A dramaturgical exploration of engineering judgment processes in undergraduate student writing

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***Abstract*— The objective of this full paper is to explore the interplay between engineering judgment and communication practices involved in completing an undergraduate systems engineering senior project. We view engineering judgment as an embodied process that emerges through discourse as individuals position themselves relative to both other individuals and disciplinary norms in a range of contexts. It happens, broadly, through a series of tasks and thinking processes through which students choose and formulate problems, make assumptions, select data, and adopt roles in relation to disciplinary norms in different contexts. We explore this conceptualization of engineering judgment using thematic and dramaturgical analysis of a single case. The data collected are a semi-structured 90-minute interview collected with one systems engineering senior after completion of their senior project and graduation from their degree program. These data are first coded using a thematic analysis approach, then re-analyzed using a dramaturgical approach. Our findings raise important issues about the blend of communication demands faced by practicing engineers that potentially impact the socialization of engineering students. Different communication demands require students to use different ways to navigate complexity. The varied communication forms also prompt students to view themselves as professionals with the capacity to judge and act from a position of professional authority that vary with the situational context.**

Keywords—engineering judgment, engineering identity, thematic analysis, dramaturgical analysis

I. Introduction

In this paper, we are guided by the question: "How is engineering judgment expressed in written communication?" We explore this interplay between engineering judgment and communication practices through a single case focused on an undergraduate systems engineering senior project. Engineering judgment is a critical topic related to educational practices that influence engineering identity formation. It is linked to technical problem-solving ability, critical thinking praxis, and situated cognition. Moreover, emerging research indicates that engineering judgment is constructed through professional and interpersonal communication practices [1]. Engineering judgments are conveyed through writing, speaking, and acting within and between groups of engineering professionals and stakeholders. To frame the study, we draw on discourse identities and academic literacies frameworks, following Lea and Street [2], and Berkenkotter et al. [3]. We explore this conceptualization of engineering judgment using thematic and dramaturgical analysis of an intrinsic case study. This analysis illustrates the variety of ways in which a student enacts engineering judgement through discourse across different writing contexts. The data collected are a semi-structured 75-minute interview collected with one systems engineering undergraduate senior after completion of their senior project and graduation from their degree program. In focusing on one student, we follow Foor et al. [4] and Pawley [5], who offer compelling arguments for deep explorations of individual experiences. Such cases are not meant to be generalizable, where one individual represents the whole, but rather opportunities to push beyond general "knowns" to highlight new directions and underexplored phenomenon missed by large aggregate studies.

II. Theoretical Frameworks

The research draws on both discourse identity [6] and academic literacy [2]. Together, these theoretical frameworks describe how students develop fluency in participating in the discourse of their discipline. This fluency involves not only understanding the language of the discipline, but also expressing oneself in that language through communication forms appropriate to the purpose demanded by a task's context, purpose, and audience expectation. Furthermore, these frameworks are important for understanding engineering judgment as learned communication processes. While prior researchers have applied discourse identity and academic literacies to research on engineering learning and identity broadly (e.g., [7]–[9]), we extend these studies by focusing specifically on engineering judgment.

A. Discourse Identity

Allie et al. [10] conceptualize learning in engineering as taking on the discourse, and thus the identity, of an engineering community. They locate learning in engineering on a continuum with two poles: an acquisition perspective and a participation perspective. The acquisition perspective views learning as 'acquiring something', thus implying that learning

has an endpoint (p. 360). On the other hand, the participation perspective views learning as an ongoing process of engaging in shared action (p. 360). Under the participation perspective, the focus is on action using the specialist discourse of the community appropriate to a particular environment or situation. Allie et al.'s discursive identity construct views educational institutions and environments as sites where students construct engineer identities through participation in the community's discourse. So, recognition by an external community is the means through which students acquire engineering identity. This discursive identity framework is particularly useful in understanding this case as our participant attempts to demonstrate membership in the community of engineering professionals through writing. Their efforts are particularly evident when we observe them comparing and contrasting "engineering writing" with "non-engineering writing."

B. *Academic Literacies*

Lea and Street [2] provide a useful description of the academic literacies framework. Their conceptualization was formulated as part of a research effort aimed at moving away from a "skills-based, deficit model of student writing [the study skills model] and to consider the complexity of writing practices, [the academic socialization model], that university students engage in" ([2] p. 157). Their investigation explored student and faculty perceptions of student writing in higher education using case studies at two institutions in southern England. The academic literacies framework posits that reading and writing within disciplines are processes through which students learn and synthesize disciplinary knowledge. The academic literacies framework fuses the academic socialization and study skills models within institutional practices, power relations, and identities. The study skills model assumes that writing practices are skills that can be learned by students and transferred to other areas. Thus, if a student is deficient in writing skills, the goal is to "fix" the problems with students' ability to learn such skills. The academic socialization model views the task of the instructor as inducting students into the culture of the academy. The main challenge faced by this view is the heterogeneity of academic cultures among different disciplines, departments, or institutions. As a result, instructors or students may oversimplify the complexity implicit across different academic subcultures students encounter. The academic literacies view bridges these two models of student writing by viewing student writing as academic practices situated in sites of discourse and power, i.e., academic disciplines and institutions. It recognizes that students must "deploy a repertoire of linguistic practices" ([2]p.159) drawing on identities, social meanings, and disciplinary meanings appropriate to the diverse disciplines and discourse communities students encounter in their studies. Problems in student writing in the academic literacies approach can be understood in terms of the contested relations of power and authority negotiated by student and instructor, and not only in terms of study skills or academic socialization into a 'homogeneous' set of academic writing standards.

Combining discourse identity and academic literacies is useful for the present work because our research investigates the ways students understand the communication roles they must assume in light of the professional identities they hope to enact. For undergraduate writers like the one we interact with in this paper, this professional identity conceptualization is complicated by the challenge of navigating the range of faculty expectations faced during their curriculum. Additionally, academic literacies recognizes the tensions students face as they anticipate their future professional socialization requirements while experiencing immediate undergraduate institutional practices and power relations.

C. *Engineering Judgment*

We draw on these two frameworks specifically to explore the interaction of writing processes and engineering judgment. While most prior research on engineering judgment investigates engineering judgment as something an individual does, in practice the work of engineering judgment is typically done among groups of individuals to negotiate complexity. That is, individual engineers exercise judgment in and through discussions with other professionals to resolve complex, open-ended situations. Weedon [1], [11], [12] exemplifies this perspective, investigating engineering judgment as the enacted, embodied communication processes situated among teams of engineers. He conceptualized engineering judgment in part as the ability to recognize the rhetorical tactics required to satisfy an 'emergent' task. In the context of our work, 'emergent' can be understood as 'improvisational' or 'contingent,' as engineering teams respond to new information, unexpected changes in project requirements, or team dynamics. Researchers taking this perspective [1], [13], [14] explore the variety of ways that engineering judgment emerges as engineers iteratively enact conceptualization, understanding, and communication of their work products and processes.

III. Methodology and Data

A. *Data*

The data analyzed in this paper are drawn from a single semi-structured interview with an undergraduate systems engineering student approximately one month post-graduation from their undergraduate program. The student studied at a U.S. mid-Atlantic private institution. This semi-structured interview was collected as part of a larger study whose goals and objectives were described in [15]. Relevant methodological details are as follows. First, at each interview, the participant was asked to bring an example of a past writing sample they believed represented good engineering writing as well as writing samples related to their senior research project that could show how they have made engineering judgment choices in writing. The questions used during the semi-structured interview were designed to investigate students' responses to the broad ideas: "What is Engineering and Writing?" and "How are Engineering Judgments and Process Expressed in Writing?" The questions exploring the first idea were intended to understand students' backgrounds with and dispositions towards writing, then build on this understanding to explore how students understand the role of writing in engineering practice. The questions exploring the second idea were intended to explore the choices students express in their writing, and the processes used to construct the written document.

The student writing assignments providing context to this interview were drawn from systems engineering and economics. The writing samples provided by the student for these assignments were composed as a result of unstructured guidance since the student was completing culminating projects in their major field of study (systems engineering senior project) and their minor field of study (economics proseminar). Despite the different academic fields, both work products were composed as a result of work processes that would require a considerable degree of student judgment and decision-making. During the course of the interview, it became clear that although the projects were drawn from different fields, there were several similarities shared in terms of the quantitative analysis methods used. Both studies were data-driven statistical analyses of datasets freely constructed by the participant in response to their proposed problems. Despite these similarities, a key difference between the two writing samples was that the economics sample was composed as an individual effort, while the systems engineering sample was a work product from a group project.

The interview was approximately 75 recorded minutes in length and was manually transcribed prior to coding in Atlas.ti 8 qualitative analysis software. The initial interview protocol was designed to be conducted in two phases; however, given COVID-19 considerations at the participant's institution, the protocol was modified so that the data were collected in a single interview using Zoom. While the participant and interviewer were able to share screens and audio connection, no video was used during this interview. The participant was also instructed to bring two writing samples to the interview: a sample of what the student considered "good technical writing" and a final written deliverable for their senior project. During parts of the interview, the participant would use the screen sharing feature to show the interviewer specific choices made in their writing, or to explain specific aspects of their work during the interview. After the manual transcription was obtained, a single member of the writing team conducted first- and second-cycle coding of the transcripts using thematic and dramaturgical coding methods described below.

B. Intrinsic Case Study

We orient this study as an intrinsic case study following Stake [16], which advises that "case study is defined by interest in individual cases, not by method of inquiry used" (p. 134). Although the case reported in this paper is an intrinsic case study, the larger research project in which it is situated is an instrumental case study, where each participant represents a single case, with multiple interviews and documents As noted earlier, in focusing here on a single case, our goal is not to generalize, but rather, following Foor et al. and Pawley [4], [5], to illustrate the complexity of the phenomenon (engineering judgement as enacted in communication practices) through deep exploration of a single individual. To do so, we used a multi-cycle qualitative coding approach involving descriptive coding and dramaturgical coding.

C. Thematic Analysis

First-cycle descriptive coding was used to develop themes. Descriptive coding summarizes in a word or short phrase the basic topic of a passage of qualitative data [17](p. 102). In conjunction with descriptive coding, in vivo coding was also employed so that the meanings of passages of data could be captured in the language of the participant. In vivo coding also helped to prioritize the participant's voice when generating themes or processes related to writing practice and engineering judgment. A preliminary codebook of approximately 15 codes was created based on prior literature and a review of the audio recording and interviewer field notes. The transcribed interview was then coded by the interviewer using descriptive codes and in vivo coding. Additional descriptive codes were generated through a combination of interviewer judgment and in vivo coding, and the interview transcript was coded a second time employing the expanded codebook. Ultimately, 44 descriptive/in vivo codes were obtained. These codes were then evaluated to recognize potential patterns and organized into high-level themes. Finally, an operational model diagram [17](p. 226-228) of these higher-level themes was formulated to represent potential processes observed in the data.

Table 1. 20 most frequent codes assigned to interview data

Code	Frequency	Code Type
discourse	71	Descriptive
judgment	65	Descriptive
engineering writing	29	*in vivo*
research process	25	Descriptive
perception	23	Descriptive
making and analyzing assumptions	19	Descriptive
"higher level of understanding"	16	in vivo
analysis	15	Descriptive
"humanities writing"	14	in vivo
analytical process	13	Descriptive
"make connections"	13	in vivo
skill transfer	13	Descriptive
symbols and equations	10	Descriptive
writing as narrative	8	Descriptive
writing process	8	Descriptive
"client"	7	in vivo
professors' perspectives	7	Descriptive
"readability", "focus on readability"	10	in vivo
co-production	5	Descriptive
invisible college	5	Descriptive

D. Operational Model of a Student Writing Process via Thematic Analysis

As noted, first-cycle coding resulted in 44 codes. To identify major themes, these codes were analyzed for co-occurrence patterns and for frequency of occurrence. The 20 most frequently occurring codes appear in Table 1. Codes that occurred with the lowest frequency tended to be either in vivo codes corresponding to a particular incident or writing characteristic recalled in the data (e.g., "useless for our client", "I enjoy writing"), or to an exploratory descriptive code assigned to a segment whose meaning may not have recurred in other easily discernible segments (e.g., "writing for understanding", "synthesis").

The next stage was to identify co-occurrence patterns. The co-occurrence frequencies were grouped into codes that co-occurred greater than 10 times, 5-9 times, and fewer than 5 times. The codes that co-occurred fewer than 5 times were considered to be either descriptive or in vivo codes that may have been used to describe a specific segment, but may not

have been representative of the participant's writing, research, and analysis practices more generally. Additionally, many of the most frequent codes in Table 1 may reflect participant perceptions of writing ability and process, but these codes may not generalize to their project work. For example, while the code "humanities writing" may be common, it does not frequently co-occur, meaning that it describes the participant's understanding of the features of humanities writing, but may not directly describe the participant's work processes.

Therefore, the focus of the analysis is directed to the co-occurrence frequency groups 5-9 and greater than 10. Only two pairs of codes co-occurred greater than 10 times: "discourse" and "judgment" (23 co-occurrences), and "judgment" and "making and analyzing assumptions" (11 co-occurrences). No other code combinations co-occurred more than 10 times. These pairs indicate a strong relationship between the processes/activities coded as "discourse" and "judgment", implying that this participant explored the literature or made efforts to understand their client, then carefully weighed what they learned in consideration with what they understood to be technically appropriate. The determination of technically appropriate was partly based on the skills they had learned, but mostly, their judgment was used to clarify audience expectations based on their participation in the discourse, while also clarifying or establishing the scope of their work in the context of their participation in the discourse. The participatory aspect of "judgment" is strengthened when one considers co-occurrence with "making and analyzing assumptions." Judgment is involved in understanding how to structure problems and assumptions subsequent to engagement with the literature and/or clients and stakeholders. The codes in the 5-9 frequency group provide additional insight into the role of judgment and discourse in the participant's work.

E. Dramaturgical Analysis

Second-cycle dramaturgical coding was applied to the data to explore student writing and judgment processes as performance, with characters, dialogue, setting, context, and scenarios. Our approach follows Saldana [17], which suggests that interview transcripts be viewed as "monologue, soliloquy, and dialogue." The operational concepts, summarized in Table 2, include participant-actor objectives, conflicts or obstacles confronted by the participant-actor, participant-actor tactics or strategies, participant-actor attitudes toward the context, emotions experienced by the participant-actor, and participant-actor's unspoken thoughts or impressions.

Table 2. Saldana (2016) dramaturgical character analysis categories [17].

Dramaturgical Character Analysis Categories
OBJ: participant-actor objectives, motives in form of action verbs
CON: conflicts or obstacles confronted by the participant-actor preventing them from achieving objectives
TAC: participant-actor tactics or strategies to deal with conflicts or obstacles and to achieve their objectives
ATT: participant-actor attitudes towards the setting, others, and the conflict
EMO: emotions experienced by the participant-actor
SUB: subtexts, the participant-actor's unspoken thoughts or impression management, usually in form of gerunds

The data were coded in terms of these six dramaturgical elements, which enabled us to suggest performative elements the participant engages in during their writing process. These performative elements suggest higher-level units that further organize the processes identified during thematic analysis. For example, a strategy such as "give the client what they want" might involve a combination of thematic elements such as "judgment," "discourse," and "analysis." The specific configuration of the thematic elements operationalized by the dramaturgical elements could aid in suggesting mechanisms of engineering judgment for further investigation. The dramaturgical coding involved three steps. The first step was to select a segment of text. Typically, this segment was no larger than a single sentence, although occasionally large block of text could be selected. Second, the segment was assigned a code category from Table 2. Third, an in vivo code or theme describing the content of the code segment was applied. This procedure yielded 143 dramaturgical codes.

Table 3. Co-occurrence of high-level themes with descriptive and in vivo codes.

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)

IV. RESULTS

A. Thematic Findings

The co-occurrence analysis resulted in four themes associated with higher-level processes: Discourse, Judgment, Engineering Writing, and Research Process, as summarized in Table 3. The "discourse" theme represents a basic work process engaged by this participant. In general, whenever the participant consulted others through conversation or a review of the literature, these data were coded as "discourse". This included the participant determining technical details of their work through "analytical process" by comparing with what seemed appropriate based on prior training and comparison with published and unpublished exemplars. Discourse sometimes required a "higher level of understanding" due to the discourse practice of the multiple disciplines the participant drew on. At the same time, discourse also meant that the participant relied on relationships with clients/stakeholders to identify and formulate meaningful problems through "co-production" and "perception".

The next high-level theme identified is "judgment". Although judgment is a frequently occurring code in the data, judgment seems to be improvisational and ad hoc. Judgments

emerge from the tasks at hand and can be highly specific to the immediate demands of the work. Judgment is co-occurring in this data with "research process", implying that judgment plays a key role also in guiding the literature review and problem formulation stages that are heavily influenced by the participant's participation in discourse.

Third, “Engineering writing” is an in vivo code that reflects the participant's descriptions of engineering writing content and quality criteria. The co-occurrence with "symbols and equations" (6), indicates that engineering writing uses symbolic features that present a potential barrier to understanding or engagement. This barrier is reinforced with the in vivo code "higher level of understanding" that reflects the participant's judgment that engineering writing frequently requires a higher degree of discourse literacy that may prevent intuitive understanding of decontextualized claims or vocabulary.

The final theme is “research process”. Research process can reflect a variety of aspects of the participant's writing and research praxis. The participant frequently reflects on literature review and their own thoughts in order to "make connections" and “perceive” problems or potential solutions that might be interesting and relevant to their audience.

Finally, these codes were arranged into thematic maps to explore interdependence among the themes research process, judgment, and discourse. Assuming engineering writing is an important subtext, the remaining three themes and proposed inter-relationships are illustrated in Figure 1. At a high-level, the map in Figure 1 illustrates the participant’s orientation to the research process and the discursive tasks required in their work. Discourse requires interaction with the literature, interaction with clients, interaction with professors, or other groups external to the participant. Judgment is defined as evaluation, comparison, or selection. Research process is the theme that captures what the participant refers to as collection and analysis of literature, summary or encoding of discourse activities, collection and analysis of data, and procedural or mechanistic components of their project work.

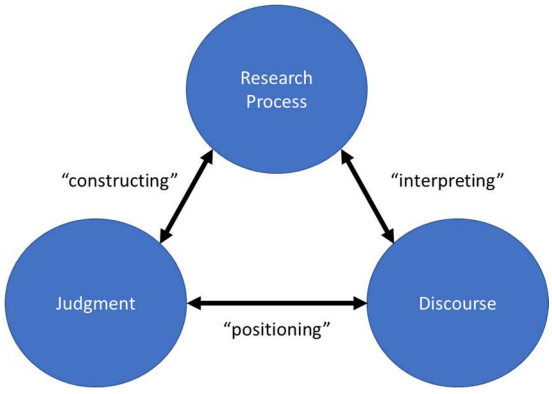

Figure 1. Thematic analysis of student orientation to analytical and discursive tasks.

These high-level themes then mutually inform each other through constructing, interpreting, and positioning praxis. Constructing praxis is the activity commonly referred to as problem formulation, and is the outcome of the intersection between judgment and research process mechanisms. Consider this excerpt illustrating constructing praxis:

So one thing I haven't sort of talked about is that when we were doing a lot of the research into how to build this tool we quickly found out that geographic data is really large and, like we downloaded a map of New York that we could mess around with in our software and that was, like, a four gigabyte file and that was just for one state. So it's like, okay, if we try to do this for the whole country we would need, like, a much better laptop than we had at the time, you know, a 200 gigabyte file. And it would certainly be useless for our client because, you know, if we can't work with a 200 gigabyte file they certainly can't work with that large of a file either…So you know, we sort of - this is sort of where we reflect that thought process. We need to eliminate a lot of areas from consideration to limit, practically speaking, to limit the processing time and the amount of work that this takes because it's, like, okay, if I'm not going to bother considering anywhere in Iowa why am I even looking at Iowa to begin with?... So we had a constraint to, like, eliminate places. And then we had what we called, what we defined, as like market-level variables. So which markets are the most suitable? So it's, like, okay, should you go into D.C., New York, Denver, Orlando, Chicago, Seattle. So we started defining market as, like, a large city. Yeah, market size was determined to be a metropolitan statistical area, so we'll take it any MSA, which MSA should they go into?

Here the participant describes how their group began to review literature and data sources to inform their problem formulation. The group ends up changing the problem formulation to adapt to constraints on computational power. The participant and their team assessed their own computational resources in light of the size of the data files, judging their resources to be inadequate. The participant’s team also judged the client likely have at most the level of computing power the team possessed, and decided to reconsider data requirements that might exceed the available computing power. To change their data requirements, the team considers changing the scope and the variable types to reduce the computational power required to manipulate the data. If they had not undertaken these steps, their work product would likely be “useless for [their] client” since the client would likely be unable to deploy the product.

Constructing praxis is related to interpreting praxis, located at the intersection between research process and discourse. In interpreting praxis, the participant’s discursive practice shapes the research process by interpreting technical structures through the language and requirements of the audience. Additionally, the selection of processes is conducted by anticipating the meaning that will be applied to the output in discourse. Consider this excerpt:

…They were certainly a lot more involved in the early phases because we were still working with them to get the weights and their requirements; make sure, like, we got that all set up. They were somewhat involved in, like, building out the tool. I wouldn't say a ton just because I guess because they don't really how the tool is made as long as it gets made, but we

kept them in the loop just to say, you know, this is sort of what we're looking at. Here's why you might see, you know, these things…And we went through the hassle of sort of explaining why in the world it is that we modelled a city where they already were because we were sort of saying we want to make sure that we can prove that this is somewhat accurate..It's, like, okay, if we look at the cities that it's already in would you recommend the places that ended up, great, if we did and okay if we didn't. So they were involved in this process, but I'd say, like, this middle process of creating the tool probably not that involved.

Here, we see the participant describing client involvement in the identification of project requirements and criteria. The participant and the client co-produced the analysis through the client's engagement in identifying the criteria driving the research process. The participant also indicates that the client is involved in helping to build the tool. This involvement is less to ensure the technical validity of the product and more to ensure that the product represents the client's preferences and objectives. Because the client is not involved as much in "[the] middle process of creating the tool," the client-participant interactions contribute to interpretation, i.e., the interpretation and acceptance of output justifies the research process.

Finally, the participant engaged in positioning praxis at the intersection of judgment and discourse. This praxis is related to selecting the genre and content of communication with those outside the team. In the senior project, the participant is primarily concerned about communication with their client, so positioning praxis involves participating in discourse through forms and language responsive to the concerns and interests of their client. For example, when asked how the writing sample might have looked different if it were completed for work and not for school, the participant responds:

So I think what I have found in the professional world is that people's eyes tend to roll to the back of their head if you give them a long document that they have to read. So I would probably say I might not even write this if this was for the professional world. I might just skip to have it be a long-form presentation with a lot of notes, so probably, you know, you could argue that I would be writing this paper in the notes of a presentation, but at the end of the day I think I'd rather use some visual or something like that.

This initial response foregrounds the time constraints faced in communication tasks. But upon reflection, the participant articulates a role for the technical report genre of their sample:

It's, like, I've seen countless presentations on this tool that we have. Like I just - in the presentations, like, you need so much background knowledge to understand what it is that they're talking about and such a complex tool that you need documentation like this. And so when I look at the presentation I don't really understand what they're talking about, right, but then when I go and read … the engineering documentation that supports the presentation it makes a lot more sense and it's a very helpful document. That's probably where this type of thing I would probably categorize it in is, not as an end product for anyone, but as, like, an engineering support document. So like, if I was thinking about this, like in the reverse case, if I'm presenting this or I present something like this paper or whatever I present, the presentation and then have this paper be a backup or like a reference material. So probably have this rather be a backup or reference material.

Clearly, the interrelationships in Figure 1 should not be interpreted to be linear nor sequential. These relationships involve considerable complexity. Some of this complexity can be seen by augmenting the thematic map of Figure 1 with the co-occurrence relationships from Table 3 to create the thematic map presented in Figure 2. In Figure 2, the node for "research process" has been replaced by the themes it frequently co-occurs with—"perception" and "make connections"—which are also further described by three additional themes—"co-production", "analytical process", and "making and analyzing assumptions."

For example, here judgment and discourse act on the research process indirectly through sub-processes such as making connections, analytical process, and co-production. The direct mutual relationships in Figure 1 can only be understood by identifying the paths through Figure 2 that constitute them. Figure 2 begins to foreground the interactive aspects involved in the participant's writing and analytical processes, leading us towards dramaturgical analysis.

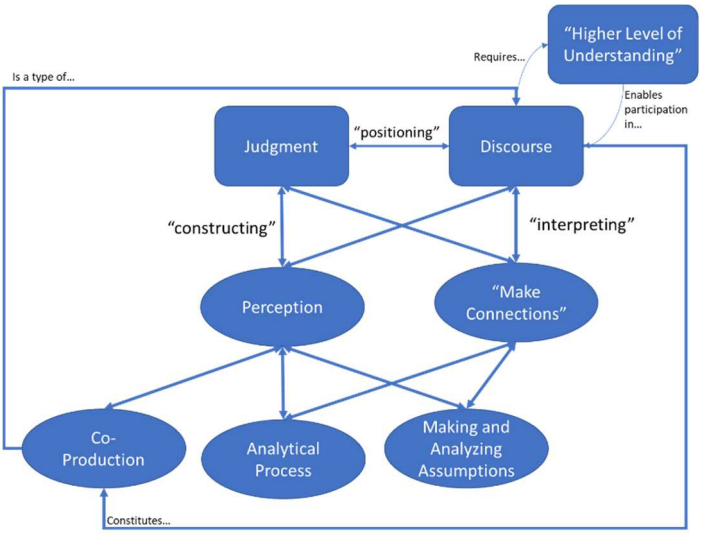

Figure 2. Augmented thematic map of participant writing and judgment processes.

B. Dramaturgical Analysis of a Student Writing Process

The discourse literacies perspective implies a performative orientation towards writing and engineering judgment, and the dramaturgical analysis explored this performative dimension. As noted earlier, the dramaturgical analysis yielded 143 codes spread across the six categories listed in Table 1. Here we summarize key findings in each category.

OBJ: Analysis yielded 15 objective codes that illuminate the operational models reported earlier by contextualizing them within the participant's stated writing objectives. Some objectives relate to writing style, such as "approachable

writing". This participant highlighted their humanities training and was very conscientious about the readability of the text and being perceived as a good writer. In addition, the participant was very careful to retain their own voice. Although the participant clearly valued the role of literature review, they primarily engaged discourse praxis to "distinguish [them]self", "construct the best-supported argument", and to "build [their own] idea of [their] paper." This participant's interview responses conveyed a clear sense of authority over their ideas, and that authority was manifest throughout their work processes. Other objectives reflected immediate practical concerns, such as: "compose", "find our own client", "give the client what they want", "sell our own project", and "specific recommendations to client". A final grouping of objective codes involved analytical concerns, such as "analyze data", "select a good topic", and "test my ideas." Most of the objective codes identified are audience-focused and reflect the types of discourse activities the participant and their team engaged in order to complete their project.

CON: The challenges and problems the participant needed to resolve to achieve the objectives are reflected in the 19 conflict codes. For example, in attempting to achieve the objective "understand what they're saying" when reading engineering writing, the student perceived the conflicts "it's a lot less intuitive", "higher level of understanding needed", and "engineering writing is inaccessible". While this participant enthusiastically engaged in the discursive practice of literature review, there was an acknowledgment of the difficulty posed by engineering mathematics and details. This difficulty in understanding was exacerbated by the fact that engineering reading seemed less important since professors assigned much less reading and engineering professors had different expectations of student writing content compared with humanities professors. Another important challenge is that the literature review leads to "multiple voices in [their] mind", making it more difficult to consider how "people [might] start to poke holes" in their arguments. Whether the participant's discursive praxis was client-focused (senior project) or discourse-focused (economics proseminar), the participant faced conflicts regarding understanding what elements of context were most important and how to establish the quality of assumptions.

TAC: In order to resolve these conflicts, the participant utilized a range of tactics, with 50 tactics codes emerging to capture strategies or actions chosen to resolve a conflict identified to achieve an objective. For example, suppose we select the objective "give the client what they want." This involves conflicts that must be resolved—"clients used similar competing product" and "time and knowledge constraints." To resolve these conflicts, the participant employed strategies such as: "assess our capabilities", "assess client capabilities", "dialogue with client", "prioritize simplicity", and "talk to client about needs". These helped to inform the participant's group's judgment while directly informing their research process and communication choices.

EMO, ATT, SUB: The emotion (9), subtext (27), and attitude (23) codes provide additional insight First, the emotion codes indicate "pride in their work" and "identification with engineering work", despite moments of "confusion" (in understanding the literature or de-contextualized engineering claims) and "disappointment" (in the quality of others' assumptions or support for their claims). The subtext codes reinforce some of the emotion codes identified. One unspoken subtext in the data is the novelty the participant expects to encounter and contribute. The participant is "being drawn into the problem" while they work to "understand prior works", aim to "combine novelty with mastery", "evaluate pitches from potential clients", and "learn from prior students' experiences". Another subtext theme is translating between two groups' language or conventions. For example, the participant attempts to translate between technical language demanded by analytical techniques and client needs (e.g., "create a codex"). Similar tasks are reflected in codes such as "explaining disagreements" and "navigating two worlds". Also, many subtext codes reflect the judgments the participant must engage when building models or resolving perceived contradictions in the literature. For example, the participant responses suggested they "questioned professors' criteria and judgments" even as they questioned whether a published article's "assumptions really supported [its] analysis." Finally, the participant's communication style and genre choices were influenced by subtexts reflecting that "engineering writing is detailed" but should also be "readable". Thus, the emotion, subtext, and attitude codes provide background to the explicit objectives and conflicts identified above.

To illustrate how these codes work together to provide a richer understanding of the themes identified in section 4.1, consider the following interview excerpt:

So I sort of start to build the idea of my paper through my research by trying to, like, put all those authors in conversation with each other in a way… And then when I actually start to write the paper I'll pick and choose, like, the arguments that I think are the strongest and have the best support, even if they might be, you could say, like, dissenting opinions or something like that or most authors might not agree with his person, but I think they make a very good point for X, Y, Z reasons. I'll create, like, a very basic outline of, okay, now that I've done all this research what do I think the answer is now?. Okay. Is it different from what I thought? Why? I usually document that more for my own reasons than for the writing…So I'm like, okay, what information is in my mind about something? Let me make sure I highlight that in my paper. And then I start to think about, you know, my outline of my, like, main arguments that I gathered from research and from my own thought process. And I'll start to fill out my outline. And I'll usually read over my notes and then write. And I usually don't try and pull directly from any author as I write. So I'll usually be, like, okay, this is what my overarching topic is going to be for this paragraph or for this section. Here's everything I know about that from what I wrote. And then I go back and say, okay, where can I supplement my thoughts with, you know, citations or quotes from the authors that I'm using.

Here the participant describes their transition from literature review to composing their paper. At first, the participant's objective is to build the idea of their paper. However, this objective is complicated by the fact that the

participant has to juggle multiple voices in their mind as a result of their research. The tactic they use to deal with this conflict is to "put all those authors in conversation with each other." To do this, the participant enters the discourse of the technical community they are drawing upon, then makes substantive judgments about the arguments presented in the discourse. The participant further implements the conversation tactic by making connections among the authors and analyzing the quality of each author's arguments and assumptions. The objective these themes contribute to is the participant's goal of constructing the best argument by building on the conversations they construct from their engagement with the discourse. Because an unspoken subtext is that the participant might be expecting surprises or potentially new information, the participant reflexively asks "what information is in my mind about something", and uses the tactic of "writing from their own notes" to clarify their own thoughts. As the participant says they "usually don't try and pull directly from any author as [they] write," an unspoken subtext of this participant's orientation to the process is that they place high value on writing from their own voice. Moreover, this excerpt seems to describe a research process that this participant repeats or refines each time they undertake a writing project.

V. Discussion and Conclusions

This intrinsic case study of a senior systems engineering student's writing and engineering judgment processes yields some interesting insights into the intersection between engineering judgment and engineering identity that warrant further exploration. While disciplinary literacy suggests a discourse community shares a "model of knowing", our case study suggests that some students may attempt to retain multiple "models of knowing" as they move across courses and departments. In this case, the major/minor combination may have left this participant with associations across both disciplines, possibly endowing them with the flexibility to identify more fully with one or the other in the future.

Additionally, Berkenkotter et al [3] describe an "invisible college," the scholarly community that extends beyond one's own institution. Their invisible college possesses a corpus of publications and communication forums that constitute the discourse of the invisible college. This invisible college's discourse includes substantive knowledge—specialized literacy within a discipline—and procedural knowledge—"the ability to construct text structures appropriate to formal expository discourse" [3] (p. 37-38). This case suggests that invisible college metaphor may be strained in the perception of some students. In the case presented above, our participant not only consults the discourse of the scholarly community, but also the discourse of stakeholders in their work. Thus, based on the trajectory of one's career, an undergraduate engineering student may need to master the substantive and procedural knowledge of non-scholarly as well as scholarly communities constituting their audiences.

Prior research on disciplinary literacy [18] also shows that students vary in their ability and willingness to incorporate feedback based on the degree of authority they assert over their texts. Our case study indicated that participation in the discourse community (e.g., reviewing literature and formulating potential contributions) could result in a crisis of authority over their texts, where students may hesitate to accept or critique the claims of other scholars while simultaneously hesitating to assert the novelty and validity of their own claims.

At the same time, drawing on insights from academic literacy [2], our case study explores the diversity of "the relations of power and authority" student writers must navigate. While the first writing sample discussed by the participant represented a more traditional scholarly work, the second begins to approach the demands of engineering work. In discussing the second piece, the participant clearly describes the tensions between scholarly (e.g., what students have done before, what substantive knowledge suggests is the most appropriate analytical method) and non-scholarly (e.g., emphasizing utility to the client, describing co-production of decision tool with client) relations of power and authority. In the first, the participant is responding primarily to the demands of their professor. However, in the second, the participant is keeping the demands of their professors and client in tension. Thus, writing and communication teaching practice should emphasize the complexity of writing practices responsive to these potentially conflicting interests.

The findings from this case raise important issues about the the blend of communication demands faced by practicing engineers that potentially impact the socialization of engineering students. Although this is an intrinsic study of a single student, our thematic and dramaturgical analyses aligns with prior work that suggest familiarization with the range of communication demands is central to the preparation of engineers [19]. On the one hand thematic analysis indicates that none of the key processes—research, judgment, and discourse—are independent of the others. Moreover, the dependence of research process and judgment on discourse means that the communication process is not merely a reporting of the results of research and analysis. Rather, the communication demands and the analytical demands mutually shape one another. As we expand this study to include additional student cases, we hope to deepen our understanding of these interactions and identify implications for teaching.

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