WIP: Translating an Evidence-Based Mentoring Framework for a Center-Scale Graduate Research Environment

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Graduate engineering education increasingly takes place within center-scale research environments, where mentoring relationships are distributed across institutions, disciplines, and research teams. While structured, evidence-based mentoring frameworks have demonstrated benefits in bounded program settings, their translation to complex, center-scale research environments introduces new challenges.

This work-in-progress paper examines the early implementation of a structured mentoring framework within the NSF Human AugmentatioN via Dexterity Engineering Research Center (HAND ERC), building on prior programmatic efforts. Rather than re-evaluating the framework's effectiveness, the paper focuses on the translation and adaptation process, including how mentoring structures, mentor preparation, and tools such as Individual Development Plans (IDPs) function in a distributed research context.

Drawing on formative data from center-wide engagement surveys (n = 18) and mentoring-focused workshops (n = 7), the paper presents early results showing strong perceived support (up to 95%) and clarity regarding expectations (77%). Using a mixed-methods approach, we triangulate these quantitative findings with qualitative feedback to identify specific translation challenges, such as maintaining developmental synchronicity for senior doctoral students and navigating institutional normative misalignment. These observations inform the ongoing refinement of center-level mentoring structures and offer design-relevant insights for graduate programs seeking to implement structured mentoring at scale.

Introduction: Challenges in Graduate Mentoring at Scale

Graduate education in engineering increasingly occurs within research environments that span multiple institutions, disciplines, and funding structures [1]. Large collaborative efforts offer graduate students access to advanced infrastructure, interdisciplinary research, and expanded professional networks, but they also place new demands on mentoring systems originally developed for smaller, co-located research groups [2,3].

Building on prior research demonstrating that structured, evidence-based mentoring frameworks can positively influence graduate student outcomes—including research self-efficacy, professional identity development, and persistence in engineering pathways—this paper examines how evidence-based mentoring frameworks must be redesigned to function effectively in center-scale graduate research environments [4]. Mentoring frameworks that are effective in bounded program settings may not translate directly to larger, multi-institutional research environments [5].

Such environments often involve distributed research projects and collaborative teams spanning institutions, disciplines, and organizational boundaries, with graduate students and postdoctoral

researchers interacting with multiple advisors and stakeholders. In these contexts, traditional one-to-one apprenticeship models can lead to inconsistent mentoring experiences, unclear expectations, and uneven access to professional development [6,7]. These challenges point to the need for mentoring to be intentionally designed as a coordinated system of roles, processes, and structures rather than treated as an extension of individual advisor–student relationships.

From a systems-design perspective, adapting mentoring frameworks to center-scale environments requires rethinking how roles, processes, and structures are organized across institutions.

This work-in-progress examines how a structured mentoring framework, originally evaluated at a single institution, adapts to a multi-institutional research center. Rather than focusing on individual outcomes, we analyze the transition as a system-design challenge. We show that achieving coherence across distributed teams requires a deliberate alignment of roles, tools, and shared expectations to navigate differing institutional norms.

Background: An Evidence-Based Mentoring Framework and the Challenge of Translation

In response to the challenges identified in distributed graduate research environments, research on graduate mentoring emphasizes the value of intentional structure, clear expectations, and mentor preparation, particularly in environments where mentoring responsibilities extend beyond a single advisor–advisee relationship. Evidence-based mentoring approaches commonly incorporate formal mentor training, explicit goal setting, and shared tools to support aligned professional development. As graduate research environments grow in scale and complexity, mentoring increasingly needs to be organized not as a single relationship but as a coordinated system of roles, interactions, and institutional responsibilities.

The mentoring framework examined in this work builds on prior programmatic efforts that integrated a train-the-trainer model for mentor development, layered mentoring relationships linking faculty mentors, graduate mentors, and students, and formal tools such as IDPs and mentoring agreements. The framework further encourages each graduate student to identify two mentors: a primary research advisor and a secondary mentor, drawn either from a closely related research project at another center institution or from the center's industry partner community. This structure is intended to address the limitations of single-advisor models in distributed research environments by supporting both disciplinary depth and broader professional perspective.

Prior implementations of this framework incorporated layered mentoring structures, formal mentor preparation, and theory-informed evaluation approaches within multi-institutional programs focused primarily on undergraduate research participation and preparation for graduate study. These efforts drew on established models of STEM participation and motivation, including social cognitive and self-determination perspectives, and employed structured mentoring tools such as IDPs and mentoring agreements. Empirical assessments from earlier implementations reported gains in students' research self-efficacy, sense of belonging, and preparedness for advanced study, providing an evidence-based foundation for subsequent

adaptation and expansion to graduate-centered contexts. These earlier implementations employed mixed-methods evaluation approaches that combined validated survey instruments and qualitative feedback to examine mentoring experiences and developmental indicators.

At the center scale, this framework represents a shift from undergraduate-focused, multi-institutional mentoring toward a graduate-centered system designed to support sustained research participation across distributed teams. Extending the framework into graduate research contexts introduces qualitatively different challenges, including longer developmental timelines, deeper disciplinary specialization, and more complex advisor–student dynamics.

In practice, adapting the framework to a center-scale environment required redesigning mentoring relationships, engagement timelines, and coordination structures across participating institutions.

In the HAND ERC, these challenges are engaged in part through a coordinated organizational structure that situates mentoring within broader outreach and engagement activities. Within these efforts, IDPs are used not as evaluative instruments but as facilitative tools to support reflection, communication, and goal alignment between mentors and mentees. Rather than prescribing uniform outcomes, the framework emphasizes structured conversations that help students articulate goals, identify developmental needs, and navigate evolving mentoring relationships.

This paper focuses on translating these core elements into the broader context of a research center. The resulting center-scale framework is intended to be adaptable to other multi-institutional research contexts, with ongoing evaluation informing future refinement and validation. Translation is treated as an adaptive process that seeks to preserve the essential features of an evidence-based approach while allowing flexibility in implementation across diverse institutional and research environments.

Implementation Context and Center-Level Coordination

Outreach and Engagement (O&E) is a foundational pillar of the HAND ERC examined in this study and is designed to ensure that members feel supported, connected, and prepared to thrive in a multi-institutional, multidisciplinary research community (Figure 1). Within this center-scale context, O&E provides the coordinating structure that aligns mentoring expectations, tools, and support activities across distributed research teams. Graduate students and postdoctoral researchers participating in the center are embedded within research teams spanning institutions, disciplines, and project thrusts.

Within this context, mentoring relationships extend beyond a single advisor and often involve multiple faculty mentors, senior researchers, and peers. The mentoring framework is implemented at the center level to provide coherence across this distributed environment while allowing individual research teams to adapt practices to their local contexts. This framework also reflects the integration of prior programmatic experience from multiple partner institutions,

including leadership from a partner institution–based effort with an established graduate mentoring culture.

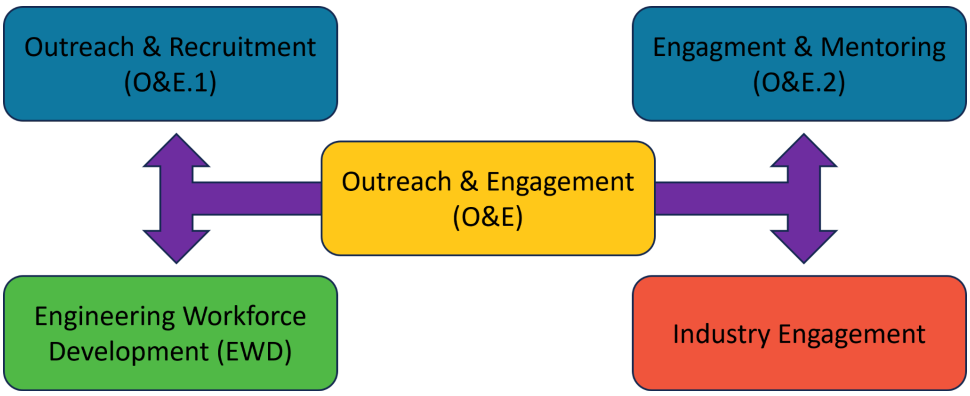

Figure 1: Conceptual placement of Outreach and Engagement (O&E) within the broader HAND ERC ecosystem. The figure highlights how O&E interfaces with recruitment, mentoring, workforce development, and industry engagement functions that shape the graduate research environment examined in this work.

Methods and Implementation Approach

This work-in-progress study employs a descriptive, formative evaluation approach to examine the early implementation of the mentoring framework. The emphasis is on understanding implementation processes and coordination dynamics at the center level, rather than on summative assessment of individual mentoring outcomes or program effectiveness.

Multiple sources of implementation data inform this analysis. A center-wide engagement survey was administered to faculty, graduate students, and postdoctoral researchers to capture perceptions of mentoring, engagement, clarity of expectations, and overall research environment. The engagement survey is intended to support transparency, continuous improvement, and action planning rather than summative evaluation.

In addition to survey data, feedback was collected from mentoring- and IDP-focused workshops designed to help participants articulate their career goals and professional development needs. Survey results are reviewed by leadership and engagement teams and used to inform improvement actions for subsequent years. Qualitative input from open-ended survey responses and facilitated discussions is used to identify recurring themes related to mentoring clarity, communication, and professional development.

Quantitative survey responses were analyzed descriptively using proportion agreement, and qualitative comments from open-ended responses and workshops were reviewed to identify recurring implementation themes.

Early Observations and Implementation Feedback

Although a comprehensive evaluation is ongoing, several early and context-dependent observations have emerged from the initial implementation of the mentoring framework. Graduate students' and postdoctoral researchers' survey responses reflect generally positive assessments of mentoring support structures, communication, and connection within the research environment.

Across eight engagement survey items (n = 18 respondents), between 67% and 95% of respondents agreed or strongly agreed with statements reflecting mentoring support and engagement (see Appendix for full survey data). Specifically, 95% agreed that people in the Center are helpful and supportive, 84% reported feeling respected, and 77% indicated that they knew what was expected of them. Additionally, 83–100% reported having recent conversations about professional development. These findings suggest that participants perceive mentoring structures as supportive and that expectations and career-development conversations are generally clear and normalized.

Feedback from a dedicated IDP-focused workshop (n = 7) further supports these observations. Six of the seven participants rated the workshop's content, relevance, and overall quality as "good" or "excellent." Following the session, all respondents reported being moderately or highly confident in using or updating their IDPs and in discussing those plans with their mentors.

Qualitative feedback, however, highlighted the challenge of tailoring structured mentoring tools to a diverse trainee population. One senior trainee noted:

> *"As a 6th-year PhD student, some of the material seemed more tailored to students earlier on in their program. Maybe you could make the material more flexible based on where students are at."*

Taken together, the survey results and workshop feedback provide preliminary triangulation across quantitative and qualitative sources. Patterns of perceived clarity, as reflected in Likert-scale responses, were reinforced by facilitated discussions, while qualitative input identified a specific translation challenge: the need for mentoring frameworks to remain developmentally relevant across the full longitudinal span of graduate training. These early results reveal that while tools such as IDPs are valued, variability in adoption and relevance across career stages highlights the importance of flexibility and ongoing facilitation in a distributed research environment.

Discussion: Navigating the Challenges of Translation at Scale

The early observations presented here underscore the qualitative complexity of translating an evidence-based mentoring framework into a multi-institutional graduate research setting. While the core components of the framework remain intact, moving from a bounded program to a center-scale environment introduces several key translation challenges that require ongoing attention to context and coordination.

Addressing Developmental Synchronicity

A primary challenge identified in this implementation is the wide range of trainees' developmental levels within a center-scale ecosystem. Unlike smaller, cohort-based programs in which students often enter at similar stages, the HAND center comprises researchers ranging from first-year doctoral students to senior postdoctoral fellows. Feedback from IDP workshops highlighted that materials perceived as vital by early-career students can be viewed as "more tailored to students earlier on in their program" by senior doctoral candidates. This suggests that translating a structured framework effectively requires developmental flexibility, ensuring that tools remain a facilitative resource throughout the longitudinal span of graduate training rather than being perceived as a redundant administrative requirement for senior researchers [8].

Institutional Normative Misalignment

A second challenge arises from differing institutional mentoring norms. Some partner institutions already maintain formal mentoring programs and have authored their own versions of IDPs. In these cases, requiring participation in a center-level IDP may be perceived as duplicative or misaligned with local expectations. The challenge for center leadership lies in maintaining coherence and shared expectations while allowing mentoring practices to be responsive to the local norms and team structures of each participating university [9].

Defining the Boundaries of Participation

A final tension concerns the scope of participation in an ERC environment, where many graduate students contribute intellectually to the center's research without being directly funded by it. Determining whether and how these HAND ERC-affiliated but non-HAND ERC-funded students should be included in mentoring structures raises questions about equity, capacity, and the practical boundaries of center-scale systems.

Rather than viewing this variability in adoption as a weakness, this work suggests that flexibility is an inherent condition of mentoring at scale. In a multi-institutional environment, uniform implementation may be counterproductive. Successful translation appears to depend on a modular approach that preserves the essential features of an evidence-based framework while allowing individual research teams to adapt practices to their specific local contexts [10].

Next Steps and Feedback Sought

As a work-in-progress study, this paper documents the early implementation and translation challenges of a center-scale mentoring framework rather than long-term summative outcomes. Future work will focus on a longitudinal assessment of mentoring experiences to determine if the positive perceptions recorded in early surveys (84% feeling respected, 77% knowing expectations) persist as the center matures.

Specifically, the authors plan to refine the IDP-focused workshops in response to feedback on developmental synchronicity. This includes developing modular content that can be adapted for

senior PhD students and postdoctoral researchers, ensuring the framework remains a "facilitative tool" rather than an administrative burden at later career stages.

The authors seek input from the graduate education community on the following:

- Balancing Consistency with Local Norms: How can center-scale programs maintain a "coordinated system" of mentoring without creating redundancy for students at institutions with existing, robust mentoring requirements?
- Scaling Qualitative Mentoring: Which elements of structured frameworks—such as the secondary mentor model or formal mentoring agreements—are most critical to preserve when operating across distributed, multi-institutional teams?
- Inclusivity vs. Capacity: How should centers define the "functional boundaries" of their mentoring systems to include affiliated, non-funded students without overextending coordination resources?

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Appendix

Survey questions asked of Center graduate students and postdoctoral researchers.

Q1 I am respected in the Center.

Q2 The Center has an honest and open environment, and lines of communication are always open.

Q3 People in the Center are helpful and supportive.

Q4 I know what is expected of me in the Center.

Q5 It's okay to fail and learn in the Center.

Q6 This year I've had opportunities to learn and grow in the Center.

Q7 In the last 6 months, someone has talked to me about my project's progress.

Q8 In the last 6 months, someone has talked to me about my development.

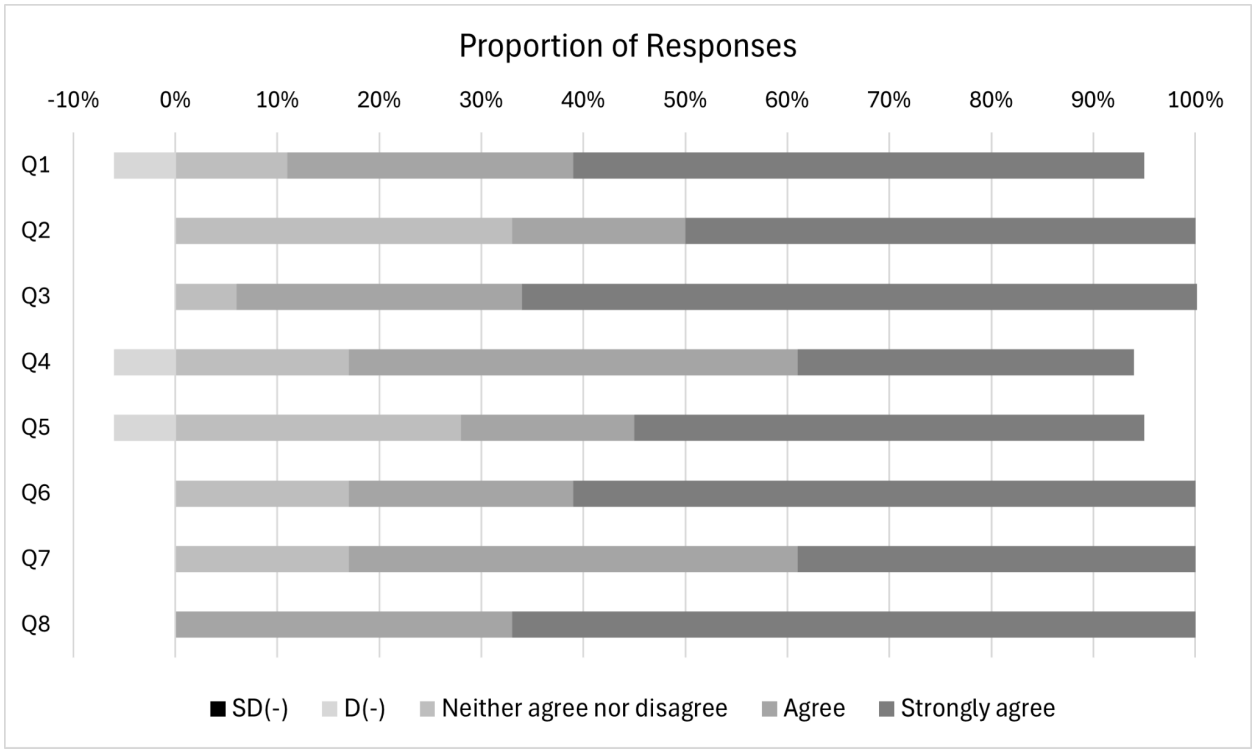

Figure 2: Survey responses.