2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION
Paper ID #51513

Function Word Analysis of Student Reflective Writing in an Integrated Engineering Program

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Introduction

Engineering education has increasingly emphasized the development of reflective practitioners alongside technical proficiency. Reflective writing practices, including structured journaling and post-project analysis, support critical thinking, metacognitive awareness, and the transfer of learning to complex, real-world problems [1-3]. Motivation also plays a fundamental role in students' engagement with reflective activities. Prior educational psychology research demonstrates that students' motivational beliefs such as self-efficacy and goal orientation are strongly associated with their use of self-regulated learning strategies and academic persistence in challenging contexts [4-5]. Together, this work suggests that reflection is not only a cognitive activity but is linked to motivational dynamics over time.

These dynamics are especially relevant in project-based and work-integrated engineering programs, where students take substantial responsibility for directing their own learning [6]. The Twin Cities Engineering (TCE) program provides a context for examining reflection in such environments. TCE is an upper-division programs within the Department of Integrated Engineering that primarily serves transfer students entering as rising juniors from partnering community colleges [7]. The program follows an ABET-accredited, project-based learning curriculum in which complete four semester-long, industry-sponsored design projects prior to graduation. Students work in teams of three to five and complete Design and Professionalism courses each semester, integrating technical problem solving with communication, teamwork, and professional responsibility. Project deliverables are defined by industry sponsors and may include prototypes, testing procedures and results, or formal technical documentation. A required weekly seminar further supports student learning through discussions of design processes, leadership, ethics, metacognition, and learning strategies.

In this curricular structure, reflection functions as a critical integrative mechanism. As students navigate technical uncertainty, team dynamics, sponsor expectations, and developing professional identities, reflective writing provides a structured means for interpreting experience and guiding future action. TCE students complete regular written reflections that prompt them to describe what happened during project work, identify key takeaways, consider future applications, and recognize additional learning needs. These reflections are intended to foster metacognitive awareness, support self-directed learning, and connect present activities to longer-term professional goals. Building on prior exploratory work, the present study examines students' reflective writing using linguistic methods to examine patterns of motivation and engagement over time [8]. Specifically, this work engages function word usage in a longitudinal corpus of reflective texts with Linguistic Inquiry and Word Count (LIWC) to illustrate how motivation is expressed and evolves within a project-based engineering curriculum, contributing to broader conversations about reflection, self-regulated learning, and professional formation in engineering education [9].

Literature Review

Work in engineering education has established reflection as a key mechanism for developing adaptive, critically oriented practitioners rather than technicians who simply apply procedures. Reflective activities such as journaling, post-project memos, and structured prompts have been linked to deeper learning from experience, more sophisticated problem framing, and the capacity to navigate uncertainty in authentic engineering contexts. Research on self-regulated learning highlights that motivational beliefs of students like self-efficacy, shape the extent to which they engage in reflective practices, persist in challenging tasks, and deploy metacognitive strategies overtime [10], [11].

Other bodies of work in educational psychology suggest that language offers a powerful, often underused lens into these cognitive and motivational processes. In STEM classrooms, the language used by instructors and students mediates how concepts are framed, how agency is distributed, and how learners position themselves relative to knowledge and practice. Functional words are especially informative because they are selected largely outside of conscious awareness and organize the structure rather than the topical content of discourse [12], [13]. Building on the work of Pennebaker and colleagues, function-word patterns have been linked to indicators of status, analytical thinking, and honesty, as well as to motivational tendencies aligned with McClelland's needs for achievement, affiliation, and power [12],[13],[18].

McClelland's theory, which formed the basis for the linguistic model used in this study, posits that individuals differ in their dominant needs for achievement (pursuing excellence and mastering challenges), affiliation (seeking close, cooperative, relationships), and power (influencing and directing others) [14],[17]. When educators understand these motivational profiles, they can design learning environments and experiences that better support engagement, performance and development [15],[16],[18]. Prior engineering education studies have examined student motivation and attitudes longitudinally, often using self-report surveys, but comparatively little work has leveraged linguistic methods to infer motivational and cognitive patterns embedded in naturally occurring student texts. This study addresses that gap by using LIWC-based function word analysis of reflective writing within an integrated, project-based engineering program, to explore how the language used by students reflects achievement, affiliation, power, and indicators of self-reflection, analytical thinking, and honesty.

Methods

Context and participants

The study was conducted in the TCE program at Minnesota State University, Mankato, an upper division project-based program that primary enrolls transfer students entering as juniors. The curriculum centers on four semesters-long, industry-sponsored projects supported by design and professionalism courses with a weekly seminar emphasizing leadership, ethics, metacognition, and learning strategies. Within this structure, students complete weekly written reflection

journals in one course that also connected to other aspects of the program like technical, design, and professional areas of engineering. These reflections are intended to help them interpret project experiences, identify key takeaways, plan future application, and articulate further learning needs.

The dataset includes reflective reports from all 119 students who participated in the program from its inception in 2013 through Spring 2024. Because students typically remain in the program for four semesters (junior 1, junior 2, senior 1, and senior 2), many contributed multiple reflections across their engineering trajectory, enabling both cross-sectional and longitudinal perspectives. In total, 4,638 reflection entries were available for analysis related to motivational drives, and a subset of 1,016 entries was used for analyses focusing on function word indicators of status, analytical thinking, and honesty.

Data sources and research question

Each weekly reflection asked students to respond to four prompts: (1) what happened? (2) what was the take-away? (3) what is the future use of the take-away, and (4) what other learning would be valuable. These prompts were designed to elicit descriptions of experience, interpretation of significance, transfer to future contexts, and identification of additional learning needs. The guiding research question for this study was to broadly assess: *"how do students in the program utilize language in reflective writing?"*

Linguistic analysis with LIWC

All reflections were compiled into a text corpus and processed using LIWC-22, a widely used software tool for automated analysis of psychological and linguistic features in text. LIWC calculates the proportion of words in each text that fall into pre-defined categories, including both content categories (e.g., affect, cognitive processes) and function-word categories (e.g., pronouns, articles, prepositions, auxiliary verbs, conjunctions). Consistent with prior work on function words and motivation, the analysis focused on coding two sets of LIWC-derived indices [12], [13], [18].

The first set comprised indices related to McClelland's motivational drives for achievement, affiliation, and power, operationalized through word categories and dictionaries shown in previous studies to correlate with these needs. [18] A dataset of 4,638 reflections was analyzed for these drive-related indicators. The second set centered on function-word markers of status (first-person singular pronouns or "I-words"), analytical thinking (primarily articles and prepositions), and honesty (patterns involving prepositions and conjunctions) [12], [13]. These indices were computed for a subset of 1,016 reflections that met predefined criteria for length and completeness necessary for stable LIWC estimates.

To interpret the motivational drives, mean LIWC scores for achievement, affiliation, and power were compared to benchmark values reported for other populations in published LIWC-based studies, including samples of college students and adults engaged in various writing tasks. [18]

For the status, analytical, and honesty indicators, descriptive statistics (means and standard deviations) were examined to characterize typical usage and variability within the Integrated Engineering cohort. The analysis was descriptive and comparative rather than inferential; the goal was to position the linguistic patterns of this engineering student corpus relative to established LIWC norms and prior findings on function-word indicators of motivation and cognition.

Findings and Discussion

Motivational drives in reflective language

Analysis of the motivational-drive indices showed that students' reflective writing was characterized by a high achievement drive, moderate-to-high affiliation drive, and comparatively low power drive. The mean achievement drive score was 3.19, suggesting that students frequently used language associated with setting goals, tackling challenging tasks, and striving for excellence. This pattern aligns with the program's emphasis on complex, industry-sponsored projects and its expectation that students manage ambiguity and assume responsibility for project outcomes, echoing prior findings that project-based environments can support the development of strong achievement-oriented motivations.

Affiliation drive had a mean of 2.66, indicating a substantial, though slightly lower, emphasis on language related to collaboration, relationships, and social connection. This is consistent with the team-based nature of the curriculum and with engineering education research that positions teamwork and professional communication as central to students' formation as engineers. Variation in affiliation scores across reflections suggests that not all students or teams experience collaboration in the same way, pointing to the importance of intentionally supporting inclusive group dynamics and psychological safety. The mean power drive score, at 1.03, was markedly

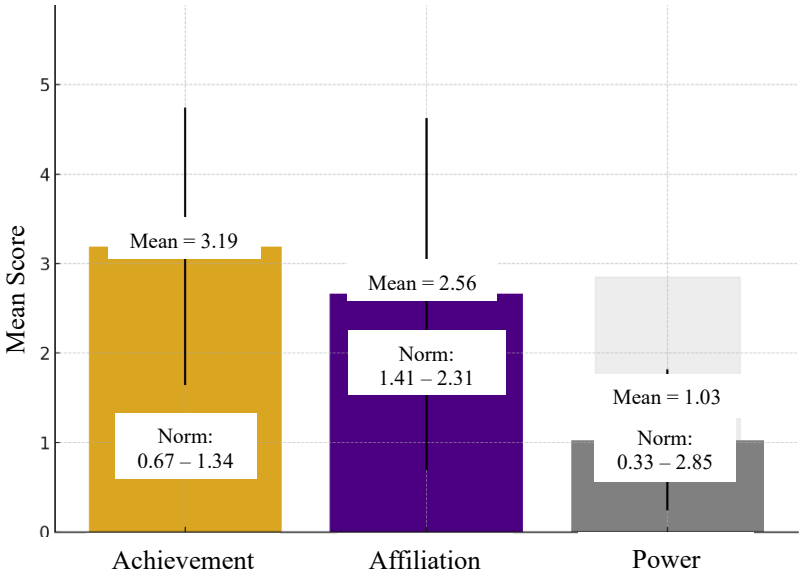

Fig. 1: Motivational Drives with Standard Deviation and Norm Ranges

lower than the other two drives, suggesting relatively less emphasis on authority, dominance, or control in the students' language. In the context of an integrated, collaborative program, this pattern may reflect a culture that values shared leadership and influence through expertise rather than hierarchical power, aligning with calls in the engineering education literature to foster cooperative rather than authoritarian leadership models.

Viewed comparatively, achievement is quite higher than the norm, and affiliation is slightly higher. Initial evidence leads us to believe that that student engineers in this program have higher achievement drive than reported values for other populations but more analyses need to be done towards understanding correlations, if any. These findings suggest that the program's project-based structure supports a motivational profile organized around achievement and collaboration more than power. For educators, this implies that challenge-based and design-oriented tasks may be particularly well matched to students' existing motivational tendencies, while leadership development efforts might explicitly frame influence as a collaborative, expertise-based process rather than as formal authority. The relatively low power drive scores also raise questions about how students perceive decision-making and agency within teams, and whether some undergraduates may hesitate to assert ideas even when technically competent, which is an issue with implications for equity and inclusion in team settings.

Function-word indicators of status, analytical thinking, and honesty

The analysis of function-word indicators provided complementary insight into students' cognitive and self-reflective orientations. First-person singular pronouns ("I-words") had a mean of 4.25 with a relatively high standard deviation of 2.07, indicating moderate self-focus on average but substantial variability across reflections and students. Moderate I-word usage suggests a balance between personal reflection and outward or task-focused reporting, which is desirable in reflective writing that aims to connect individual learning with team and project contexts [12], [13]. High variance, however, indicates that some students write reflections that are highly self-referential while others lean toward impersonal or purely descriptive accounts, echoing prior findings that students differ in how they position themselves relative to engineering work in narrative accounts

Indicators of analytical thinking were particularly pronounced. Prepositions, one of the core function-word categories contributing to LIWC's analytical thinking index, had a mean of 14.19, reflecting frequent use of language that structures relationships among ideas, processes, and entities. Elevated use of articles and prepositions has been associated with formal, logical, and detail-oriented writing, which is consistent with expectations for engineering communication and with the program's focus on rigorous problem solving [12], [13]. This pattern suggests that students not only engage in analytical thinking during design work but also represent that thinking in written form, making their reasoning and connections more visible for instructors and peers.

Honesty-related indicators, operationalized through the combined use of prepositions and conjunctions, also showed meaningful patterns. Conjunctions had a mean of 6.13 with relatively low variability, indicating a consistent tendency to link ideas using terms such as “and,” “but,” and “because.” Prior LIWC research has associated such patterns with complex, truth-oriented language, in which writers explicitly connect causes and consequences or acknowledge contrasting perspectives [12], [13]. In the context of reflective writing, sustained use of conjunctions can signal that students are integrating multiple aspects of their experiences, weighing trade-offs, and articulating lessons learned rather than merely listing events. These linguistic markers align with the program’s intent for reflections to support metacognitive awareness and ethical reasoning, suggesting that the reflective prompts and curricular context are indeed eliciting higher-order processing.

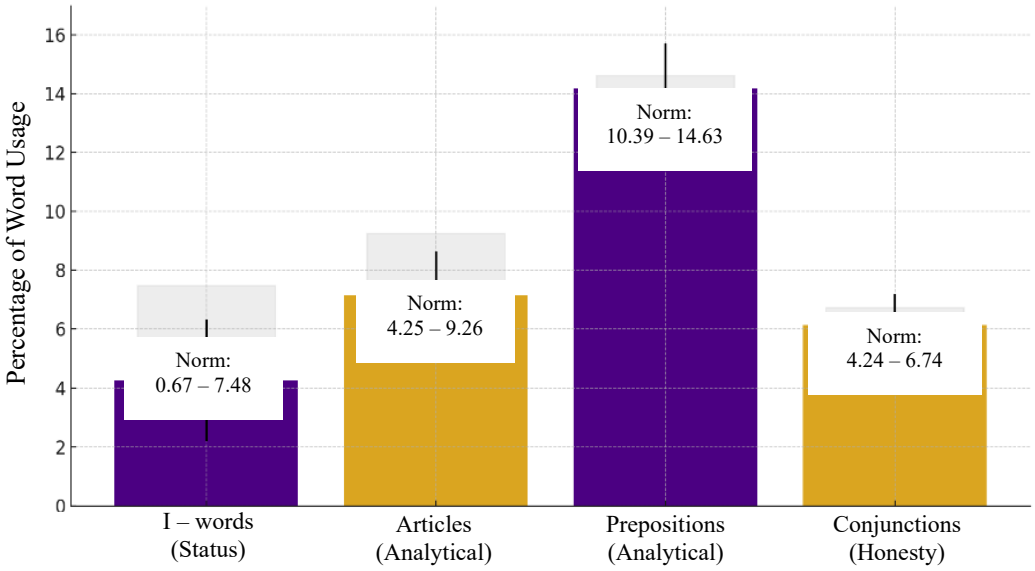

Fig. 2: Function Word Use with Variability and Norm Ranges

Educational implications and limitations

The convergence of high achievement drive, moderate affiliation drive, and strong analytical language suggests that project-based engineering programs can cultivate motivational and cognitive profiles that are conducive to professional growth, particularly goal orientation, collaborative engagement, and structured analytic reasoning. For instructors, function-word analysis offers a complementary form of evidence that extends beyond grades or self-report surveys, providing early, subtle signals about how students are engaging with the curriculum and how they see themselves as learners and engineers [12], [13]. These patterns could inform the design of reflective prompts and targeted supports, for example, creating prompts that encourage underrepresented students or quieter team members to claim their contributions, or scaffolding

reflections that invite students to connect their achievement-oriented language with resilience and help-seeking.

At the same time, several limitations constrain the interpretation and generalizability of these findings. The data come from a single integrated engineering program with a specific project-based, industry-engaged model, so linguistic and motivational patterns may differ in more traditional curricula or at other institutions. The study focuses exclusively on written reflections, which capture only one modality of students' communication; important aspects of motivation, identity, and collaboration may be expressed in spoken interactions, design artifacts, or informal communication not analyzed here. Additionally, while LIWC provides validated, theory-informed indices, it remains a dictionary-based tool: function-word categories are proxies rather than direct measures of motivation, analysis, or honesty, and cultural or contextual factors may shape word use in ways not fully captured by existing dictionaries. [12], [13]. Furthermore, prior studies using this linguistic model have not specifically focused on engineering student populations, which may limit the extent to which these measures fully reflect discipline-specific language use.

In its current form, this work helps us to connect with the motivations of student engineers. Future work could disaggregate the corpus to examine changes in function-word patterns over time as students progress from junior to senior years, compare across campuses or program models, and attend explicitly to the language of students from historically marginalized groups in engineering. Combining function-word analysis with qualitative coding of reflection content or with other measures of motivation and identity could deepen understanding of how language, motivation, and professional formation interact in integrated engineering programs

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