguments or communicate engineering judgments as they take on engineering roles.

Approach to Research

To explore the research questions listed above, our project was designed as an instrumental case study [6] using semi-structured artifact-based interviews as the primary data source. Our semi-structured interviews are designed to focus on the ways students produce engineer identities through their written projects. Course documents (including assignments and related material) as well as reflective field notes and analytic memos are used to provide additional contextual data.

Participants

Our project includes 6 undergraduate systems engineering participants enrolled in the systems engineering senior project at the lead author's institution. All of the students have received prior instruction in writing in the disciplines (WID) courses that focus on the application of risk, uncertainty, and statistical decision theory to engineering problems, and have had prior experiences completing substantial semester long projects in engineering teams. These projects have required the student participants to apply engineering judgment to problems with significant uncertainties and conflicting objectives.

Data Collection

Two semi-structured interviews were conducted with each study participant—except the first participant due to instructional discontinuity attributed to COVID-19 response at the lead author's institution. For this participant, both interviews were condensed into a single interview protocol. The interview questions were designed to investigate students' responses to the ideas: "What is Engineering and Writing?" and "How are Engineering Judgments and Process Expressed in Writing?" The first semi-structured interview focused on questions that explore the first idea. Our interview protocol is described in more detail in a prior FIE publication [Authors]. Example questions include:

- 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.
    - What was the purpose of this writing? What was this writing intended to achieve?
    - How well did your writing achieve this purpose?
- Based on your experience(s) and understanding, could you describe what characterizes good technical or engineering writing?
    - 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?

The second semi-structured interview focused on questions that explore the second idea. Example questions include:

- 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?
- 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 first semi-structured interviews are given at the end of the first semester and the second after project completion. Additionally, students were asked to bring relevant writing samples to both interviews. For example, during the first interview, the student participants were requested to bring with them a writing sample that reflects what they consider to be a piece of good technical writing they completed. This writing sample was used during the first semi-structured interview to explore students' perceptions of writing and communication processes more generally. During the second semi-structured interview, the focus was exclusively on the senior project, exploring

decisions that were made in response to new information, model building assumptions, decisions about work process and team dynamics, integration of feedback from supervising professors and external clients, and choices made when compiling final communication deliverables such as oral presentations and final reports.

Data Analysis

To analyze the data collected, we used thematic analysis. According to Braun and Clarke [7], thematic analysis is "a method for identifying, analyzing, and reporting themes within data." Thematic analysis resembles techniques such as grounded theory or interpretive phenomenological analysis, but does not require an epistemological or theoretical commitment in order to use the method. As a result, the method is flexible, and can be adapted to a range of theoretical frameworks—such as our constructivist Gee-Tonso lens—and can facilitate development of a detailed, complex account of the dataset. A first-pass set of *a priori* codes was obtained through a two-part process. First, a literature review of engineering judgment in student writing was conducted. This literature review suggested several possible codes that might be helpful in delineating instances of identity production in both the interview data and students' written products as participants talk about their writing experiences and represent their engineering identities in writing. To further refine the *a priori* codes, a hybrid descriptive-dramaturgical analysis was conducted on the pilot interview collected during COVID-19 instructional discontinuity. This analysis helped to further refine the codes in two ways. First, the descriptive analysis enabled the team to reflect on how appropriate the *a priori* codes might be for exploring the data corpus. Second, the dramaturgical analysis reflected the student's identity production differently due to the focus on subtexts and "character development" theme categories recommended by Saldana [8]. Dramaturgical analysis requires the researcher to re-consider the data as a monologue; thus requiring the researcher to implicitly consider the interview data themselves as a site of identity production. Another round of preliminary analysis was conducted on the set of five first-round interviews with the remaining five participants to further assess the reasonableness of the codes and discuss additional emergent codes that arise to help refine our engineering judgment categories and high-level themes. The semi-structured interviews were all transcribed by a third-party transcriptionist, checked by a member of the team for accuracy, and analyzed using Atlas.ti software.

Results

Engineering Judgment

The first task we embarked on—and are still working towards—was a literature review theorizing engineering judgment at the intersection of decision making, writing, and identity. Engineering judgement is closely linked to cognitively complex decision-making tasks that require students to synthesize and extend knowledge from multiple sources (e.g., data, other experts, heuristic practices), position themselves as experts capable of making judgement (i.e. adopt a particularly identity position), and persuasively communicate the judgement to stakeholders. These intersections have multiple implications for educators in developing and scaffolding course assignments that will be explored in Phase 2 of the project.

In our literature review, previously published in part at ASEE [9], we discussed that in engineering education research on engineering judgment, the context described by researcher and educator resembles a closed-loop, naturalistic, decision making process much more than an open-loop process. The term "closed-loop" is used in decision science to refer to decision

processes that incorporate monitoring and feedback to adjust decisions in response to emergent information in the decision context. This is opposed to "open-loop" where decision processes assume goals, objectives, available alternatives, and outcomes of those alternatives via well-understood rules or causal mechanisms known *a priori*. Our ongoing work positions engineering judgment within the naturalistic stream, acknowledging that engineering judgments faced by students should prepare them to participate in decision situations characterized by:

- incomplete rather than complete information;
- ambiguous specifications rather than clear requirements;
- uncertainty about operational performance rather than certainty in projections; and,
- augmented memory or information processing through interaction with external sources, tools, and experts rather than complete and adequate internal memory.

The interaction among these characteristics yields complex, potentially poorly structured problems—having poor data quality, ambiguity, and high-stakes. Thus, the development of engineering judgment in order to make decisions in the face of complexity is an important educational objective. Prior research suggests that decision making under complexity involves several interacting cognitive processes including but not limited to: perception (reception or collection of information from the natural, social, or operational environment), memory (storage, organization, and retrieval of the perceived information), judgment (transformation of the perceived and stored information into meaningful alternatives), choice (evaluation and selection from among these meaningful alternatives on their merits), feedback (knowledge of outcomes obtained from prior judgments and actions), and learning (reinforcement of the consequences of past decisions)

Dramaturgical Analysis of Engineering Judgment Processes

Next, we conducted a dramaturgical analysis of the first pilot interview [10]. This analysis yielded several key findings that merit further exploration: a) Students move across different discourse communities during their undergraduate careers and seek to integrate – sometimes successfully and sometimes not – multiple models of knowing. b) Although models of disciplinary literacy focus on academic communities, within undergraduate engineering education, students also encounter and struggle to attend to non-academic audiences and stakeholders. Moreover, the needs and expectations of academic and non-academic audiences may be in tension and result in struggles over power and authority in texts.

To conduct our analysis, we used an exploratory coding technique that first employed both *in vivo* and descriptive coding to determine high-level themes that seemed to emerge from the data. Table 1 below lists several high-level themes that emerged from consideration of the *in vivo* and descriptive codes obtained from that work:

Table 1. Descriptive (right column) and high-level (left column) themes obtained from exploratory coding of pilot interview. [10] © IEEE. Reused with permission.

Suggested Theme	Frequently Co-Occurring Code(s)
Discourse	Analytical Process (5), Co-Production (5), "Engineering Writing" (9), "Higher Level of Understanding" (5), Making and Analyzing Assumptions (9), Perception (8), Research Process (8)
Judgment	Research Process (8)
"Engineering Writing"	Symbols and Equations (6), "Higher Level of Understanding" (9)
Research Process	Judgment (8), "Make Connections" (7), Perception (7)

These themes interact with one another to produce the communication acts engaged by our study participant. The thematic analysis produced the following thematic map, shown in Figure 1 indicating these interactions. The main themes of discourse, judgment, and research process appear on the figure, with the research process theme further expanded to show perception, analytical process, co-production, and making assumptions. As these processes intersect, certain actions or behaviors are indicated. For example, when judgment and discourse intersect, the student is positioning their work or themselves within the discursive community they are participating in. Thus, this link reflects the way that the student's judgment is modified by identity considerations. Similarly, the relationship between judgment and analytical process proceeds through an intermediate step of "perception", which relates to the types of problems or concerns the student considers to be worthy to construct or investigate. Because perception is influenced by discourse, this theme also involves consideration of identity in that the student determines what problems are worth pursuing by referencing the standards and expectations of the discursive community. These themes were then re-considered through the use of dramaturgical analysis. In this step, the interview transcript was coded using the six dramaturgical character analysis categories recommended by Saldana [8]. In conducting this analysis, the student's association with multiple discourse communities—and challenges navigating them both—were better foregrounded and placed the themes from the descriptive coding into context.

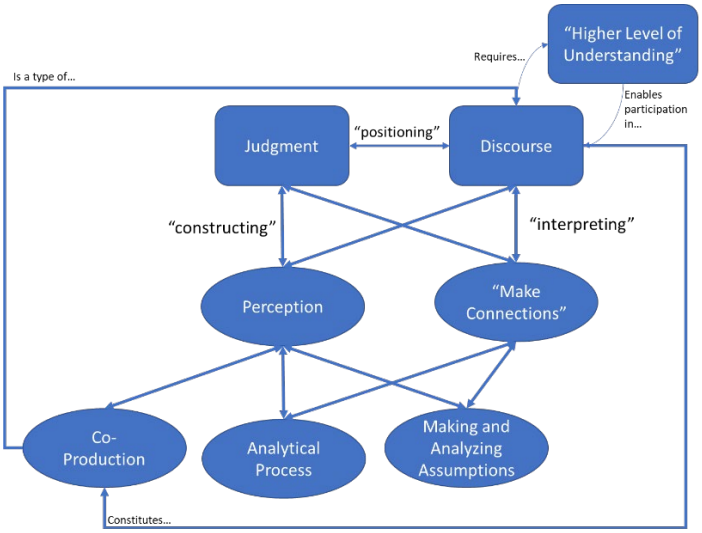

Figure 1. Thematic map showing intersecting processes of judgment, discourse, perception, and analytical process. [10] © IEEE. Reused with permission.

Thematic Analysis of Engineering Judgment and Student Writing Practices

The exploratory analysis above helped to establish coding procedures that could be used to explore the entire data corpus. The next stage of the research was a thematic analysis of the first set of five interviews. The thematic analysis of the first set of five interviews [11] illustrates the ways in which engineering judgment emerges from the interaction of complex components of a decision context. The codes obtained from the exploratory analysis described above were refined and provided the basis for *a priori* codes used to investigate the role of judgment in both constructing and communicating engineering judgments in their writing projects. Through this analysis, we demonstrate that judgment is not an isolated step in a distinct 'problem solving' step but emerges as students' conceptualization and understanding of the problem evolves. The interviews illustrate the ways in which judgments about their project emerged at different stages in their writing, shaped by both how they understood engineering discourse within and beyond the course and how they understood their audiences. The four emergent themes—framing and positioning, audience awareness, analysis, and synthesis—worked together to support students' ongoing acts of engineering judgement. These emergent themes are presented in Figure 2.

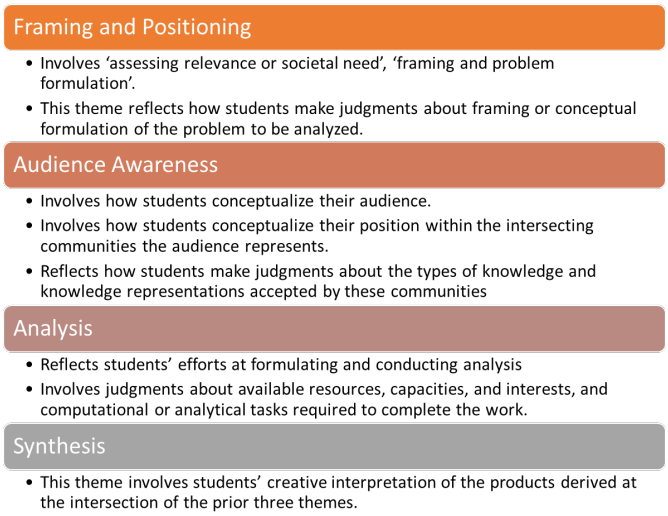

Figure 2. Emergent themes resulting from thematic analysis of initial interviews.

Our findings lay the groundwork for further studying student decision-making as they interact with both existing knowledge and interpretive practices. Our results support the idea that writing practices can help to support how engineering students learn to apply and interpret that knowledge in specific contexts. Through our current work, we are continuing analysis of the entire corpus of eleven interviews, and further refinement of the emergent themes.

Conclusions and Ongoing Work

The data from this project provide a foundation for an understanding of engineering judgment that conceptualizes students as decision makers who participate in acts of engineering judgment. These judgments may be constructed individually, or constructed jointly through the interactions of multiple individuals working in teams to navigate ambiguity, uncertainty, and conflicting objectives. Our multi-disciplinary project conceptualizes engineering judgment as an interplay among several interdependent cognitive processes, and shows how the theories of identity as in interpretive lens, academic literacies, identity production, and naturalistic decision making can help to explain how undergraduate students come to view themselves as professionals capable of participating in acts of engineering judgment. The data described in this paper support currently ongoing research in which we are refining our theories of engineering judgment, completing a more comprehensive thematic analysis of our interview corpus, and initiating development of pedagogical orientations, approaches, and assignments that might be considered by instructors interested in advancing the capacity of engineering judgment among their students.

Acknowledgments

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