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Building Capacity for Instructional Change: A Critical Review and Conceptual Framework for Discipline-Based Education Research (DBER) Postdoctoral Professional Development

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Abstract

In this theory-focused full paper, we present a critical review of research to connect existing knowledge about STEM postdoctoral associate professional development (PD) and PD programs for building the capacity of emerging Discipline-Based Education Research (DBER) scholars to enact instructional change. The aim of this work is to consider the extent to which and how we support postdocs engaged in instructional change – a workforce whose capacity for instructional change toward national priorities cannot be assumed from the existence of or increase in postdoctoral roles alone. Our argument depends on connecting literature bases that are often read separately. We review (1) STEM postdoc PD research, which highlights both the promise of postdocs as innovation drivers and the relational tensions that can constrain their work; (2) DBER PD research, which provides models for developing emerging scholars' capacity to translate evidence into instructional change; and (3) the limited but illustrative literature on DBER-specific postdoc change, which demonstrates what postdocs can contribute but not yet how their change capacity emerges. Based on our synthesis, we lack understanding of the process by which postdocs work in relationships to contribute to change resulting from DBER. We argue designing programs assuming challenges will or should not happen as postdocs develop change agency, or that relationships will not be important to addressing tensions, means both postdocs and programs will fall short of meeting research innovation goals. Implicit assumptions must be addressed.

Based on our critical literature review, we present propositions for how postdocs can develop capacity for instructional change resulting from engaging in DBER. This work offers an initial case for broader STEM postdoc PD programs building capacity for change resulting from research. We visualize our propositions into a conceptual model that can guide future development of postdoc-specific PD models and studies of how postdocs (and in turn, their fields) develop capacity for change.

Keywords— postdoc, professional development, professional agency, instructional change

I. Introduction

As Discipline-Based Education Research fields expand, the number of postdoctoral positions has been posed as perhaps growing [1], following broader trends in STEM fields [2], [3], [4]. Our web scrape of an engineering and physics education research job boards spanning 2008-2026 [5], [6] revealed DBER postdoctoral job positions grew as a share of all listings, peaking at 58 positions in 2022 before a recent decline, particularly from 2025 to time of publication. This recent pattern likely reflects funding cycles that also emerged in 2019-2020 around the COVID-19 pandemic and in 2014-2015, when there was a surge in DBER faculty positions compared to temporary positions (see Figures A1 and A2 in the Appendix). Many postdoctoral ("postdoc") roles have been positioned as drivers of change, or innovation resulting from research, in both DBER and STEM broadly [1], [7], [8], [9]. However, little scholarship examines how DBER postdocs develop capacity for instructional change resulting from their engagement with DBER scholarship [10]. We argue the perceived rise in DBER postdoc positions includes an implicit assumption that more postdocs mean more change towards evidence-based teaching. While examples of successful DBER faculty professional development (PD) models for developing change capacity exist (e.g., the PEER Collaborative, Rigorous Research in Engineering Education (RREE), and the NSF Research Initiation in Engineering Formation (RIEF) Program) [11], [12], [13], [14], [15], [16], [17] and STEM Postdoc PD ***literature*** is robust [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], DBER-specific postdoc PD remains underexplored [7], [10], [28], [29], and understanding how DBER postdocs' agency emerges remains nascent. A brief vignette illustrates what this gap looks like in practice and why "capacity for change" cannot be assumed from the role alone.

Motivating vignette (hypothetical): A DBER postdoc in two collaborations

Consider a new DBER postdoc, Dr. Sam Rivera, hired into a mechanical engineering department on a two-year contract to support a redesign of introductory thermodynamics using active learning. Sam arrives with strong training in mechanical engineering and thermodynamics, prior TA experience in their field, and genuine interest in teaching, but quickly realizes the role assumes education research methods and instructional change principles they have not yet had the chance to develop.

Sam raises this gap with their supervisor, Dr. Chen, who connects Sam to a cross-college DBER working group that meets monthly to workshop study designs, classroom data sources, and common pitfalls. In course redesign meetings, Sam is asked to translate broad goals ("make it more active") into concrete routines, measures, and iteration plans. Over the semester, Sam's suggestions begin to get taken up, sometimes modified by faculty constraints (room layouts, grading norms, departmental politics), but increasingly treated as part of the team's shared plan. Dr. Chen draws on Sam's instructional expertise and time for implementation, while Sam relies on Dr. Chen for institutional knowledge and positional authority. Sam starts to describe themselves as a legitimate contributor to the change effort, not just a helper executing other's decisions.

In a second and simultaneously running assignment, Sam supports a different course led by Dr. Patrick, who is skeptical of active learning and was not involved in the original redesign. Sam proposes modest modifications (e.g., a short pre-class warm-up and a small in-class problem-solving routine) and offers to collect simple student feedback but is repeatedly acknowledged by Dr. Patrick as being "thoughtful," without ultimately being taken up. With no clear mandate and little standing in that course, Sam begins to pull back, redirecting effort toward contexts where buy-in exists.

The same postdoc, in the same institution, experiences two trajectories: growing influence in one setting and constrained action in another. What determines whether early mismatch becomes engagement and learning, or frustration and withdrawal? *In the Discussion, we revisit this vignette to show how our framework makes these dynamics observable.*

This paper presents a theory-focused critical literature review leveraging Onwuegbuzie et al.'s [30] Between-Study framework. We synthesize and compare scholarship on STEM postdoc PD and PD programs building emerging DBER scholars' capacity for research and instructional change, resulting in a set of propositions for a conceptual framework. By comparing and contrasting, synthesizing, and analyzing findings across these spaces through the lens of relational agency [31], [32], we connect them and answer: **RQ:** "*What propositions are key to understanding how DBER Postdocs develop capacity for instructional change?*" The contributions are (i) propositions synthesizing convergences and divergences across literature and (ii) a conceptual framework organizing propositions to inform future research and PD design. We find that DBER postdocs develop capacity for instructional change not through individual effort alone, but in collaboration with established change agents within structured support systems. This means designing PD that intentionally builds collaborative structures, mentorship relationships, and opportunities to productively navigate tension in postdoctoral and instructional change work, rather than assuming postdocs will drive change simply by virtue of being hired into the role.

II. Methods

We conducted a theory-focused critical literature review using the Between-Study framework, a qualitative approach for analyzing and interpreting multiple sources through comparison, contrast, and synthesis to develop understanding of connections between them [30]. Guided by Sutton et al.'s [33] definition for critical reviews, we aim to demonstrate both extensive research and a critical examination of its quality. Rather than seeking generalizable truth or replicability [34], we synthesized and critiqued findings with theory to propose an innovative model for conceptualizing how DBER postdocs build capacity for instructional change. Our analysis was guided by two rhetorical questions, functioning as "structural questions" in the Between-Study framework [28, p. 22] to organize comparison and synthesis across literature sources: *How can postdocs be successful as developing scholars and change agents? What support is required for developing change capacity through relational agency?*

II.A. Methods of Identification and Analysis

We started with a handful of studies on (1) STEM postdoc PD (including Bahnson et al. [18], [35] and Mendez et al. [21]) and (2) PD for building emerging DBER scholars' capacity for change (including Pitterson et al. [11]; Jensen et al. [13]; Mirabelli et al. [17]; and Solorio et al. [36], [37]). Through initial handsearching of these papers' references, Webb performed initial expansion of our dataset. Considering feedback in weekly meetings with other authors, Webbtested representation (i.e., extraction of sufficient meaning for research questions) via additional expansion through ERIC database keyword searches such as DE: "Postdoctoral Education" AND "STEM Education" and DE: "professional development" AND "instructional change." Note

that DE here refers to "Heading or Keyword (Phrase Indexed)" in EBSCOhost database searchers. DE here performs an *exact* search for subject headings and author-supplied keywords describing an article. Keyword searches were limited to combinations across titles, abstracts, and full texts and guided by inclusion criteria that sources must be journal articles, books, conference papers, presentations, or reports (i.e., no magazine articles or dissertations). Selected articles were from 2012 on (based on the first National Academies DBER report [38], where and when the term "DBER" was popularized to discuss the STEM discipline-based education research enterprise [39]). Our full corpus gathered at abstract review level included 75 papers. For development (i.e., analysis of how data from one source informs others), Webb focused on comparing and contrasting abstracts related to our two rhetorical questions. Notes synthesizing findings were tabled, used in writing this paper and for constructing summary tables in the Appendix. We settled on this corpus at the abstract level via more expansion, checking additional literature to ensure no new themes related to rhetorical questions arose.

During full review of the 75 papers, we documented discussions on our rhetorical questions and assessed them via triangulation (i.e., seeking convergence from sources) and complementarity checks (i.e., seeking clarification) until theoretical saturation for answers to rhetorical questions was reached (i.e., Webb was encountering no new relevant information via exploring additional sources). Papers were analyzed and organized according to those (a) discussing postdocs primarily as successful developing scholars and (b) successful change agents, as well as those mentioning (c) supports for postdocs developing as scholars and (d) PD supports for developing postdocs as change agents to address common challenges faced.

To develop propositions for answering our research question, we drew on Lee et al.'s [40] approach to critical reviews defining and visualizing a conceptual framework. Propositions, as defined by Merredith (cited in [40, p. 898]), are "normative statements that summarize links between concepts from an array of related literature." Lee et al.'s style of review is organized based on rhetorical questions, clustering insights from literature into a conceptual model. Our review took a similar approach, but we also synthesized findings through the lenses of Coso Strong et al.'s [31] professional agency and Edward's [32] relational agency theories. Our methods also involved *between source triangulation* (i.e., looking for corroboration of propositions across sources) and *between source initiation* (i.e., exploring contradictions between literature and considering how contradictions might be resolved) towards a renewed understanding of: "*How can DBER Postdocs develop capacity for instructional change?*" Here, *triangulation* was useful for ensuring that the philosophy of our framework obtained from one source converged with others. Webb performed ongoing review of propositions with domain experts who recommended additional literature for consideration; trustworthiness was also supported by multiple author team reviews as themes developed in writing. These methods helped us ensure there were no contradictions in our propositions. Figure 1 illustrates the conceptual model overviewing our propositions and connections between them.

While these methods resulted in theoretical saturation for our research questions, our scoping decisions may have affected synthesis. Specifically, we (a) included only education research on STEM postdocs and DBER faculty, when DBER postdocs also wrestle with non-STEM-specific issues and other disciplines' research related topics. We also (b) excluded research addressing deficit framings of postdoc experiences. We had to necessarily bound the literature, and the STEM and education research we did review included a wide range of postdoc experiences, institutional contexts, and interaction dynamics; further empirical work will be essential to test and refine propositions across broader populations of postdocs.

III. Integration of Agency Theory

To develop the propositions from the literature, we chose to center on DBER postdocs' professional relational agency [32]: how these emerging scholars identify "available moves" [31] toward change and how capacity for change is negotiated and enacted through relationships, distributed expertise, and joint action [31], [32]. This framing is guided on two theoretical foundations, professional agency toward impact in engineering education from Coso Strong et al. [31] and relational agency from Edwards [32], as well as asset-based pedagogical approaches. These theoretical foundations clarify why postdocs may be positioned as agents, in principle, yet can often be constrained in practice (i.e., relational agency and available moves), while the asset-based approach provides a focus on the strengths of learners– or their positive "assets" – in contrast to just

their needs or challenges [23]. Importantly, asset-based thinking does not mean ignoring barriers postdocs face but rather shifts the focus of deficit-based thinking towards conversations where tensions encountered are opportunities to leverage strengths already possessed, as well as strengths possessed in collaboration [32].

Coso Strong et al. argue DBER faculty agency toward change manifests as scholars' abilities to "see" opportunities or "moves" available to them that can enable change toward their impact goals on STEM education [31]. Perceiving these opportunities requires emerging scholars to take "strategic actions" or "perspectives" towards innovation in instruction. Coso Strong et al. note the role networks and social capital play in this agency, describing how relationships with others improves scholars' professional capital and awareness in ways that enables new moves, or broadened horizons of action [41] for change. These scholars [31] also noted how professional development was critical to DBER faculty capacity for change, and that "critical incidents" where emerging DBER scholars experienced often uncomfortable learning and help-seeking were required to enable pedagogical shifts before unfamiliar to them within their classrooms. Coso Strong et al.'s [31] professional agency was operationalized for DBER faculty using their expertise and networks to impact higher education toward improvement based on DBER, but their initial participant pool did include DBER postdoctoral scholars. Additionally, both emerging faculty and postdocs occupy a liminal position between their developmental needs and work contributions, and there may be moves available to postdocs that are unavailable to more established faculty worth uncovering, since postdocs are evaluated on different terms than they are.

Similar to emerging faculty, student teachers also take on synergistic roles, operating as professionals not quite independent in their practice. Edwards's [32] relational expertise originally referred to the distributed nature of what K-12 student teachers know, meaning because these educators were still training, they worked with supervisor's knowledge combined with their own [42], [43], [44], [45]. Student teachers' expertise existed in relationships, and their agency, or ability to use that knowledge toward change [31], was relational too. Edward's [32] relational expertise and agency has been operationalized to K-12 student teacher pedagogical change [42], [43], [44], [45], [46], doctoral training supporting relational agency of emerging scholars [47], [48], and departmental instructional change efforts involving DBER faculty and postdocs working in action teams [10], providing evidence of applicability for our review. Studies guided by Edwards's theory suggest developing subjects working with experienced mentors in "joint action" [32] towards shared aims can capitalize on distributed (relational) expertise or "knowing how to know who," in ways that expand those aims [10], [32]. This framing suggests an activity system (e.g., a department) learns through the expansion of the aim (e.g., instructional change) because acting subjects (e.g., collective group of change makers implementing DBER) are learning how to do change at the same time they are changing a system. In other words, working together toward shared aims helps subjects see new possibilities for goals and demands for their own development that emerge as necessary for reaching new goals. It also means a "learning system" benefits from co-construction of collaborators within it. We argue *relational professional agency toward impact* offers a lens for understanding how DBER postdocs work with others to contribute to instructional change resulting from DBER. Combining Coso Strong et al.'s and Edward's frameworks together allows us to capture dynamics distinct to postdocs that faculty-focused applications alone may miss. Aligned with Between-Studies [30], through organizing literature, comparison and contrast of findings, and synthesis through the lens of professional agency [31], [32], we connected our three strands to answer our research question.

While agency theory offers valuable insights, it does also present limitations. Some agency frameworks risk individualizing structural problems, are difficult to operationalize, vary significantly by context, and complicate attribution of instructional change outcomes to specific individuals within groups [49]. We mitigate these concerns by grounding work in relational agency, where agency is a property emerging in specific kinds of interactions and through social and structural relationships rather than residing within individuals. We consider our propositions testable starting points requiring empirical validation; our model offers an illustration operationalizing mechanisms through which agency actually develops in interactions, offering criteria for how constructs can be empirically observed and supported.

IV. Findings

Our Propositions are all followed by supporting synthesis. First, we highlight similarities and differences between diverse arguments for what PD is needed to support DBER postdocs as agents of change.

Proposition 1: Many DBER postdocs occupy dual roles developing as researchers while also serving as change agents (e.g., leading course redesigns, supporting curricular reform). This dual positioning creates "**critical tensions**" that can lead to disengagement, or, when postdocs actively navigate constraints and build capacity through relationships, to engagement and agentic action for innovation.

Proposition 2: Productive navigation of "critical tensions" depends on relationships. DBER postdocs must negotiate their capacity to enact change with collaborators who hold more institutional power but may lack the expertise postdocs bring.

IV.A. STEM Postdoc PD Literature on Tensions and Navigation in Relationships (P1&P2)

Most STEM postdoc literature reviewed frames *tensions as problems requiring solutions,* addressed by clearer role definitions, better communication, additional mentorship training, and structural interventions [19], [20], [22], [24], [26], [50]. These recommendations place burden on faculty and institutions rather than recognizing postdocs' own capacity to navigate these tensions. Some STEM Postdoc literature counteracts this framing [35]. Rybarczyk et al. [51] found postdocs designed and delivered courses otherwise unavailable to students; Price et al. [52] documented postdocs creating more student-centered courses than national averages despite no prior teaching experience. Jach & O'Brien also describe postdocs "taking matters into [their] own hands… necessary because of the lack of clarity surrounding [their] positional power " [23, pp. 380–381]. These studies suggest tensions can be precursors for change, not just obstacles.

However, little reviewed STEM postdoc PD literature examines how postdocs work with others *in relationships* to resolve tensions and affect change. Tõnismann & Bran [53] come closest (so do [23] and [50]): they found postdocs facing career misalignments taking ownership by building networks and working with supervisors to align expectations with reality. Their argument acknowledges postdoc agency while also recognizing agency requires postdoc PD and is exercised relationally, not in isolation, examining how postdocs actively reflected upon their preparation gaps and sought support from more experienced others in response. Karalis Noel et al. [19] similarly argue centering postdoc-faculty interdependence toward joint action, or shared creation toward instructional change as opposed to individual agency, results in a more "productive exchange." We therefore argue promoting DBER postdocs' active navigation of tensions through relationships holds a key for change that does not require additional mentorship training or structural interventions to cancel out misalignments. Relationships in the face of tensions are what keep tensions "critical;" tension is necessary to spur agentic action, and relationships support effective responses for broadening capacity for innovation from research.

IV.B. DBER PD Literature on Critical Tensions and Active Navigation in Relationships (P1&P2)

In contrast, DBER literature tends to frame "critical tensions" as an inherent to, and necessary for, collaborative change work. Solorio et al.'s case study describes a DBER faculty who, motivated by isolation, shifted toward "advocating for environmental changes that create more supportive norms in response to the needs of community members" [36, p. 9] while developing tools to do so through their PD program. For instance, the Science Education Initiative (SEI) Handbook [7] acknowledge challenges DBER postdocs face (e.g., rank difference, imposter syndrome, temporary positions) while structuring positions so postdocs work with faculty toward shared goals, experiencing tensions as part of development rather than barriers to it. SEI postdocs regularly met with peers and mentors outside of supervisors, learning to ask for help and take ownership of needed support. The SEI structured postdoc positions to be "co-constructional," with postdocs working alongside faculty toward shared change goals. This "co-constructional" model enabled not just changes in courses but also changes outside the SEI scope that would not have happened otherwise [54].

What makes these tensions productive rather than things to eliminate? The small body of DBER postdoc-specific literature points to relationships and distributed expertise as the key mechanisms. Fisher et al. [10], studying of SEI-like action teams, drew on relational agency to understand how postdoc-faculty collaborations toward change functioned. They found DBER postdocs' capacity to contribute to change was not diminished by their lack of independent authority but rather enabled by their role positions within teams. Postdocs contributed expertise in evidence-based teaching and time that faculty lacked; faculty contributed positional authority, disciplinary credibility, and institutional knowledge postdocs did not have. This *distributed expertise* meant neither party could enact change alone—the object of instructional change

expanded, or benefited, through joint action. In this asset-based framing, tensions postdocs face in navigating relationships with supervisors and departmental structures are not obstacles to change but the very conditions under which agency develops and collaborative change becomes possible.

IV.C. Synthesis: Propositions 1 & 2

Literature from both STEM postdoc PD and DBER PD documents what we term "critical tensions", though the former tends to frame them as deficits needing resolution, while the latter more often recognizes them as necessary features of collaborative instructional change. Critical tensions can be uncomfortable learning experiences, aligned with notions of "cognitive dissonance" [31], [55]. For DBER postdocs, this means experiencing a mismatch between one's developmental role as a scholar in transition, and one's expected role as a productive contributor to deliverables. These tensions foster strong emotions that motivate action, especially when emerging scholars would not otherwise question practice [31], [55].

Critical tensions can lead to *engagement*, *disengagement* [48], or *agentic actions* toward innovation [31], [55] - each shaping whether and how postdocs-driven instructional change happens. However, tensions only become productive when postdocs engage in learning through relationships; without these interactions they may disengage [48]. DBER PD should therefore involve providing postdocs opportunities to work in relationships, developing the strategic perspectives and actions needed to address "critical tensions" and collective action toward field-level instructional change.

The key distinction between our literature bases in terms of Propositions 1 and 2 is not the presence or absence of "critical tensions", but rather how they are framed and what role postdocs (and others) are expected to play in navigating them. This reframing has implications for how we understand DBER postdoc PD. If "critical tensions" are problems to eliminate, PD should focus on removing barriers and providing resources; but if tensions are conditions under which agency develops, PD should focus on building capacity to navigate tensions productively and providing necessary relationships for them.

Next, we discuss similarities and differences between arguments for what kinds of support is required for developing DER postdocs' change capacity through relational agency.

Proposition 3: Effective DBER postdoc PD must support postdocs as developing scholars *and* change agents-in-the-making, treating these roles as mutually reinforcing and enacted through relationships with established change agents.

Proposition 4: Effective DBER postdoc PD builds ***"relational infrastructures"***: structured ways of working together (co-design, supportive networks, aligned resources) that are tailored to local contexts and enable sustained instructional change and shared agency.

IV.D. STEM Postdoc Lit: Balanced Roles, Asset-Framing, Critical Tensions (P3+P4)

As discussed, a subset of STEM Postdoc PD studies highlights the importance of postdocs' developing simultaneously individually and through relationships as active change agents [3],[20], [56]. Rybarczyk et al. [51] and Price et al. [52] describe postdocs teaching with unprecedented novelty as they learned, for the first time, to implement evidence-based instructional strategies. These postdocs developmental role (learning to teach) was necessary for enacting their agentic role (implementing novel strategies). Importantly, this development and change work was relational too: they had to work *with* faculty with expertise in evidence-based teaching in structured PD to develop skills for adopting evidence-based teaching without prior experience. Consistent with this view, multiple scholars argue postdoc positions must attend to both supervisors' and postdocs' goals at the same time [53], [48], [19], respecting bi-directionality, reciprocity [48], and necessitating "shared responsibility … that requires a mutual commitment" [19, p. 1]. This need to support balanced and interdependent roles aligns with our "dual roles" framing in Proposition 3, where development and change are mutually reinforcing. Bahnson et al. [18], [35] highlight the importance of regular, explicit discussions between postdocs and faculty supervisors about expectations for their professional relationship. Through our "critical tensions" lens, these conversations can surface misalignments in postdocs' dual roles; identifying such tensions *together* is the first step to "altering the social exchanges and role definitions" that lead to negative experiences [35, p. 1138].

Across these studies a key caution emerges, over-emphasizing individual development or "agency"

in isolation can lead to role designs that are unsustainable for postdocs and misaligned with faculty needs for instructional innovation. Instead, tensions can be framed as productive elements of professional development when supported appropriately [3], [20], [56], [57], [58]. Supportive structures take an asset-based approach toward postdocs' capacity to develop and overcome tensions. For example, by pairing informational and socio-emotional support with opportunities for co-construction toward shared goals or supports themselves. postdocs can enact professional identities, learn in context, and contribute to change alongside their supervisor [19], [59], [60], [52], [61]. Co-teaching and related collaborative practices, in particular, can help.

IV.E. DBER Lit on Effective Postdoc PD: Relational Infrastructures (P3+P4)

DBER PD scholarship corroborates STEM Postdoc literature's emphasis on balancing postdocs' developmental roles with change-making roles, but it goes further by offering PD models that weigh individual agency with relational agency in productive "critical tension," positioning emerging DBER scholars as active in their agency development in relationships [10], [13], [15], [54], [62], [63], [64]. Across both spaces, scholars suggest what we term *"relational infrastructures."* Relational infrastructures involve co-constructional activities, productive feedback loops, networking to sustain them, community-building, and funding opportunities aligned with contextualized, systems change models. These elements function synergistically rather than hierarchically, with systems approaches serving as an overarching framework shaping how co-construction, networking, etc. are integrated and enacted in response to specific departmental, institutional, and disciplinary contexts.

IV.E.1. Communities of practice with collaborative goals

Recognizing emerging DEBR scholar PD "can translate to improvements in education practice through enhanced knowledge and subsequent implementation of evidence-based approaches" [65, p. 28], Dart et al. argued for Communities of Practice as a model providing key "structured development opportunities [that] can accelerate emerging [DBER] researchers' development" [65, p. 29], making them our first "relational infrastructure." In short, DBER CoPs involve groups of people coming together because they share a concern for something they do and for doing it better. They regularly interact to collaborate towards those aims and involve levels of participation with a core group, an active group, and a peripheral group. Overtime, participants at the periphery may participate more actively toward the core, thus individuals are developing at the same time the CoP's overall capacity for instructional change expands [11].

Numerous example CoP DBER faculty PD models exist, including the PEER Collaborative [12], Rigorous Research in Engineering Education (RREE) [11], and the NSF Research Initiation in Engineering Formation (RIEF) Program [15], [13], [17]. The ultimate goal of these CoPs are "[building] the [EER] community by establishing '[a] structure and mechanism for training faculty to conduct rigorous [EER] through collaboration" [11, p. 33]. Departmental Action Teams [62], [64], are modeled as a type of learning community that, ideally, becomes a CoP where members use interactions to learn about teaching and shift their practices, working together to shift instructional change within and beyond individual departments.

IV.E.2. Productive feedback loops and funding

Though literature suggests CoPs are beneficial for building capacity for instructional change, they are also hard to sustain [66], [67]. CoPs require emotional, intellectual support, and "productive feedback loops," where "participants might raise a concern to the group, others provide suggestions, and then the original participant [reports] back after testing out suggestions" [66, p. 5]. Mirabelli et al. [16] note that the NSF RIEF grant program's dollars served as a positive feedback loop, enabling development of DBER faculty who, without funding, would not have had opportunities to integrate into EER. These studies point to the multiplier effect of funding and feedback for building emerging DBER scholars' capacity for change and sustaining ripple effects of DBER. Jensen et al. [13] and Martin et al. [15] argue building capacity for instructional change in DBER requires not just PD for research skills but also sustained engagement in social networks where scholars gain perspectives necessary to sustain agency. Without meaningful, networked relationships, faculty were, while still likely to gain skills in PD, unlikely to maintain DBER engagement. This reality reduced the potential of this CoP for DBER field-level change, making structured networking relational infrastructure as well.

IV.E.3. Contextualized and systems approaches

Contextualized, systems approaches to change are critical to sustaining the impacts of DBER and developing DBER scholars' capacity as agents for all these "relational infrastructures." Finelli et al.'s [68]

departmental action study discusses the central role of local data as the most convincing guide for faculty decision-making to adopt DBER, compared with more general claims about effectiveness. Pitterson et al.'s study of the Rigorous Research in Engineering Education (RREE) Program [11] also highlights the power of systems approaches to this change, recognizing "efforts must go beyond any one individual's decision that a course of action is superior to the status quo. This means that initiating and maintaining any change … requires movement at all levels" [11, p. 35]. In other words, DBER PD argues instructional change takes a team with local *and* theoretical knowledge of their contexts. No one actor makes all decisions or compromises when a department overhauls a course with DBER. In fact, individual agency can preclude meaningful change, making role diversity critical to sustainment.

IV.F. DBER PD Lit on Dissonance and Relationships as Necessary for Change (P4)

In the presence of support networks, funding, collaborations, CoPs, and contextualized, systems approaches to change in DBER, we know that instructional change in STEM higher education is possible, despite being constrained. DBER PD literature tells us DBER postdocs partnered with faculty toward shared goals played a central role in the successes of postdoc-specific PD models for building capacity for change based on research [7], [10], [54], [69], [70], [71], [72], but we are left asking *what is required of DBER postdocs as agents in this change*, understanding necessary for supporting this capacity development. Proposition 4 therefore brings us back to Proposition 1 "critical tensions." At the time of publication, to our knowledge, there is no evidence of how these tensions operate toward broader instructional change, but we do know that successful instructional change rests upon "cognitive dissonance." Olitsky et al. found instructional change stemming from engagement with DBER only took place when there was a change in faculties' "personal practical theories" [55, p. 629]. Popova et al. [73] therefore argued, "...efforts need to be directed toward identifying channels to challenge faculty to become more self-aware of ... disconnect between their beliefs and instructional practices … with the aim of providing resources and support to overcome barriers" [73, p. 524].

V. Discussion: Framework for How DBER Postdoc Agency Emerges in Relationships

Our conceptual model connects our Propositions to enable understanding of not just the content of DBER postdocs' contributions to change (i.e., what they do and what supports enable agency) but also the process (i.e., how agency develops). Our model advances current conceptualizations of agency through contextual application to DBER postdocs and conceptual refinement. Though agency is a common concept in higher education research, it is wrought with multiple conflicting conceptualizations [49]; agency has been operationalized in psychological, sociological, and more recently, emergent traditions, that differ in terms of their focus on individual capacities for reflecting and acting toward goals (psychological), the interplay between individuals and social structures (sociological), and interactions with others and things as situations where agency arises (emergent). Instead of focusing on agency as an individual capacity, our framework adopts a sociocultural emergent approach where agency is an achievement in specific "contexts of action," or situations happening in conditions or structures that can facilitate or constrain shared goals for innovation resulting from DBER. Our theory, oriented toward a Cultural Historical Activity Theory framing, focuses on the importance of relationships in the emergence of agency built this way – through human interaction, dialogue, and participation in joint action [32]. The conceptual advancements of our framework lie in our defined mechanisms through which agency actually develops in interactions. Discussed more in the next section, interactions wherein agency is built over time involve established agents and agents-in-the-making delegating, engaging, disengaging, or acting agentically, and recognition or rejection within those interactions. Operationalizing these terms for this specific context enables future empirical observation.

V.A. Proposed Framework

Our model for DBER postdoc agency centers on its relational emergence, where *established change agents* react to claims from *agents-in-the-making* seeking *recognition.* For DBER Postdocs, established agents central to this are often supervisors. "Dynamics of recognition" [74, p. 2] (Figure 1 arrows) are *critical interactions* to building postdocs' capacity for instructional change. *Delegation* involves established agents granting agency, and *self-agentification* is the claiming of agency, where agency is the ability to "see" opportunities or "moves" available that can enable change toward impact goals [31]. Delegation, self-agentification, recognition, and rejection take place within *structure* and *situation* [74]. S*ituations* are short

term configurations of relationships, like meetings or mediated conversations, where experienced agents act as gate keepers assessing agents-in-the-making. S*tructures* govern *situations* by determining the distribution of resources, rules, and norms determining what practices are appropriate. Through this lens, postdocs do not automatically possess agency; they develop it negotiating structures and situations in relationships.

Shown in Figure 1, key (i) *structures* for DBER postdocs are *"relational infrastructures,"* and key (ii) *situations* are "critical tensions." Following Proposition 1, interactions between postdocs and current change agents can involve strong emotional responses, or "critical tensions", where postdocs experience mismatch between current goals, beliefs, and practices and their outcomes. Mismatch can lead to engagement, disengagement, or agentic experiences, but agency development only happens with relationships, structures, and situations involving these "critical tensions" are supported by others. To illustrate, if the norm for a supervisor is not for their postdoc to pursue *deliverables* outside currently *delegated* tasks without following a certain procedure, then that postdocs' *self-agentification* for a task outside this *structure*, including pursuing *necessary professional development,* may be *rejected*. In this case, the postdoc experiences a *situation of tension* leading to *disengagement* and diminished agency, at least for a while as *recognition* is reclaimed in other *situations*. However, if the norm or *structure* is otherwise, or the deliverable or *self-agentification* is instead *recognized*, then that postdocs' action may be recognized, enabling bolstered agency. Whether a claim is recognized depends on how valuable an act of *self-agentification* is (i.e., how valuable the additional deliverable is to the supervisor), and if it is met by willingness from established agents to accept new agents. Crucially, both the *situation* and *recognition* are required; postdocs need to "know how to know who" [32] to ask for help needed to address mismatch between current practices and desired outcomes. Additionally, they need their changed practices to be recognized in meaningful *structures*. Thus, delegation is the first move in the relational emergence of postdoc agency, and, by established faculty recognizing postdocs and sharing capital with them, postdocs can transition into the second move where they create, expand, and solidify agency "using resources unique to them and providing justification that precisely these resources are needed" [74, p. 6]. In concept, this is the process by which DBER postdocs working with faculty towards instructional change happens – relational agency and distributed expertise are used as tools.

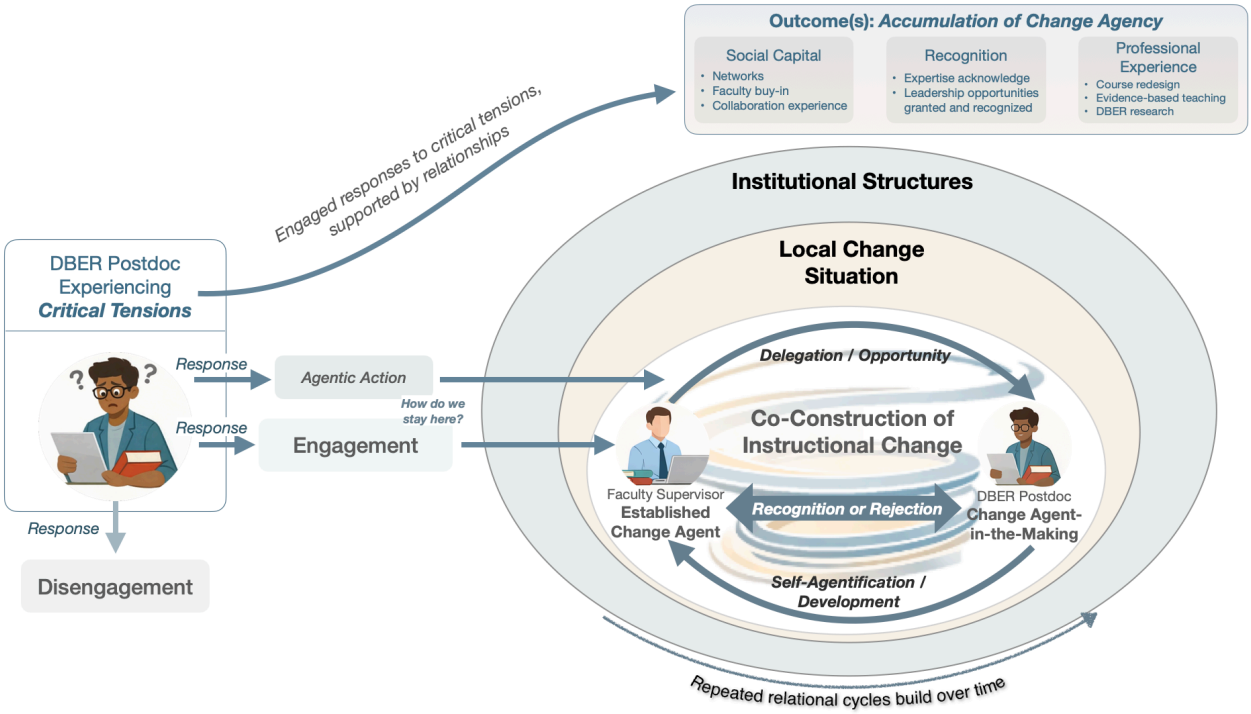

Figure 1: Relational emergence of DBER postdoc agency against structure and situation

V.B. Illustrative Example

To illustrate this framework, we presented a hypothetical postdoc's initial experiences in a composite vignette

(based on our research) at the beginning of this paper. We cannot provide empirical data yet (forthcoming), but the vignette finished below and the table after demonstrate data that could be used to examine relational agency dynamics and how.

Motivating vignette (hypothetical) continued: A DBER postdoc develops a new strategic perspective

We left off with Dr. Sam Rivera experiencing two different agentic trajectories, with increasing influence in one course (Dr. Chen's) and constrained action in the other (Dr. Patrick's). ***To understand what determined whether Dr. Rivera's early mismatch became engagement and learning, or frustration and withdrawal*****,** we share a final interesting piece from Sam's narrative that might be what pulls Sam back from full disengagement.

Later in their interview, Sam describes a conversation where a senior DBER faculty member helped them reframe the Dr. Patrick situation not as a personal failure, but as a normal feature of instructional change. Sam recounts their subsequent behavior – redirecting energy toward documenting student outcomes in the courses where buy-in existed, building an evidence base for future advocacy rather than continuing to push against resistance. By the end of the interview, Sam's describes attaining a clearer DBER research identity, a more realistic model of how instructional change works across agents in practice, and a sense that their contributions, while constrained in some contexts, were meaningful in others. This new strategic perspective seems to have enabled their strategic actions toward building a base for future work (and therefore sustained engagement instead of disengagement with the instructional change goals).

Table 1. **Identifying Critical Tensions and Relational Infrastructures in Practice**

What happened (vignette event)	Framework label (what this is an example of)
Sam enters a two-year DBER postdoc role supporting an active-learning redesign and realizes the role assumes education research methods and instructional change principles he has not yet developed.	Critical tension; mismatch between role demands/aspirations and preparation (P1)
First Collaboration	
Sam tells Dr. Chen they need help building those skills.	Self-agentification / help-seeking as a strategic move (P1–P3)
Dr. Chen connects Sam to a DBER working group.	Delegation and recognition; relational infrastructure (P3, P4)
In redesign meetings, Sam's suggestions shape decisions.	Joint action / distributed expertise; recognition granted (P2, P3)
Second Collaboration	
Dr. Patrick praises the proposals as "thoughtful" but does not adopt them.	Recognition withheld / rejection; constrained agency (P1, P2)
Third Faculty Interaction	
A third faculty member with DBER research background normalizes challenges with instructional change and faculty resistance	Productive feedback loops as relational infrastructure; strategic perspective shift; Critical tension mismatch between role demands/aspirations, motivating further preparation (P4, P1)

V.C. Implications of the Model for Postdoc Positions, PD Design, and Empirical Observability

Our conceptual model helps move literature on PD for emerging DBER scholars from a focus on individual professional agency toward impact [31] to a relational one. Strategic actions and perspectives gained through working *with others* expands our understanding of how "knowing how to know who" [32] in DBER plays a predominate role in agency and thus the broader impacts of the field on instructional change. These dynamics make it important for PD to foster "critical tensions" and "relational infrastructures" so postdocs are put in situations where they can co-construct with faculty and vie for recognition of agency within open structures. In practice, PD programs can present onboarding framing dual-role tensions as both expected and generative. Additionally, these programs can include cohort and cross-departmental communities that give postdocs relational support beyond supervisors. This proposed model can guide facilitated postdoc-supervisor conversations to surface expectation misalignments before they harden, as well as position scopes that formally include PD rather than leaving postdocs to pursue training on their own. Our framework also offers criteria for studying relational agency development empirically. Critical tensions are observable as *expressed mismatches between expected and actual role conditions,* identifiable in interview data through language of surprise, dissonance, or reconstruction of previous understanding, or in observations of mentorship or meetings where delegation and self-agentification unfold. Relational agency moves (delegation, self-agentification (strategic perspectives and actions), recognition, and rejection) can be coded attending to who initiates each move, under what conditions, and with what outcome(s) ((dis)engagement, group learning, change impact). Surveys could complement; longitudinal measures of perceived mentorship support and fit [75], belonging [76], and

professional agency [77] would allow researchers to track how dynamics shift across interactions and time.

VI. Limitations and Future Work

This paper reports a review of literature toward a framework, meaning we need additional stud(ies) to fully theorize how DBER postdoc professional agency emerges in relationships. Though the details need to be worked out, this illustration provides a necessarily limited example of how this work can happen and a first foundation to further theorize questions like *"how do DBER postdocs negotiate their professional agency in interactions with faculty?"* and *"how can DBER postdoc PD models support field-wide capacity for instructional change?"* We can unpack these questions by analyzing DBER postdoc and faculties' perceptions of relationship dynamics. By asking about situations of "critical tension" in collaborations towards instructional change based on DBER, we might better understand processes of delegation, agentification, recognition, rejection, and agency development toward mapping this complex process. Additionally, we recognize that our asset-based framing of tensions may make it appear we frame tensions as generative and developmental alone, ignoring the ways tensions can be structurally constrained or harmful. We adopted this framing because there is already a wealth of literature in our review that takes deficit perspectives, whereas research on DBER faculty suggests emerging scholars need to navigate tensions to build capacity to enact change based on research. To strike theoretical balance between our Between-Study's spaces, the illustrative examples we provide for our conceptual model in the Discussion section acknowledge both the productive potential and structural constraints of "critical tensions" in postdoc development. We also cite a wealth of literature discussing tensions leading to negative experiences in the coming sections.

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Appendix

Figure A1: Postdoc vs Faculty Listings Over Time (EERjobs and PERjobs combined) [5], [6]

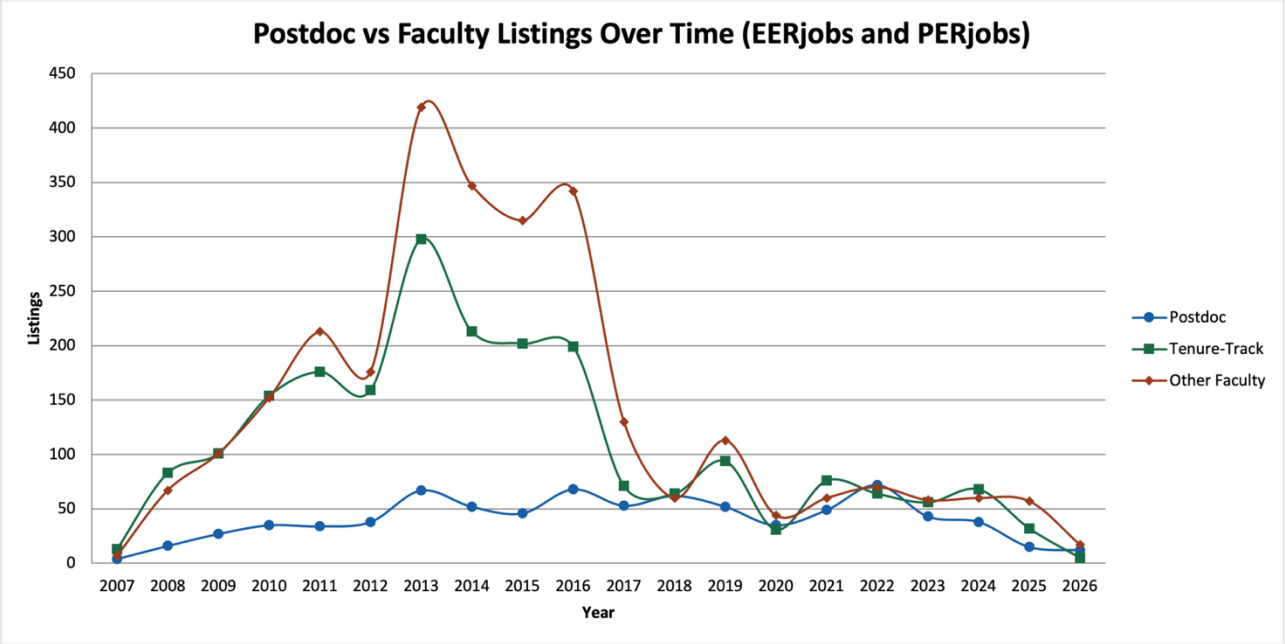

Figure A2: Total Listings by Type — Stacked (EERjobs and PERjobs combined) [5], [6]

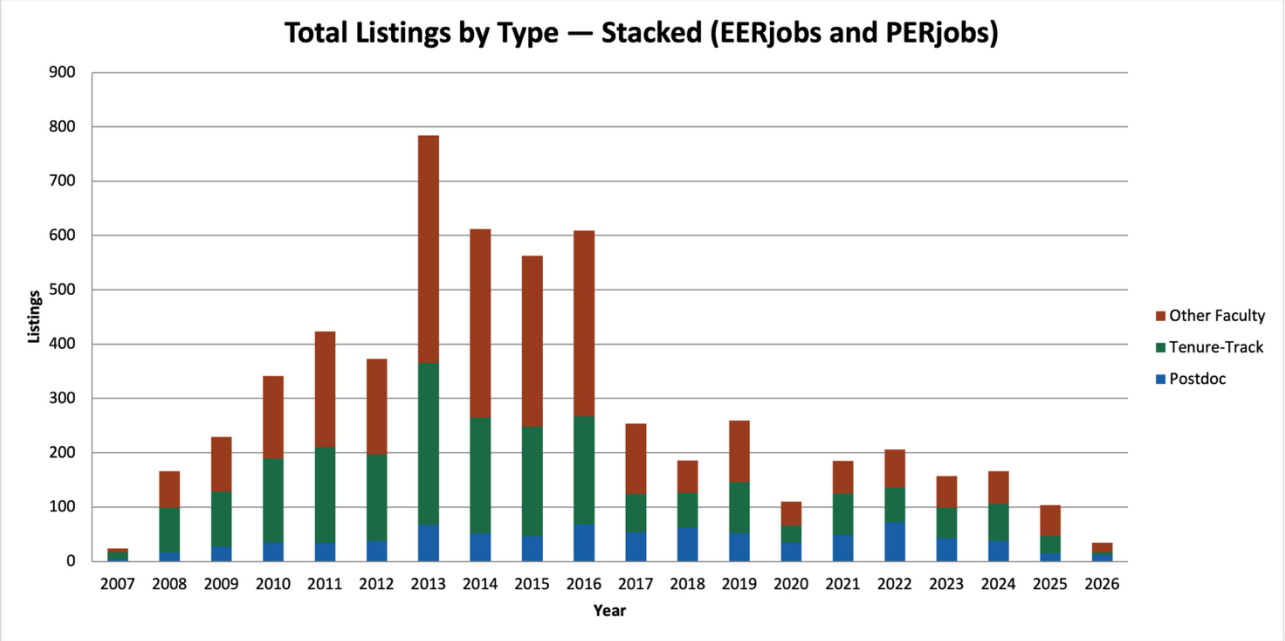

Table A1: Selected Representative Publications for Propositions

STEM Postdoc PD Literature	Emerging DBER Scholar PD Literature
Recognition of the active role STEM postdocs play as their social and professional capital develop together with the help of multiple mentors [18], [19], [20], [35], [56], [78]	Importance of networks, collaborative relationships, and community beyond the supervisor-DBER postdoc dyad [1], [11], [12], [13], [15], [16], [17], [36], [37], [62], [64], [66], [67], [79]
Importance of networks and collaborative relationships beyond the supervisor-STEM postdoc dyad [23], [53], [57], [58]	Recognition that DBER scholars' professional capital and social capital develop together [28], [65], [80]
Opportunities for co-constructional support (collaboration, idea-sharing) alongside informational and socio-emotional support [19], [22], [23], [52], [59], [60], [61], [78]	Opportunities for co-constructional support (collaboration, idea-sharing) alongside informational and socio-emotional support [7], [37], [54], [69], [70], [72], [81]
Balancing development and agency without overweighting either through a focus on postdocs' strengths [3], [23]	Balancing development and agency without overweighing either through a focus on postdocs' strengths [1], [7], [8], [54], [69], [70], [82]
Balancing development and agency without overweighting either through a focus on "critical tensions" encountered in systems of activities, roles, and relationships [3], [50]	Balancing development and agency without overweighting either through a focus on "critical tensions" encountered in systems of activities, roles, and relationships [11], [31], [55], [68], [73]
Balancing individual professional agency with relational professional agency toward impact (enabling simultaneously attendance to the goals of STEM postdocs, supervisors, and their objects of practice) [48], [78]	Balancing individual professional agency with relational professional agency toward impact (enabling simultaneously attendance to the goals of DBER postdocs, supervisors, and their objects of practice) [8], [10], [37], [72]