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# Work-in-Progress: A Grounded Theory of Interdisciplinary Identity Formation in Engineering Education

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## Motivations

Engineering education has a critical task of preparing future professionals with technical knowledge and skills in multiple domains that are necessary to solve society's complex, ill-defined problems [1]. In response to these needs, interdisciplinary engineering education has been expanding both at the undergraduate [2], [3] and (more recently) at the graduate level [4], [5]. However, faculty and higher education leaders are often charged with creating interdisciplinary structures for their work and their students' work on an *ad hoc* basis. This task is made more difficult by having an incomplete understanding of how interdisciplinary identities are developed and sustained. As we consider how to transform higher education to better prepare students for multi-, inter-, trans-disciplinary futures, we would benefit from better understanding how faculty identity works in the presence of the cultural and structural limitations of monodisciplinary programs.

Hence, this study develops a new framework for understanding the protective factors of developing and then sustaining an interdisciplinary professional identity for faculty within engineering education. This study uses a qualitative methodology for establishing new theoretical frameworks using empirical evidence – grounded theory. As a work-in-progress paper, we do not present a full grounded theory here; rather, we explore the first phase of its development and the benefits for fellow faculty developers and leaders in engineering education.

## Brief Review of the Literature

In grounded theory research, connections to the existing research literature are often parsed and mobilized after the new theoretical framework is established in analysis [6]. This serves the purpose of allowing the framework to emerge from the data, rather than being overly shaped by prior work. That said, we provide a brief review of the literature that is relevant to establishing the contributions of this study.

**The Rise of Interdisciplinary Engineering Programs.** Engineering education has become increasingly inter- and transdisciplinary to prepare students to cross disciplinary boundaries as they solve unique and complex problems of our increasingly dynamic world. This need for integration of expert knowledge from multiple fields has fueled the launch of inter-, trans-, and multidisciplinary programs in fields such as robotics [7], [8], neuroscience [9], [10], and engineering education [11]. Despite the rise of such programs, affiliated faculty still mainly reside in monodisciplinary departments; administering successful interdisciplinary programs requires that faculty navigate multiple departments with policies, procedures, and budget models that may conflict with each other and therefore impede the development of interdisciplinary students and successful program outcomes [12], [13].

**The Origins of Interdisciplinary Faculty.** Limited attention has been given to how faculty who are trained and exist within monodisciplinary structures develop and sustain their interdisciplinary identities. Previous research has explored the interdisciplinary identity formation of doctoral students [12], [14], [15], [16], [17], [18] and on undergraduate students [13] in a bid to better understand outcomes of emergent interdisciplinary programs. The literature on interdisciplinary faculty identities largely focuses on addressing effective identity-fostering teaching practices (e.g., [19]) and the decision-making processes of faculty who engage in interdisciplinary graduate education (e.g., [20]). In this study we explore how faculty with traditional STEM backgrounds develop interdisciplinary scholar and teacher identities. This analysis can inform strategies for fostering interdisciplinary identity among engineering educators in existing academic roles.

**Lessons for Research on Professional Identities.** Conceptualizing a professional identity as static is limiting. Although an individual's personality tends to be stable across time, professional identities are dynamic, with "constant negotiation-re-negotiation of past, present and future identity experiences, within the notion of identity-trajectory" [21]. Within such dynamics, barriers to the development of interdisciplinary identities arise from professional values communicated via social networks and reinforced within departmental structures [22], [23]. Interdisciplinary faculty face additional challenges and opportunities in the trajectory of their professional identities as they navigate multiple disciplinary identities [24], renegotiate them within their current context, and as they shape future experiences to further refine their identity.

## Methods

This study uses grounded theory, a qualitative methodology that is appropriate when there is not yet consensus on an adequate explanation for how a phenomenon occurs [25]. This approach allows researchers to develop a new conceptual model of the phenomenon in question based on the shared experiences, knowledge, and perceptions of people experiencing the phenomenon. The grounded theory in this study reflects the experiences of faculty who do research crossing disciplinary boundaries and who teach multidisciplinary courses and constructs a new framework for the processes involved in how they developed professional identities as faculty members.

**Data Collection.** We began data collection with three faculty members who meet two criteria: 1) their expertise is in an interdisciplinary STEM area (e.g., neuroscience), and 2) they have been successful in achieving major career milestones (e.g., tenure, teaching award). Interviews were conducted by Author C with Author B participating in two of the three. They lasted for half an hour to an hour and were audiorecorded with consent for transcription using Otter.ai.

The interviews were semi-structured and began with the same question: "How would you describe yourself as an academic? Do you introduce yourself as an [fill in the –ist from their primary departmental appointment] or as something else?" The next question asked was, "When did you start the interdisciplinary part of your work?" The interviewer then probed, as needed, for example to ask, "Tell me about your educational background and training" and "Who mentored or supported you in being interdisciplinary?" Much of the interview's focal topics were naturally introduced by the participant without specific probing.

Sampling in grounded theory involves theoretical sampling in multiple rounds based on emerging findings, rather than seeking to meet a certain threshold of participants. We have not yet reached saturation in our analyses for this study. We plan to conduct a second interview with the three participants whose data were analyzed for this work-in-progress paper, as well as expand beyond these three individuals, as appropriate, to reach saturation of our themes.

**Analysis Procedures.** Coding of data was conducted in a first round of open coding, using gerund codes to describe mechanisms of identity development and contextual codes to describe elements of faculty development environments. Author B and Author C coded the data in this phase with peer debriefing after each code was applied to build strong consensus on which codes were emerging from the data and to ensure interrater reliability moving forward. A second round of coding was then conducted with the final set of codes to apply them to the full dataset.

Axial coding was begun in a third round to form an initial framework for this paper. We plan to re-examine the framework and continue axial coding after we reach saturation in future rounds of data collection and analysis.

## Initial Findings

Our initial analysis identified three phases of interdisciplinary faculty identity development: (1) initiating an interdisciplinary focus, (2) developing an interdisciplinary academic portfolio, and (3) reinforcing an interdisciplinary identity long-term. These phases occurred within an environment that included pre-conditions for becoming interdisciplinary and both inducers and barriers for sustaining it that were navigated by participants over time (see Figure 1).

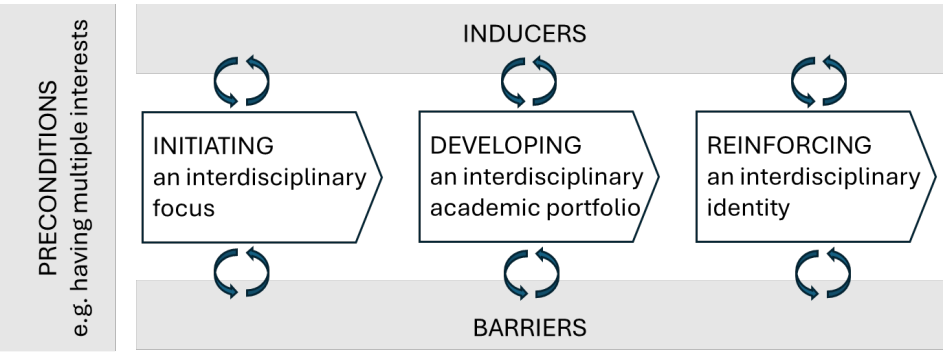


Figure 1. Interdisciplinary Faculty Identity Development Model

**Initiating an Interdisciplinary Focus.** Two of the scholars described real-world experiences as a major influence in initiating their interdisciplinary focus, though in two different ways. Christina noted that her work as a computer scientist initiated her into a field that is inherently interdisciplinary in that it involves solving real-world problems – which are, themselves, not bound to a single disciplinary way of working.

> The truth is that computer science, in essence, is just very interdisciplinary. It's very open to collaborations with people from other fields because computer science is all about

> writing computer programs...to kind of find algorithmic solutions to problems. And then you identify or find problems in the other fields [to solve].

She became interdisciplinary because her interests led her to become fluent with a set of tools for solving problems.

Jackson shared a similar initiation through real-world problems, though his were of a more personal nature.

> One of my favorite aunts from my village - I come from a very small village in India...and my aunt was the village cook. My aunt used to be this lovely person who used to go through vats of stuff, put this much amount of salt, this much amount of sugar in that sweet dish. And at the age of 37 she had early onset Alzheimer's and by 38 she was gone. So seeing a person so close to me...who could make a feast of 700 people without a doubt, now not knowing the difference between salt and sugar overnight...How's the brain doing it?...Oh my god, I really want to know what's happening to the brain here.

Similar to Christina, Jackson describes neuroscience as being inherently interdisciplinary. Though they both spoke about the relationship between their field being interdisciplinary and the nature of real-world problems, Jackson began with a real-world experience that moved him towards interdisciplinary study, whereas Christina's interdisciplinary studies led her to addressing real-world problems.

Also noted as initiating mechanisms were the experiences of asking big questions that move beyond disciplinary boundaries, connecting with mentors who encouraged interdisciplinarity, and interacting with structures that foregrounded interdisciplinarity at the beginning of their formal training.

**Developing an Interdisciplinary Academic Portfolio.** After describing the various ways they were initiated into interdisciplinary research, the participants spoke about why and how that interdisciplinary approach "stuck" as they continued their early careers. Two aspects of developing an interdisciplinary academic portfolio emerged across participants: (1) questioning disciplinary silos and (2) seeking out interdisciplinary spaces, projects, and people.

While all three participants spoke about how their graduate studies had been in interdisciplinary areas, Christina and Jackson have been founders of new interdisciplinary programs at WPI and Derrick was recruited due to the existence of two other interdisciplinary programs. As Derrick shared, "What drew me to [WPI was] the GPS program and the IQP, really. I didn't really know anything about WPI…And I saw this ad and was like, 'Wow – that's what I do. That kind of big problems.'" Questioning disciplinary silos is something each participant did as they were building their careers at WPI beginning pre-tenure.

Often, the participants described how these two mechanisms reinforced each other, particularly in their early careers. Christina told a vignette in which her department chair connected her pre-tenure to a research project at a local medical school that was looking for a computational partner. "My department head was the one who proposed that one," she shared. "But also there

were other senior faculty in my department [who encouraged me]…at that time, WPI was just, like, creating a lot of opportunities for people from different departments to come together and talk." Jackson, who joined the university several years after Christina, also describes how he sought out opportunities to engage in cross-disciplinary projects and opportunities early in his career – and was allowed to question disciplinary silos along the way.

**Reinforcing an Interdisciplinary Identity.** The mechanisms that have been involved in reinforcing an interdisciplinary identity are the least examined at this stage of our analysis. A few meaningful themes have emerged that will be further assessed with additional data. One is taking senior positions that value interdisciplinarity. Christina, who has moved into a "middle management" position within the university, spoke multiple times about how having some leadership capacity to further strengthen the opportunities for others to embrace interdisciplinary work has reinforced her own identity. For example, she says "that's why I introduced myself to a Provost who was interviewing here before he became the provost – like, showing we're very interdisciplinary here. We're proud of that." Being a fellow computer scientist, Christina's estimation of WPI held particular sway in this case.

Other themes within the reinforcing stage that have begun to emerge are navigating organic growth and intentional collaboration across disciplines and being rewarded for interdisciplinary research and teaching within the institution.

**Environmental Factors.** As we coded our data, we identified several environmental factors that supported and undermined the development of the faculty's identities becoming interdisciplinary, in turn. Preconditions existed for each of the three scholars as they each spoke about how they initially became interested in interdisciplinary work. One precondition was that each person talked about having a broad variety of interests, rather than a singular area. This curiosity set each scholar onto a path where they sought engagement with multiple disciplines to fulfill a natural instinct.

While engaging across disciplines, each scholar talked about how this created fertile ground for the development of interdisciplinary mindsets and approaches. Derrick described how *having multiple interests* led to interdisciplinary interests in part because of his ability to explore where they overlap. "I see in a lot of ways, interdisciplinarity, or transdisciplinarity, is just the recognition and interest in both approaching things from a broad perspective, but also the commonality that exists between the different perspectives." This exploration of the common ground among collaborators from different fields working on the same policy issues together became a thread that runs through Derrick's academic trajectory.

The economics behind various fields and the future of work are meaningful preconditions that influenced identity pathways of our participants – and is directly connected to the motivations for interdisciplinary programs increasing across higher education. Christina noted that the job market and financial viability of the interdisciplinary field to which she switched, computer science, was far more attractive than the prospects in her original area of study in applied mathematics. This external market force played a major role in her decision to move into more formal interdisciplinary roles and environments.

As we continue the next stage of coding, we will continue to identify inducers and barriers within the institutional environment that seem to influence interdisciplinary identity formation across the stages. For example, the extent to which interdisciplinary work is allowed to develop organically has begun to emerge as a condition that reinforces interdisciplinary identity work throughout the three phases.

**Discussion**

We are developing an emergent framework for the creation of interdisciplinary faculty identity to inform guidance for interdisciplinary education programs, centers for teaching and learning, and other academic leaders in higher education. For change agents within these units on higher education campuses to successfully attract faculty to teaching students across disciplinary boundaries, we need ways of planting seeds and nourishing that interdisciplinary identity. Relying on a framework already grounded in empirical data may provide more efficient and effective ways of accomplishing these goals.

**Implications for Research.** Our work transcends prior efforts to describe or improve interdisciplinary identity formation within STEM as we identified elements often overlooked in prior work (e.g., [26]), such as preconditions and inducers to identity formation. For instance, the work of Hancock and Walsh [27] summarized approaches to understanding developing professional STEM identities through graduate education and early professional experiences, such as "disciplinary knowledge + research skills + scientific norms = professional scientific identity" (p.40). While they identify shortcomings of existing identity formation models and propose reforms, they and other researchers often omit exploring individual characteristics that inform interest in interdisciplinary fields and that are the precursors to such an identity (e.g., Jackson's aunt, Christina's real-world problems). As we continue collecting data and refining our analyses, we have the opportunity to address this gap in the literature.

**Implications for Interdisciplinary Programs.** The resulting framework will have pragmatic implications beyond contributions to research. Exploring the function of individual characteristics and experiences may provide hooks for interdisciplinary programs to help faculty connect with students. For example, we already talk about the job prospects of interdisciplinary training with our students here at [redacted] and many faculty may do the same. Connecting that extrinsic motivation with the intrinsic motivation of satisfying multiple interests at once, as seen in our data as another precondition for developing interdisciplinary identities, might strengthen that bridge between faculty and students.

This framework might also serve as a resource for faculty in interdisciplinary programs charged with advising students about their futures. Whether students are considering a career in academia or not, exploring the ways that the generations before them have navigated interdisciplinary career paths can help students who do not fit into more traditional STEM fields feel seen and validated – something for which Generation Alpha has a heightened need for academic engagement and success.

**Implications for Faculty Development.** When completed, our framework will offer a theoretical foundation that explains the precursors, formation, reinforcement, and maintenance of

interdisciplinary STEM faculty identities grounded in empirical data. The framework will be a useful tool to faculty-focused structures in institutions with growing interdisciplinarity, providing scholars support in the formation, reinforcement, and trajectory of an interdisciplinary identity positions faculty for career success. Inter-, trans-, and multidisciplinary programs that can position these scholars as a new "normal" can provide innovations that solve complex global challenges, which are impossible to address utilizing a monodisciplinary lens [21].

In addition to supports for early career formation and professional development, referencing this framework might provide new ways of thinking about how to continue to nurture faculty mid-career into full professor status – areas that are too often ignored or under-resourced. Faculty who perhaps have begun their careers within more traditional monodiscipline departments may be interested in the kinds of opportunities that interdisciplinary development can provide after they receive tenure. The factors shaping the initiating and developing phases of identity development identified in this project might serve as rich ground for professional development programming, mentoring, and imagining alternatives to administration positions for continued growth for some faculty. Such identity support is necessarily long-term and must be personalized, respecting the agency of the individual [23] while acknowledging the precursors to their interdisciplinary identity, incorporating their inducers, and identifying their barriers. In sum, providing holistic support for interdisciplinary identities benefits faculty career success and creates broader pathways for solving the world's multifaceted and complex global issues.

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