# Development of a Diagnostic Tool to Identify Graduate Students' Self-Determined Communication

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## Abstract

Effective communication is essential for the professional development and preparation of graduate engineering students, yet existing instruments do not adequately define and assess how students develop autonomy, competence, and relatedness in academic discourse. Grounded in Self-Determination Theory (SDT), this study presents the Communication & Facilitation of Learning in Oral & Written Scholarship (COMM-FLOWS) diagnostic tool, a novel instrument designed to identify self-determined communication in graduate education. This research addresses two key questions: (1) How do the adaptation steps contribute to the theoretical and practical development of the COMM-FLOWS tool? (2) In what ways do the measures of the COMM-FLOWS tool differ from those of the original Basic Psychological Needs Satisfaction – General (BPNS-G) scale in capturing self-determined communication in graduate education?

Using an adaptation framework informed by Chenel et al. (2018)'s decision-aid methodology, this study modifies the BPNS-G scale to capture the nuances of oral and written communication in an academic setting. The adaptation process involved seven structured steps: (1) identifying a scale for adaptation, (2) appraising the original scale, (3) understanding the context of graduate student communication, (4) adapting and developing items, (5) aligning items with SDT and graduate student experiences, (6) validating content and testing usability, and (7) preparing the tool for deployment. These steps ensured that the COMM-FLOWS tool remained both theoretically grounded and practically relevant for assessing how engineering graduate students navigate advisor-student and peer-peer interactions, scholarly writing, and professional presentations.

This study makes two novel contributions to graduate engineering education. First, it introduces a decision-aid approach to communication assessment by transforming COMM-FLOWS from a static diagnostic instrument into an active component of an interactive framework designed to support advisor-student dialogue and individual self-reflection. Second, it advances self-determination theory in engineering education by extending SDT constructs beyond research motivation to the development of communication necessary for academic and professional success. Pilot testing indicated that participants completed the 76-item tool within 20 minutes, with feedback confirming its engagement, clarity, and relevance.

The findings have significant implications for graduate advising, curriculum design, and professional development programs in engineering education. By embedding COMM-FLOWS into advisor training, communication workshops, and peer mentoring, institutions can foster more autonomous, competent, and connected communicators—ultimately enhancing students' preparedness for academic and industry careers. Future research should explore the tool's broader applicability across disciplines and its potential to improve advisor-student communication, research productivity, and graduate student well-being.

## Introduction

Communication in professional and academic settings demands coherence, integrity, depth, and adherence to scholarly standards—qualities that must be developed with intention. A larger study investigates the motivations shaping the development of communication among engineering graduate students, using self-determination theory to examine how students experience autonomy, competence, and relatedness throughout this process. In doing so, it seeks to identify the environmental, relational, and internal factors that influence communication development over the course of graduate education. The present paper contributes to this broader effort by adapting an existing scale to better reflect the practical realities and normative expectations of graduate-level oral and written communication.

Effective communication skills are crucial for PhD graduates' employability, leadership, and professional advancement in engineering. PhD graduates who communicate effectively are perceived as more capable of leading teams, securing funding, translating technical ideas to non-technical audiences, and providing technical guidance across various roles [1], [2], [3], [4], [5]. As a result, engineering education increasingly emphasizes communication skill development as a foundation for academic success, career growth, and personal development [6], [7]. To cultivate these skills, graduate students engage in both formal activities, such as structured coursework and research, and informal experiences, including mentoring and extracurricular activities [8], [9], [10], [11]. While these engagements support communication development, a student's self-determination —defined as their motivation to engage in learning, which includes feeling in control, capable, and well-connected to others [12] —plays a critical role in their growth.

Self-determination drives engagement in developmental activities by fostering motivation. This motivation propels individuals to proactively participate in activities that interest them, empowering them as active agents of their growth [13]. Motivated students are more likely to engage deeply with learning activities, leading to improved skill acquisition [14], [15]. This motivation stems from the fulfillment of basic psychological needs—autonomy, relatedness, and competence—in learning [16]. Thus, recognizing the pivotal role of a student's motivation, we adopted a theory-driven approach to explore how engineering graduate students develop as effective communicators. To guide this exploration, we selected Self-Determination Theory (SDT) as the theoretical framework, as it emphasizes the role of motivation in learning and development [12], [17]. Finally, existing scales that measure aspects of communication development do not provide a structured tool for guiding shared decisions. To address this, we draw from the concept of patient decision aids (PDAs) in healthcare [18], which supports shared decision-making between doctors and patients. Just as PDAs provide structured information and foster collaboration in medical contexts, the COMM-FLOWS tool functions as a decision aid in advisor-student and peer interactions, helping graduate students navigate autonomy, competence, and relatedness in academic communication.

While existing scales allow us to assess specific aspects of communication development, they have notable limitations. Communication assessment scales such as the Communication Competency Assessment Instrument (CCAI) [19] and the Self-Perceived Communication Competence Scale (SPCC) [20] evaluate communication appropriateness, effectiveness, and self-

perception. However, they do not address the motivation driving communication development. Moreover, these scales fail to capture the lived experiences of graduate students, particularly regarding academic communication practices and norms. To bridge these limitations, a new tool is needed to assess how engineering graduate students become self-determined communicators—motivated individuals in control of, competent in, and connected through oral and written communication. Rooted in Self-Determination Theory, this study addresses these limitations by adapting the Basic Psychological Need Satisfaction in General (BPNS-G) scale to develop the Communication & Facilitation of Learning in Oral & Written Scholarship (COMM-FLOWS) tool. The research questions guiding this study are as follows:

1. How do the adaptation steps contribute to the theoretical and practical development of the COMM-FLOWS tool?
2. In what ways do the measures of the COMM-FLOWS tool differ from those of the original BPNS-G scale in capturing self-determined communication in graduate education?

**Theoretical Framework**

Deci and Ryan's Self-Determination Theory (SDT) serves as the theoretical foundation for this study's scale adaptation. SDT emphasizes three psychological needs—autonomy (the sense of control and ownership), competence (a feeling of efficacy and capability), and relatedness (a sense of meaningful connection with others)—as fundamental drivers of motivation [12], [17], [21]. When these needs are satisfied, individuals engage more actively in learning and skill acquisition [17]. Conversely, when these needs are thwarted—such as when a person feels restricted in their choices (low autonomy), doubts their capability (low competence), or feels isolated from others (low relatedness)—they experience reduced motivation, disengagement, and diminished development [17]. These principles are particularly relevant in the context of graduate education, where motivation plays a central role in communication development.

Motivation fosters engagement and persistence in academic communication, supporting skill development. Writing and other communication tasks demand sustained motivation, persistence, and self-regulation for long-term success [22]. Students are more likely to develop communication skills when they see their value, can express themselves freely, receive structured guidance, and feel supported by their academic community [22]. A motivated student—one whose psychological needs for autonomy, competence, and relatedness are met—is more likely to persist in communication development to become a self-determined communicator. Building on the concept of the self-determined communicator, we operationalized these three SDT needs in our survey design to assess how graduate students experience autonomy, competence, and relatedness in both written and oral communication [23], [24].

In this study, autonomy in written communication reflects students' sense of ownership and freedom in expressing ideas in academic writing (e.g., essays, literature reviews, research papers) that align with their values and perspectives. In oral communication, autonomy refers to students' ability to express themselves authentically in formal and informal scholarly discussions while navigating external pressures. Graduate students who are self-determined communicators

demonstrate autonomy by confidently articulating their perspectives in both written and oral scholarships.

The concept of autonomy in communication sets the stage for students to express themselves authentically, while competence measures their ability to do so effectively. Competence in written communication measures students' depth and coherence in structuring their ideas clearly, maintaining academic precision, and effectively conveying their research in writing. In oral communication, competence refers to students' knowledge, skills, or attributes in articulating ideas persuasively, engaging audiences, and effectively communicating their research. As a critical component of being a self-determined communicator, competence fosters a graduate student's ability to present knowledge with clarity and confidence.

Building on the foundation of autonomy and competence, relatedness serves as the next crucial element in a self-determined communicator. Relatedness in written communication assesses how connected students feel through their writing, including whether they feel understood, respected, and supported by readers, peers, and advisors. In oral communication, relatedness captures students' sense of connection when speaking within academic settings, encompassing experiences of support, respect, and mutual understanding during presentations, discussions, and collaborations. Since communication is inherently relational, graduate students who are self-determined communicators rely on supportive relationships such as mentorship, collaboration, and academic networks [25], [26], reinforcing their motivation to refine their communication skills.

**Methods**

This study follows a Participatory Design (PD) approach to ensure the COMM-FLOWS tool reflects the lived experiences of graduate students. Similar to the development of Patient Decision Aids (PDAs) in medical research, where iterative user feedback refines decision-support tools [18], this study employs structured pilot testing and qualitative evaluation in real academic settings before broader implementation. This method prioritizes usability, contextual relevance, and adaptability to diverse research environments.

We adapted the BPNS-G scale to develop the Communication & Facilitation of Learning in Oral & Written Scholarship (COMM-FLOWS). Our tool adaptation process follows a structured approach inspired by Chenel et al. [18], who outline best practices for adapting decision aids to specific cultural and contextual needs. Just as patient decision aids (PDAs) must be tailored to different patient populations, our adaptation process ensures that BPNS-G is restructured to reflect academic communication norms, advisor-student and peer-peer interactions, and the development of self-determined communication skills in graduate education. The key steps in our adaptation process include: (1) identifying a scale for adaptation, (2) appraising the original scale, (3) understanding the context of graduate student communication, (4) adapting and developing items, (5) aligning items with SDT and graduate student communication, (6) validating content and testing usability, and (7) preparing the tool for deployment. These steps ensure that our process is clearly articulated and directly aligned with the study's goals.

The following sections detail each adaptation step for the COMM-FLOWS tool.

*Step 1: Identifying a Scale for Adaptation*

To identify a suitable scale for adaptation, we conducted a systematic literature search for SDT-based instruments, compared potential scales for their alignment with autonomy, competence, and relatedness, and ultimately selected the BPNS-G as the most appropriate candidate.

Grounded in a theoretical framework, we began our survey adaptation process by searching the literature to identify existing scales measuring the core constructs of Self-Determination Theory (SDT). The goal was to identify a scale that accurately reflected the constructs of autonomy, competence, and relatedness while remaining relevant for adaptation to study self-determined communication in engineering graduate school.

To systematically identify potential scales, we conducted a search using specific keywords in research databases. Keywords included ‘self-determination theory,’ ‘autonomy,’ ‘basic psychological needs,’ and ‘survey instrument’ searched in databases such as Web of Science and Engineering Village. The search, conducted in October 2024, was limited to English-language articles, and reference lists of selected studies were also reviewed for additional relevant sources.

From this search, we identified several existing scales used for measuring SDT. Some of these scales include the Basic Psychological Needs Satisfaction and Frustration Scale [27], Basic Psychological Needs Satisfaction at Work [28], Engineering CAReS: Basic Psychological Needs Satisfaction in the Engineering Workplace [29], and the BPNS-G (selfdeterminationtheory.org). Ultimately, we selected the BPNS-G for adaptation due to its broad focus on autonomy, competence, and relatedness in general life, making it particularly well-suited for our context in engineering graduate school.

*Step 2: Appraising the Original Scale (BPNS-G)*

We analyzed the structure, item distribution, and constructs measured by BPNS-G, reviewed its previous adaptations and applications, and identified necessary modifications to align the scale with PhD communication contexts. As part of this appraisal, we examined existing literature to evaluate the scale’s content, structure, and theoretical alignment [18], tracing its development to uncover its origins and the rationale behind its adaptation.

The BPNS-G is an adaptation of a pre-existing scale designed to measure the basic psychological needs outlined in Self-Determination Theory (SDT). Originally developed to assess need satisfaction in an individual’s general life, the BPNS-G was derived from the Basic Needs Satisfaction at Work Scale (BNSW-S), which was initially designed to measure need satisfaction in the workplace [30], [31], [32], [33]. The BPNS-G consists of 21 items: 7 measuring autonomy, 6 measuring competence, and 8 measuring relatedness. To capture both satisfaction and dissatisfaction dimensions, the scale includes a combination of positively and negatively worded statements rated on a Likert scale [32]. Example items include: "I feel like I can decide for myself how to live my life (autonomy)," "Most days I feel a sense of accomplishment from what I do (competence)," and "I really like the people I interact with (relatedness)."

Beyond its structural components, the BPNS-G has been widely used and adapted across various fields. It has informed studies on autonomy support [28] and engineering graduate students' motivation to teach [31] and has contributed to the development of scales such as the Balance Measure of Psychological Needs (BMPN) [34]. Its adaptability underscores the importance of tailoring its items to specific contexts to enhance relevance and applicability.

Given its flexibility for adaptation, we identified the need to refine the scale's items to better align with academic communication in graduate education, ensuring that it meets the objectives of the COMM-FLOWS tool.

*Step 3: Understanding the Context of Graduate Student Communication*

To ensure the adapted tool accurately captured PhD academic communication, we first examined how communication occurs in graduate school to understand its dynamics. This analysis was essential for adapting the Basic Psychological Needs Satisfaction – In General (BPNS-G) scale to reflect the nuances of academic communication. To achieve this, we reviewed literature on written and oral communication in graduate education, gathered student insights through focus groups and surveys, and consulted professional development experts on communication practices in graduate school.

We drew on best practices for modification to guide our adaptation process. According to Chenel et al. [18], effective adaptation involves reviewing relevant literature, engaging with stakeholders, and soliciting input from both the target population and an advisory group. These steps help ensure that the adapted tool remains aligned with the practical realities of the population for which it is being developed. Applying these steps, we conducted a literature review on communication in graduate school, gathered input from engineering graduate students, and consulted a professional development expert as part of the third step in our adaptation process. The following section provides a detailed discussion of our approach.

*i. Literature Review on Communication in Graduate School*

We reviewed the literature on communication in graduate education to guide our adaptation of the BNPS-G scale for the COMM-FLOWS tool. Our goal was to identify key communication competencies and the ways these competencies are acquired, in order to inform our framing of the basic psychological needs in communication for graduate students. Our review highlighted academic communication expectations for graduate students, the methods through which they develop communication skills, and the expectations placed on them in both academic and professional settings.

*ii. Soliciting Ideas from Engineering Graduate Students*

To complement the literature review, we gathered insights directly from engineering graduate students to capture their lived experiences with oral and written communication. This crowdsourcing effort aimed to identify areas where students experience—or aspire to

experience—autonomy, competence, and relatedness in communication during their graduate studies. Participants highlighted key communication activities, including idea generation, literature reviews, research meetings, workshops, poster presentations, grant writing, and conference presentations. These insights played a crucial role in the adaptation process, helping refine the COMM-FLOWS tool to reflect graduate education's communication realities better.

*iii. Engaging with a Professional Development Expert*

To structure the ideas sourced from graduate students into coherent items for the COMM-FLOWS tool, we leveraged the expertise of the first author. She is a professional development expert specializing in graduate student career growth. With a background in engineering workforce development, she has designed development frameworks and contributed to scholarly work on the career advancement of engineering students. Her insights were critical in refining and expanding the communication ideas sourced from students, ensuring that the items comprehensively represented communication practices in graduate education.

Building on the student-generated ideas, the first author enriched and refined these concepts, translating them into meaningful and practical items for the COMM-FLOWS scale. She added depth and context to the students' input, ensuring their perspectives were aligned with the realities of graduate school communication practices. For example, during the crowdsourcing process, students identified autonomy in choosing a dissertation topic as a fundamental aspect of communication. However, the first author pointed out that this autonomy is often constrained by the research lab's focus and the advisor's expertise. Selecting a topic outside these boundaries could misalign with research group goals, adding complexity to the decision-making process.

*Step 4: Adapting & Developing Items*

As part of adapting and developing items, we modified existing BPNS-G items to reflect PhD communication, created new items where necessary to address missing dimensions, and refined wording to ensure alignment with graduate student experiences. This adaptation process was informed by feedback from graduate students and an expert reviewer, guiding the restructuring of BPNS-G items and the development of new ones to comprehensively capture oral and written communication in academic settings. For example, we modified the original item, 'Most days I feel a sense of accomplishment from what I do,' to 'I felt a sense of accomplishment in crafting well-supported, critical arguments in my writing.' These modifications ensured that the COMM-FLOWS tool effectively reflects how autonomy, competence, and relatedness manifest in graduate students' academic communication.

*Step 5: Aligning Items with SDT and Graduate Student Communication*

As the adaptation process progressed, we systematically aligned the COMM-FLOWS tool items with both the theoretical framework guiding the study and the lived communication experiences of graduate students. This alignment was essential to ensure that the tool accurately captured the realities of communication in graduate education while remaining grounded in Self-Determination Theory (SDT). To achieve this, we conducted an item-construct mapping to confirm SDT alignment, cross-checked items against graduate student communication

experiences, and revised or eliminated items that did not fit theoretical expectations or practical applications. This process ensured that the COMM-FLOWS tool authentically reflected the voices of graduate students while maintaining its conceptual integrity.

To achieve experience-based alignment, we collaboratively reviewed the COMM-FLOWS tool items, assessing their terminology and phrasing to ensure they accurately reflected language familiar to graduate students. This refinement enhanced resonance and relatability, ensuring that the items effectively captured students' oral and written communication experiences in graduate school. Items that did not align with these experiences were either revised or omitted.

Following the experience-based alignment, we conducted a theoretical alignment check using an item-construct mapping exercise. This exercise ensured that the COMM-FLOWS tool remained fully grounded in SDT, with all theoretical constructs adequately represented and free from omissions or overrepresentations [35]. Each COMM-FLOWS tool item was carefully cross-checked against the operationalized definitions of autonomy, competence, and relatedness in oral and written communication to maintain conceptual accuracy, as presented in Table 1.

Table 1: Theory Alignment and Experience-based Alignment

| **COMM-FLOWS Tool Item** | **Construct (brief definition)** | **Notes** |
|---|---|---|
| "I was free to choose my written dissertation's focus based on my research interests within the boundaries of my advisor's area of expertise." | Written Autonomy (Power to shape knowledge) | Captures the respondent's ability to make independent choices about their academic work, reflecting the autonomy subdimension in formal writing processes. |
| "I felt comfortable expressing my need for oral communication support." | Oral Autonomy (Ability to seek support) | Represents autonomy in communication by measuring the willingness to advocate for one's needs in oral contexts, a key aspect of self-determined behavior. |
| "I valued engaging in scholarly writing projects while in graduate school." | Written Competence (Effectiveness and capability in academic writing) | Indicates the respondent's sense of accomplishment and appreciation for developing scholarly writing skills, aligning with the competence subdimension. |
| "By the end of graduate school, I had developed the ability to clearly and professionally communicate complex topics orally." | Oral Competence (Proficiency in oral communication ability) | Demonstrates the respondent's adeptness of oral communication, showing growth in effectively conveying complex topics to different audiences. |

| | | |
|---|---|---|
| "Participating in writing sessions with peers made me feel connected to my academic community." | Written Relatedness (Connection through collaborative writing) | Reflects relatedness by emphasizing the social bonds and sense of belonging fostered through group writing activities. |

*Step 6: Validating Content & Testing Usability*

To validate the COMM-FLOWS tool, we conducted a content assessment to ensure its adequacy, representation, and relevance in measuring the intended constructs. This process involved expert review by communication scholars and SDT experts to assess clarity and theoretical accuracy, as well as a think-aloud study with graduate students to evaluate usability and interpretation. Insights from both experts and users guided refinements to the tool, ensuring that items were grammatically structured, theoretically sound, and reflective of graduate students' lived experiences in oral and written communication. Through email exchanges and interactive think-aloud sessions, participants provided valuable perspectives on how potential respondents might interpret and engage with the tool, leading to key modifications for improved clarity and applicability.

*i. Expert Review of the COMM-FLOWS Tool*

To ensure clarity and comprehensibility of the Communication & Facilitation of Learning in Oral & Written Scholarship (COMM-FLOWS) tool, we enlisted the expertise of a highly qualified communication expert. This expert, who serves as the third author of this paper, holds a Ph.D. in Mass Communication and a J.D., with extensive expertise in privacy, online media, and technology policy. These qualifications made her an ideal candidate for evaluating the grammatical structure and clarity of the tool. We provided her with specific prompts and a detailed explanation of the evaluation criteria to guide the review process. The prompts included questions such as could you assess the clarity of each item? Are the item's labels and wording comprehensible? How would you interpret the meaning of each item? Using the prompts, the communication expert critically reviewed the COMM-FLOWS tool items.

As a result of this review, several key insights emerged regarding the clarity and structure of the scale items. The COMM-FLOWS tool had some double-barreled items, overly complex wording, and grammatical structures that needed simplification to enhance clarity, precision, and readability (Table 2). Double-barreled items, which contained two or more ideas in a single question, posed a risk of reducing comprehensibility for participants and required restructuring [23].

Table 2: Communication Expert Feedback Examples

| **The COMM-FLOWS Tool Item** | **Revealed Issues** | **Expert's Comment** |
|---|---|---|

| | | |
|---|---|---|
| I was free to decide if I wanted to submit applications for awards, fellowships, or other funding sources while in graduate school. | Clarity and simplicity of the item | Split or simplify the item's phrasing to make it more direct and concise. |
| I felt like my peers and mentors genuinely cared about improving my public speaking skills. | Double-barreled item | Split item. This item combined two distinct ideas—perceptions of peers' care and mentors' care—which could obscure individual responses. |
| I felt cared for by my advisor or mentor when they took time to provide detailed, thoughtful comments on my written work. | Grammar and style | Remove "took time" as it is inherent. However, if the time spent is a critical factor, consider making it a separate prompt from detailed comments. |

ii. *Think-Aloud Session for Evaluating the COMM-FLOWS Tool*

A think-aloud session was conducted to evaluate the content, structure, and format of the Communication & Facilitation of Learning in Oral & Written Scholarship (COMM-FLOWS) tool from a user's perspective. This session allowed target respondents to vocalize their impressions and share their real-time thoughts as they navigated through the tool [36], [37]. The goal was to gain insights into the tool's question clarity, ease of navigation within the Qualtrics platform, readability, time required for completion, and the appropriateness of the items in reflecting respondents' lived experiences [18].

To gather these insights effectively, we recruited participants for the think-aloud process. Since our target respondents were engineering graduate students, we selected four participants—three current engineering graduate students and one engineering PhD alumnus. These participants engaged in the think-aloud process following the seven-step procedure outlined by Van Someren et al. [38], which includes setting the stage (conducted via Zoom), providing instructions, engaging in a warm-up activity, outlining the moderator's role and prompts, recording observations, transcribing the session, and reviewing participant feedback. The session was moderated by the second author, a current engineering PhD student, and each session lasted between 60 and 90 minutes. Throughout the process, the moderator observed participants as they interacted with the COMM-FLOWS tool, noting their reactions and any challenges they encountered.

After the think-aloud activity, a brief follow-up interview was conducted immediately to clarify participants' difficulties or concerns. Several key insights emerged from this session. First,

participants identified a specific item that was repeated twice, highlighting the need to remove redundancy. Additionally, they suggested restructuring and reorganizing items within the Qualtrics platform to ensure that items measuring similar constructs were grouped. Participants also recommended adjusting the page layout so that each page contained no more than seven items, enhancing readability and ensuring the visibility of Likert scale labels across different devices.

*Assessing Feasibility and Usability*

In addition to refining its theoretical focus, the COMM-FLOWS tool significantly expands upon the BPNS-G's 21 general items to 76 items, capturing the nuances of oral and written communication in graduate education. This expansion involved tailoring BPNS-G items to academic communication, sourcing ideas from graduate students' lived experiences, reviewing relevant literature, and integrating insights from a professional development expert in engineering education. Given the substantial increase in tool length, we assessed feasibility and usability by piloting the web version with participants to determine completion time and engagement in a single sitting.

Findings indicated that participants completed the tool in approximately 15–20 minutes, aligning with research that suggests 20 minutes is the recommended maximum for web surveys to maintain respondent engagement and data quality [39]. Additionally, participant feedback reflected a high level of engagement and relevance, reinforcing their willingness to participate in the full data collection phase. This supports prior research indicating that perceived completion time varies based on factors such as reading speed, internet familiarity, device used, survey topic, and respondent interest [39].

*Step 7: Preparing the Tool for Deployment*

As a final step before deployment, we conducted a comprehensive review of the COMM-FLOWS tool to refine its clarity, precision, and alignment with the study's objectives. This process incorporated feedback from communication experts and think-aloud participants to assess how individuals unfamiliar with the project might interpret and engage with the tool. Based on these insights, we conducted a final content review to improve readability and ensure that all items effectively measured autonomy, competence, and relatedness in scholarly written and oral communication. Additionally, we tested the tool's technical functionality, including survey logic in Qualtrics, to confirm a seamless user experience. Finally, a pilot test with a small sample of graduate students was conducted to identify any remaining refinements before large-tool deployment.

*i. Content Review and Modification*

The COMM-FLOWS tool underwent an iterative refinement process to enhance its content validity and usability. This process involved a critical assessment of the items to ensure alignment with the SDT constructs, identification of potential misinterpretations, and resolution of complexity issues, such as double-barreled items. Several refinements were implemented to

improve COMM-FLOWS tool items' clarity and accuracy. Some items were restructured into simpler, more focused statements, ensuring that each question measured only a single aspect, thereby reducing ambiguity. Additionally, complex wording was simplified to make the items more accessible while maintaining their relevance to the study's objectives. These adjustments helped reduce the cognitive load for respondents and ensured that the tool was free from unnecessary complexity. The key modifications made to the COMM-FLOWS tool are summarized in Table 3.

Table 3: COMM-FLOWS Item Modifications Examples

| **Original BPNS-G Scale Item** | **The COMM-FLOWS Item** | **Correction Procedure** | **Correction Procedure Rationale** |
|---|---|---|---|
| I was free to decide if I wanted to submit applications for awards, fellowships, or other funding sources while in graduate school. | I was free to decide if I wanted to submit applications for any purpose (e.g., awards, fellowships, or other funding sources) while in graduate school. | Rephrasing for clarity | This item was designed to assess students' freedom in deciding whether to submit applications, regardless of the type of application, so the item was rephrased to streamline its focus. |
| I felt like my peers and mentors genuinely cared about improving my public speaking skills. | 1. I felt like my peers genuinely cared about improving my public speaking skills.<br><br>2. I felt like my mentors genuinely cared about improving my public speaking skills. | Splitting Double-Barreled Items | This item was split to ensure that responses would specifically address the intended construct for each group, resulting in clearer and more focused data. |
| I felt cared for by my advisor or mentor when they took time to provide detailed, thoughtful comments on my written work. | I felt cared for by my advisor or mentor when they provided detailed, thoughtful comments on my written work. | Simplified to preserve intent | By removing "took time to," the focus remains on the thoughtful and detailed nature of the feedback, which is central to the respondent's perception of care. |

### *ii. Technical Review in the Qualtrics System*

In addition to content refinement, a technical review of the COMM-FLOWS tool was conducted within the Qualtrics platform to ensure seamless functionality. This review included ensuring skip logic functionality and thematically arranging items to guide respondents through the survey smoothly. Additionally, the tool was tested to assess usability and confirm that all structural and functional elements operated correctly. This test was conducted with a small group of individuals, including friends, graduate students, and alumni, to confirm that all revisions had been implemented effectively and that the COMM-FLOWS tool was ready for deployment.

*Ensuring Data Quality*

To ensure the reliability of our findings, additional measures will be taken to assess data quality and response consistency. Since the COMM-FLOWS tool includes both positively and negatively worded statements, an initial step will involve checking for contradictions—for instance, if a participant strongly agrees with both "I feel confident in my writing" and "I struggle with writing clarity." Any inconsistencies will be flagged as potentially low-quality data and set aside for further evaluation. This process is critical in maintaining data integrity, ensuring that findings accurately reflect participants' experiences in self-determined communication development.

## Findings

### RQ1: How do the adaptation steps contribute to the theoretical and practical development of the COMM-FLOWS tool?

The adaptation of the BPNS-G scale was a methodical, multi-step process that ensured the COMM-FLOWS tool was both theoretically sound and practically applicable to graduate student communication. The seven adaptation steps played a critical role in shaping the tool by (1) identifying a suitable foundation for adaptation, (2) structuring the tool to align with self-determined communication, (3) evaluating its usability and relevance to graduate students' lived experiences, and (4) preparing it for deployment. These steps strengthened both the theoretical grounding and the real-world applicability of the tool.

*Establishing Theoretical and Conceptual Foundations*

The first two steps focused on selecting and refining a theoretically robust scale for adaptation. Identifying a scale for adaptation (Step 1) ensured that COMM-FLOWS was built on a validated SDT framework, preventing redundancy and reinforcing its conceptual foundation. Appraising the original scale (Step 2) identified key limitations in applying the original scale to graduate education, particularly in its lack of focus on oral and written communication. These steps clarified what core elements to retain, refine, or restructure, ensuring the adaptation process remained both methodologically rigorous and contextually relevant.

*Integrating Theory with Graduate Student Experiences*

With a solid theoretical base, the next three steps shaped the design, structure, and content of the adapted tool. Understanding the context of graduate student communication (Step 3) incorporated insights from academic literature, engineering graduate students, and professional development experts, ensuring that the tool captured real-world communication dynamics. Building on this foundation, adapting and developing items (Step 4) translated these insights into measurable survey items that assessed autonomy, competence, and relatedness in both oral and written academic discourse. Aligning items with SDT and graduate student experiences (Step 5) further refined the tool, ensuring each item was both conceptually valid and linguistically accessible to graduate students.

For example, during this stage, the tool's wording was refined to reflect how students navigate communication power dynamics in academic settings. The item "In my interactions with peers, I had the freedom to decide how to steer the direction of our conversation" prompted a key realization from a participant:

> "I did not realize the importance of steering the direction of a conversation, as I often believed that sharing ideas in a group setting should take precedence over individual control. As a result, I did not see the necessity of leading a conversation unless required." (Black Female PhD student, Mechanical Engineering)

This response underscored a broader insight—while collaborative idea-sharing is valued, individual autonomy in communication is equally essential. Such feedback demonstrated the tool's ability to capture meaningful perspectives on self-determined communication, reinforcing its depth and relevance.

*Ensuring Practical Usability and Readiness for Deployment*

After item development, validating content and testing usability (Step 6) provided empirical feedback on clarity and effectiveness. The expert review and think-aloud study helped refine ambiguous, redundant, or complex items, ensuring that the tool accurately measured communication experiences. This step bridged theoretical development with real-world application, confirming that the COMM-FLOWS tool was both methodologically rigorous and practically meaningful.

Finally, preparing the tool for deployment (Step 7) served as a quality assurance checkpoint, ensuring that all refinements, modifications, and structural adjustments were fully implemented before data collection. This process facilitated final modifications based on user feedback, ensuring that COMM-FLOWS was fully optimized, conceptually sound, and ready for deployment.

**RQ2: In what ways do the measures of the COMM-FLOWS tool differ from those of the original BPNS-G scale in capturing self-determined communication in graduate education?**

The COMM-FLOWS tool differs from the BPNS-G in three key ways: (1) contextual adaptation, tailoring the original constructs of autonomy, competence, and relatedness to academic communication; (2) expanded measurement scope, incorporating both oral and written communication experiences in graduate education; and (3) decision-aid functionality, transforming the scale from a general assessment tool into a structured diagnostic guide for advisor-student and peer interactions. These modifications ensure that COMM-FLOWS more accurately captures how graduate students experience self-determined communication within the structured and often hierarchical environment of academia.

*Contextual Adaptation: Refining BPNS-G Constructs for Academic Communication*

While the BPNS-G was designed to assess general psychological need satisfaction in life, COMM-FLOWS specifically measures self-determined communication in graduate education. The core SDT constructs—autonomy, competence, and relatedness—were adapted to capture how students develop and use academic communication skills in research, writing, and professional interactions.

- Autonomy: BPNS-G measures general self-direction (e.g., "I feel like I can decide for myself how to live my life"), whereas COMM-FLOWS assesses autonomy in communication, such as freedom to express ideas, engage in discourse, and take ownership of written and oral work.
- Competence: BPNS-G assesses broad perceptions of effectiveness (e.g., "Most days, I feel a sense of accomplishment"), whereas COMM-FLOWS measures confidence in structuring arguments, presenting research, and navigating advisor feedback.
- Relatedness: BPNS-G captures general social connectedness (e.g., "I feel close to the people who are important to me"), while COMM-FLOWS evaluates academic relationships, including advisor-student communication and peer collaborations.

By refining these constructs, COMM-FLOWS ensures that self-determination in communication is measured within the academic context, rather than as a general psychological trait.

*Expanded Measurement Scope: Incorporating Oral and Written Communication*

One of the most significant differences between COMM-FLOWS and BPNS-G is its dual focus on oral and written communication. BPNS-G does not differentiate between communication modalities, whereas COMM-FLOWS explicitly examines:

- Written Communication: How graduate students develop autonomy in writing (e.g., crafting arguments, responding to feedback), competence in structuring ideas (e.g., journal articles, grant proposals), and relatedness in collaborative writing (e.g., co-authorship, advisor feedback).
- Oral Communication: How students experience autonomy in expressing ideas (e.g., leading discussions, presenting research), competence in articulating research (e.g., defenses, conferences), and relatedness in academic discourse (e.g., engaging with advisors, networking at conferences).

By distinguishing between these two communication modes, COMM-FLOWS provides a more detailed assessment of graduate students' self-determined communication development, capturing nuances that BPNS-G overlooks.

*Decision-Aid Functionality: Shifting from Assessment to Application*

Unlike BPNS-G, which serves primarily as a self-report measure of need satisfaction, COMM-FLOWS is designed as an active component of a decision aid to facilitate advisor-student discussions and self-reflection on communication growth. This transformation was inspired by patient decision aids [18], which help individuals make informed healthcare decisions. Similarly, COMM-FLOWS is structured to:

- Help students identify strengths and challenges in communication development.
- Guide discussions with advisors and peers to foster better communication strategies.
- Encourage self-reflection on autonomy, competence, and relatedness in academic discourse.

This functional shift makes COMM-FLOWS more than just a diagnostic tool—it becomes an interactive framework for communication growth, something BPNS-G was not originally designed to provide.

**Discussion**

Research on communication development among engineering graduate students is critical for academic success and professional growth. Effective communication is essential for publishing research, securing funding, collaborating with peers, and engaging with professional networks [40]. While existing research acknowledges the importance of communication in graduate education, our study introduces self-determined communication as a key component of communication development. By framing communication through Self-Determination Theory (SDT) [17], [21], we seek to uncover how graduate students' fulfillment of autonomy, competence, and relatedness in communication influences their ability to develop communication skills. The Communication & Facilitation of Learning in Oral & Written Scholarship (COMM-FLOWS) tool provides engineering graduate studies with a tool to assess and enhance graduate students' communication.

Beyond introducing a communication tool, our work contributes to methodological discussions on scale adaptation in engineering education. While there is growing recognition of the need to evaluate measurement scales and research approaches in this field [41], inconsistencies in methodological approaches underscore the need for clearer best practices. One key challenge we encountered was the lack of a standardized, step-by-step guide for adaptation. Although several studies outline scale adaptation steps [18], [42], [43], their varying approaches create inconsistencies in application and interpretation. Given this inconsistency and the critical role of measurement scales in research, we encourage the graduate studies community to engage more actively in discussions on scale adaptation to better support graduate student research and practice in engineering education.

Our work reinforces the importance of user-centered perspectives in scale development for engineering education researchers. While quantitative methodologies play a crucial role in graduate education research, it is essential to incorporate student voices in survey design to accurately capture lived experiences. User-centered approaches, such as think-aloud sessions and expert reviews, assess a scale's relevance and representation, ultimately improving its quality [23], [44]. This assessment establishes the scale's content validity by enhancing participants' ability to interpret and respond to items, improving engagement [18], [44]. Engineering education researchers are continually encouraged to capture students' evolving realities to ensure their work is well grounded to inform graduate program curricula and mentoring practices.

**Limitations and Future Research**

While our adaptation approach followed established frameworks, we acknowledge certain limitations. The 76-item length may contribute to response fatigue, potentially affecting completion rates and data quality. Additionally, some participants with hidden disabilities may struggle with lengthy surveys, potentially discouraging them from participating in the project altogether. Hence, future research can adapt the COMM-FLOWS tool to enhance accessibility by developing shortened versions or adaptive formats.

Beyond tool length and accessibility, this study's scope of communication experiences may also present a limitation. The COMM-FLOWS tool primarily addresses oral and written communication; however, some aspects may not be fully represented despite our efforts to include diverse communication contexts. Future research could expand the COMM-FLOWS tool to incorporate additional communication scenarios relevant to graduate students, such as digital and visual communication (e.g., emails, videos, visual aids) or nonverbal communication (e.g., body language, facial expressions). Additionally, researchers could adapt the tool to capture communication within research labs, program-specific settings, or formal and informal activities (e.g., student organizations and clubs).

In addition to adapting the tool for specific contexts or expanding the scope of communication, future researchers can build on this work by field testing the tool. Future research should focus on iterative field testing of the COMM-FLOWS tool within diverse graduate research environments to assess its usability, validity, and impact on self-determined communication development. Rather than prioritizing a large-scale survey deployment, this approach follows Participatory Design (PD) principles and best practices in Patient Decision Aid (PDA) development, where structured, real-world feasibility testing precedes widespread adoption [18]. Given the nuanced and context-dependent nature of communication in research labs, targeted pilot studies in advisor-student and peer-peer discussions, professional development workshops, and writing mentorship programs will provide more actionable insights than broad-scale quantitative validation alone.

Future work should explore how embedding COMM-FLOWS into PhD training programs influences graduate student communication growth, advisor mentoring practices, and peer collaboration. Additionally, longitudinal case studies and qualitative research will be critical in understanding how students develop autonomy, competence, and relatedness in academic communication over time. Future work should also explore scaling COMM-FLOWS for broader

institutional adoption, assessing its impact on student outcomes, advisor practices, and long-term career trajectories. This approach ensures that COMM-FLOWS remains a flexible, adaptable tool for diverse graduate research settings, rather than a rigid, one-size-fits-all survey instrument.

While this study focuses on the development and validation of the COMM-FLOWS tool, future research will examine how participants' responses reflect patterns in self-determined communication development. A structured case study methodology will be used to analyze survey responses as individual cases, allowing for the identification of themes in autonomy, competence, and relatedness across oral and written communication. The planned analysis will involve (1) item-level coding, (2) construct-level analysis, (3) cross-construct comparisons, and (4) thematic analysis to uncover trends in communication self-determination. These analyses will extend beyond the scope of the current study but will provide critical insights into how graduate students experience and develop self-determined communication over time.

**Practical Implications**

The COMM-FLOWS tool is designed for use by graduate students, faculty mentors, and program administrators in engineering education. It provides a communication assessment tool that faculty can administer within research labs, coursework, and professional development programs. Mentors and faculty can leverage this structured tool to evaluate their graduate students' autonomy, competence, and relatedness in communication, helping to identify areas where additional support may be needed. Likewise, engineering graduate students can use the tool for self-assessment, gaining insight into their communication development. By applying the tool at various points in their graduate journey—such as at the beginning and end of a semester or program—both students and faculty can track communication progress over time.

Beyond the COMM-FLOWS tool's application in communication assessment, this study has a broader implication for engineering education research. It provides a step-by-step account of the adaptation process that can serve as a resource for graduate students and engineering researchers interested in adapting existing assessment scales. Our documentation of this methodological step can contribute to the ongoing advancement of the assessment scales in engineering education.

**Conclusion**

This study presents a methodological approach to scale adaptation based on Self-Determination Theory. It introduces a seven-step process for modifying the Basic Psychological Need Satisfaction in General (BPNS-G) scale to develop the Communication and Facilitation of Learning in Oral and Written Scholarship (COMM-FLOWS) tool. Beyond guiding future tool adaptations, the COMM-FLOWS tool opens opportunities for further research on self-determined communication in engineering education. Since oral and written communication skills are essential in engineering, this tool offers a structured way to evaluate and strengthen these competencies to enable them to become self-determined communicators. It provides a framework for assessing how engineering graduate students experience autonomy, relatedness, and competence in communication.

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