2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION
Paper ID #50648

A Proposed Model for Sustaining Mentee-Mentor Relationships to Support Early Career Engineers' Transitions into Industry

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A Proposed Conceptual Model for Sustaining Mentee-Mentor Relationships to Support Early Career Engineers' Transitions into Industry

The transition from engineering education to industry presents significant challenges for early career engineers, including navigating professional expectations, accessing guidance, and developing the skills necessary for workplace success. Mentorship has been recognized as a critical mechanism to support this transition; however, structured approaches to sustaining mentee-mentor relationships during this transition remain limited. This paper proposes a model, grounded in theory, literature, and empirical data, for sustaining mentorship through early career transitions, informed by the perspectives of both mentees and their identified effective mentors.

Building on prior research emphasizing the value of cultivating a network of mentors who collaboratively guide career development, offer emotional support, and help mentees refine their professional goals [1]; this study also integrates recent scholarship underscoring the importance of mentoring cultures characterized by reciprocity, relational depth, and growth-fostering interactions [2]. Together, these perspectives point to mentorship as a dynamic and evolving process that extends beyond individual relationships to a broader mentoring culture.

This proposed model draws from established frameworks in mentorship, menteeship, and workforce development, including the Center for the Improvement of Mentored Experiences in Research (CIMER) mentoring competencies [3], [4], strategies for success for mentees [5], and the Workforce Sustainability Model [6]. Data for this study include interviews with 23 early career engineers or mentees (0–5 years of professional experience) and 8 of their identified effective mentors across engineering disciplines. These interviews were analyzed using inductive and deductive analysis to identify mentoring competencies, structural supports, and relational strategies that contribute to sustained and effective mentorship.

Findings from our qualitative analysis posit that effective mentorship extends beyond traditional top-down guidance to form an effective relationship characterized by reciprocity, personal support, social capital activation, and intentional relationship maintenance. Mentors emphasized the value of mentees' proactive engagement, while mentees highlighted the effectiveness of nuanced, goal-oriented mentoring approaches. Both groups underscored the importance of cultivating a community of mentors and establishing organizational or professional structures that provide resources and spaces to sustain effective mentoring. Based on these insights, this paper proposes a model emphasizing sustainable relationship building between mentors and mentees, integration of personal and professional support, and organizational structures that sustain mentoring relationships over time. The model identifies key components of effective mentorship across individual, relational, and institutional levels, highlighting its reciprocal nature and the need for research-informed practices that promote long-term sustainability.

This study contributes to engineering education and college-industry partnership literature by proposing a framework to sustain mentorship during early career transitions, encouraging dialogue on effective practices, evaluation of mentoring ecosystems, and clearer roles for mentors, mentees, and organizations.

Introduction

Mentorship has long been recognized as a critical mechanism for supporting early career engineers in successful transitions from engineering education to professional practice. Effective mentoring has been associated with increased professional skills, confidence, clearer career trajectories, skill development, and improved retention across engineering and STEM fields [7], [8], [9]. Mentorship can also be critical for learning the elements of engineering practice, as strong relationships with experienced engineers can support early career engineers' transitions into the engineering profession [10]. Despite this, much of the existing mentoring literature and practice emphasizes discrete programs or short-term, incremental relationships, often centering mentor behaviors while underemphasizing the relational, reciprocal, and sustained nature of effective mentorship. As a result, many mentoring relationships weaken or dissolve during key transition points, particularly as individuals move from academic environments into the engineering industry [10].

In response, recent scholarship has called for a shift away from conceptualizing mentorship as a one-sided or isolated relationship toward understanding it as part of a broader mentoring ecosystem that evolves over time and across contexts [11], [12]. This perspective foregrounds the role of mentoring cultures, networks of support, and shared responsibility among mentors, mentees, and organizations in sustaining meaningful mentoring relationships. Rather than relying solely on individual initiative, effective mentorship is increasingly understood as embedded within organizational and professional structures that enable continuity, reciprocity, and growth.

Within college–industry partnerships, there is a particular need for models that support sustained mentoring relationships spanning educational and professional engineering environments. Such models can help early career engineers navigate career transitions while simultaneously contributing to workforce resilience and sustainability. Addressing this need, this paper proposes a model for sustaining mentee–mentor relationships to support early career engineers' transitions into industry. Grounded in theory, prior literature, and empirical data from interviews with early career engineers and their identified effective mentors, the proposed model conceptualizes mentorship as a reciprocal, evolving relationship supported by individual behaviors, relational practices, and organizational structures. By centering both mentee and mentor perspectives, this work seeks to advance research and practice related to mentoring within college–industry partnerships and contribute to broader efforts to support early career engineers during critical career transitions. This study is situated within the broader context of college–industry partnerships aimed at strengthening the transition from higher education to professional

engineering practice. By examining mentoring relationships that often originate in college and extend into industry, this work highlights how structured and relational partnerships can support sustained professional development across institutional boundaries.

Background

Mentoring in Engineering

Mentorship can provide students with a wide range of benefits, including increased access to knowledge and resources, psychosocial support, career guidance, improved retention, a stronger sense of inclusion and belonging, and assistance in navigating systemic barriers [7], [13]. Relationships with mentors who share similar identities or experiences, or with whom mentees have developed a high level of trust, can further enhance outcomes by fostering greater empathy, support, and access to social capital [7], [14], [15]. While a substantial body of literature documents the benefits of mentorship and effective mentoring programs within engineering education [16], [17], and other research on career development and management offers insights on mentoring once individuals enter the workforce [18], far less is known about how to cultivate and sustain mentoring relationships during the critical transitional phase between school and professional practice [10], particularly from the combined perspectives of mentees, mentors, and institutions. Mentoring has long been proven to be important for engineering career development but often falls short of its potential without supportive culture and senior leadership engagement; providing education, structured programs, and aligning mentoring with broader organizational goals helps build sustainable relationships and enable lasting mentoring success [19].

While many companies offer formal mentoring programs for early career engineers, providing potential professional and developmental benefits, research indicates that assigned mentors may not always be the best fit; constraints such as limited time, mismatched pairing, or inadequate support can reduce the effectiveness of formal mentoring [7], [9], [11], [15]. Furthermore, not all mentoring assignments are equal, and the quality of the mentor-mentee relationship plays a critical role in determining outcomes [7], [11]. This study examines effective mentoring relationships through self-identified mentors and mentees, rather than assigned pairings. It aims to understand the practices of those mentors who most holistically and effectively support early career engineers as they transition from college into the engineering industry and navigate career changes during their first five years. The findings offer insights for college–industry partnerships seeking to identify and implement effective mentoring practices, based on evaluations from both mentors and mentees.

Evidence-Based Effective Mentorship Models: Insights from CIMER

The Center for the Improvement of Mentored Experiences in Research (CIMER) provides evidence-based models to enhance research mentoring relationships in academic settings. Their model of best practices encourages mentors to communicate mentoring plans clearly, align expectations, foster mentee independence, promote professional development, maintain effective communication, address inequities and inclusion, and use assessment tools to evaluate progress

[20]. CIMER emphasizes inclusive and culturally responsive mentorship, supporting awareness of diverse identities and backgrounds through activities such as cross-cultural experiences, seminars, and relevant literature [21]. Key practices include building trust, fostering safe spaces for open feedback, addressing communication differences, encouraging creativity, and reflecting on mentee input [3], [21]. Unlike informal mentoring approaches, CIMER integrates evidence-based strategies into their model of effective mentoring that support both personal and professional development and can be adapted across diverse contexts. While these practices were originally developed and tested in academic and research settings, their demonstrated effectiveness makes them a useful conceptual framework for analyzing qualitative data. In this study, we applied the CIMER framework as a lens through which to categorize and interpret our data, providing a structured approach to understanding mentoring practices and experiences. While originally designed for academic research mentoring, we adapt CIMER's evidence-based competencies as a practical conceptual framework to guide workplace mentoring for early-career engineers entering industry.

Effective Menteeship

Research out of CIMER also highlights intentional strategies that mentees can adopt to maximize the impact of mentoring relationships. These strategies include cultivating an entrepreneurial mindset, engaging in regular self-assessment, developing growth plans, and applying strategic planning to achieve high-quality mentoring outcomes [22]. In undergraduate research settings, additional studies have emphasized the importance of leadership-enabling competencies that support the professional development of engineering students. These include communication, networking, critical thinking, problem-solving, self-awareness, and responsibility, among others [23].

Another framework for effective menteeship is the "managing up" approach, which provides practical guidance for how mentees can proactively manage their mentor relationships [5], [24]. This approach identifies several key practices that adopt a corporate type of framework to provide strategies that contribute to mentee success, including:

1. **Preparing for Mentorship:**
    - Clarify your values, work style, and habits.
    - Identify knowledge and skill gaps in areas such as personal and professional development, academic guidance, research skills, or specific technical competencies.
    - Define goals for the short-term and long-term (e.g., 3 months, 1 year, 5 years).
2. **Identifying Mentors:**
    - Leverage existing connections and seek recommendations.
    - Be persistent and consider multiple mentors, including both junior and senior individuals.

- Look for mentors who are accessible, provide opportunities, encourage risk-taking, help mentees develop their own agenda, and have prior mentoring experience.

3. **Initial Meeting:**
    - Share your background, values, and needs, and acknowledge how the mentor has already supported you.
    - Show gratitude: send a thank-you note after the meeting to show appreciation.
4. **Cultivating the Mentor–Mentee Relationship:**
    - Establish clear structure and objectives for the relationship.
    - Plan meeting agendas in advance and schedule regular meetings.
    - Ask questions, actively listen, follow through on tasks, and request feedback.
    - Apply "managing up" strategies, including setting goals and expectations and taking ownership of the mentee's development.

By intentionally applying these strategies, mentees can build productive, meaningful mentoring relationships that support both professional growth and academic success [5].

While the literature on effective menteeship provides valuable guidance on how to view mentorship as a two-way relationship and how to be an effective mentee, much of this research is situated in formal academic or research settings. To capture the nuances of sustaining effective mentoring relationships as engineers transition from education into professional practice, it is necessary to follow engineers during this critical period. Doing so allows us to understand how they actively cultivate mentoring relationships and networks while navigating the shift from school to work or moving between organizations. In this study, we use these effective mentee strategies as an initial lens to guide the coding and categorization of our data on early-career engineers navigating transitions into the engineering industry, while still allowing nuances and additional strategies to emerge from the data.

Structural and Environmental Supports to Sustain Mentorship: Workforce Sustainability

Arguably, just as important as effective mentoring and mentee practices are organizational settings and systems that support sustained mentorship. Systemic barriers to mentorship can significantly limit early-career individuals' access to its benefits [21], [25], [26]. Therefore, it is critical to identify the practices, policies, and cultural norms that can help to sustain and enable mentoring relationships to thrive in the workplace.

The Workforce Sustainability Model, developed in 2019 for construction workplace settings, has also been validated and applied in construction, engineering, and other professional contexts [27], [28]. The model provides a framework for characterizing and evaluating the sustainability and inclusivity of a workforce. It identifies attributes that support long-term workforce effectiveness and well-being. As Gambatese et al. articulate, workforce sustainability involves

not only recruiting highly skilled individuals but also creating and maintaining an environment conducive to their professional growth and personal well-being.

The model encompasses key attributes, indicators, and metrics, including:

- **Nurturing:** the degree to which employees feel supported, encouraged, educated, and cared for as individuals.
- **Maturity**: the degree to which employees develop leadership competencies, responsibility, and accountability in their roles.
- **Connectivity:** the extent to which workers feel engaged, connected to others, and involved in decision-making.
- **Community:** the extent to which workers feel accepted, share commonalities, and experience camaraderie within their organization or industry.
- **Value:** the degree to which employees feel appreciated, recognized, and respected.
- **Diversity:** the extent to which the workplace is inclusive and representative of varied backgrounds.
- **Equity:** the degree to which employees feel fairly treated, evaluated, and compensated without discrimination.
- **Health and Well-being:** the level of safety, health, and satisfaction experienced in the workplace and career [6].

Within the attribute of nurturing, the model explicitly evaluates the effectiveness of organizational mentoring practices. For example, organizations that receive the highest rating for nurturing on the model, are those that implement a formal onboarding process, directly supervised by upper management and human resources, that includes a multi-week or multi-month mentorship plan tailored to the position [6].

Originally designed as a quantitative survey to assess a workplace's ability to sustain, retain, and support workers [6], this research repurposes the Workforce Sustainability Model as a qualitative lens for analyzing narrative data from early-career engineers and reflections from their mentors. Using the model in this way allows us to identify the critical attributes that enhance workplace environments, sustain the workforce, and support enduring mentoring relationships in engineering industry settings.

Positionality

In qualitative research, understanding emerges collaboratively through interactions between researchers and participants, with interpretations shaped by researchers' identities, backgrounds, and social contexts [29]. To enhance transparency, our team explicitly reflects on our positionalities and acknowledges how these perspectives may influence data collection, analysis, and interpretation.

The first author is a White woman and an early-career civil engineer with experience in engineering research two U.S.-based engineering industry positions. Frequently being the only, or one of the few, women on her engineering teams, she has a personal and professional commitment to understanding and improving the experiences of early-career engineers, especially those from underrepresented groups. Although her experiences of gendered isolation resonate with some participants' stories, she also acknowledges her privilege as a cisgender, straight, White woman, which means that some participant experiences may differ considerably from her own. To address this potential influence, she engaged in ongoing reflexive practices, including memoing and journaling, and sought guidance and feedback from the second author, other mentors, and lab members who share identities with participants. Deliberate efforts were made to create a safe and supportive environment that encouraged participants to discuss their most pressing concerns, fostering empathy and understanding during vulnerable moments [30]. Furthermore, her prior connections with many participants, through student organizations, work experiences, and friendships, helped build trust and rapport, which she believes supported more open and authentic story sharing during interviews.

The second author identifies as an African American woman, civil engineer, and workforce development scholar. She brings a professional lens informed by over 15 years of mentoring engineers through educational and career transitions. This experience sensitizes her to how early-career engineers leverage relationships, skills, and access to opportunity structures to navigate workplace norms and uncertainty. Her longstanding engagement in both engineering industry and academia informs an asset-based orientation to the research, with attention to the forms of capital early-career engineers mobilize. At the same time, she acknowledges that her mentoring and workforce development commitments may shape her attention in the data; accordingly, she prioritizes reflexivity and analytic transparency to ensure interpretations remain grounded in participants' accounts.

The third author identifies as an African American woman, engineer, and engineering education researcher. With ten years of engineering industry experience, she is attuned to how her industry experiences inform her perspective on mentoring and professional practice. As a researcher, she drew on her extensive work in mentoring within engineering and educational ecosystems to help inform the use of the CIMER model and the framing of our proposed model of sustaining mentoring.

Research Question

What factors enable early career engineers to sustain mentoring relationships across the transition into industry, including relationships begun during internships or college and those formed after hire?

Methodology

This research is part of a larger longitudinal narrative inquiry aimed at understanding the professional development and long-term retention of early-career engineers. The complete methodological framework is described in [30]. Drawing on asset-based approaches, this study focuses specifically on the knowledge, skills, strategies, and attitudes that early-career engineers and their mentors leverage to sustain effective mentoring relationships. A qualitative research design was employed to explore participants' experiences in depth and within the context of their sociocultural environments and to understand the perspectives of both the early career engineer mentees and their identified mentors. This approach allows for the collection and analysis of rich, descriptive data, capturing the meanings, perspectives, and practices of individuals as they operate within their professional settings [31], [32].

Data Collection

Data for this study were collected in two phases. In Phase 1, early career engineers were interviewed about how they learned to successfully navigate entry into engineering industry careers and what effective mentorship looked like from their perspective. In Phase 2, mentors identified by these early career engineers as particularly effective were recruited to participate in interviews reflecting on their mentoring practices, the actions mentees can take to help sustain and improve mentoring relationships, and the structural supports within the engineering industry that may enhance mentorship.

Following Institutional Review Board (IRB) approval from the first and second authors' institution, data were collected through semi-structured interviews that included a reflective journaling exercise. All data in this qualitative study were de-identified to protect participant information, and participants provided informed consent, with the option to withdraw at any time, in accordance with the IRB guidelines. For Phase 1, early career engineer participants were recruited through convenience sampling the personal and professional networks of the research team and snowball sampling of other participants recruited through the initial participants and participated in individual semi-structured interviews [30]. At the time of data collection, all early career participants were either working in engineering in the United States or actively navigating job transitions within the field. Eligibility was defined as being within 0–5 years post-graduation with a bachelor's degree in engineering. Participants represented multiple engineering disciplines and a range of identities across gender and race/ethnicity. Demographic information was not collected via a formal survey; instead, participants self-disclosed aspects of their identity during interviews if they chose to do so. Additional participant information is summarized in Table 1.

All interviews were conducted by the first author, with the second author present for one interview to support rapport-building and follow-up prompting. The first author, herself an early career engineer, disclosed her positionality to participants to foster trust and shared understanding. The interview protocol was intentionally designed to explore practices associated

with both effective mentorship and effective menteeship. At the conclusion of the Phase 1 interviews, early career engineer participants were asked to identify the mentoring practices that had been most helpful in their transition into the engineering industry and to identify or contact mentors they viewed as particularly effective for recruitment into Phase 2. The interview protocol included semi-structured questions with extensive follow-up prompts tailored to individual responses. Mentees were asked, for example, "*Can you identify a mentor (i.e., a person from anywhere in your life) that has been critical in supporting you as you navigate an early career in engineering? Would you be willing to share how you know them and potentially connect them with us [for phase 2]?*" and "*How has mentorship (formal or informal) influenced your career trajectory, and what qualities in a mentor have been most beneficial for your professional development?*" Mentors were asked, "*What strategies or approaches have you found most helpful in mentoring early career engineers?*" and "*Thinking back to the most impactful mentoring relationships you've been part of, what knowledge, skills, or personal qualities made the mentee most effective in that relationship? Can you share an example of how those qualities showed up in action?*" Both mentees and mentors were also asked, "*What aspects of your work environment make you feel valued and supported, and what changes would you like to see to enhance your ability to engage with mentors/mentees?*"

Phase 2 of data collection involved contacting the mentors identified by early career participants as most supportive in navigating their professional journeys. These mentors were not required to be within the participants' organizations or even within the engineering industry; rather, they were individuals the participants identified as effective mentors for early career engineers. Of the 23 mentors identified, eight agreed to participate and were successfully interviewed. We speculate that limited availability, senior professional roles, and organizational transitions contributed to challenges in scheduling interviews with additional mentors. Despite the smaller sample for phase 2, data saturation was reached within both the mentee and the mentor interview datasets.

Participants

All participant information was self-disclosed during the interviews. Table 1 aligns the early career engineers (mentees) with the mentors they identified as effective. As shown, some participants took part in two separate interviews, first as early career engineers, sharing their experiences, and later as an identified effective mentor of another participant, reflecting on effective mentoring practices. Mentors were self-identified by early career engineers based on individuals they perceived as critical to their professional development. The table presents the mentors we were able to contact and interview, with data collection continuing until thematic saturation was reached. As a result, not all early career engineers included in our findings have a corresponding mentor represented in the table. The table also indicates the context in which each mentor–mentee pair first connected (e.g., college, internship, professional organization, or workplace), providing insight into where these formative relationships originated.

Table 1. Participant Information

Early Career Engineer (Mentee) Pseudonym	Gender	Race	Position	Time in industry	Mentor Pseudonym	Gender	Race	Position / Relationship	Time in industry
Alice	Woman	White	Environmental Engineer	3 years					
Brittany	Woman	Black	Civil Engineer	3 years					
Cheryal	Woman	Black	Biomedical Engineer	3 years	**Mango**	Woman	Black	Algorithms Engineer – Internship Mentor	4 years
China	Woman	Black	Civil Engineer	2 years					
Clara	Woman	Black	Software Engineer	2 years	**Teal**	Man	Undisclosed	Software Engineer - Mentor through Professional Organization	4 years
Coffee	Woman	White	Biomedical Engineer	2.5 years					
Elle	Woman	White	Civil Engineer	3 years	**Soursop**	Man	Undisclosed	Civil Engineer -Mentor through Professional Organization	45 years
Grace	Woman	South Asian	Civil Engineer	2.5 years	**Ocean**	Man	White	Civil Engineer -Mentor through Professional Organization	25 years
Kasey	Woman	White	Aerospace Engineer	.25 years					
Kaylee	Woman	White	Aerospace Engineer	.25 years					
Kelsey	Woman	White	Civil Engineer	3 years	**Clementine**	Woman	White	Engineering Education Faculty – Undergraduate Research Mentor	6 years

Kim	Woman	Asian/ White	Aerospac e Engineer	4 years					
Mango	Woman	Black	Algorithm s Engineer	4 years	**Persim mon**	Woman	Undis-closed	Biomedical Engineer – Mentor through Professional Organization	5 years
Mary	Woman	Black	Biomedic al Engineer	1.3 years					
Persimmon	Woman	Undis closed	Biomedic al Engineer	5 years					
Sandy	Woman	Black	Civil Engineer	2.5 years					
Steve	Man	White/ Latino	Software Engineer	1.5 years	**Valerie**	Woman	Latina	Civil Engineer – Mentor through relationship established in undergraduate program	1.5 years
Strawberry	Woman	Black	Biomedic al Engineer	3 years					
Susan	Woman	Black/ Latina	Biomedic al Engineer	.75 years	**Coffee**	Woman	White	Biomedical Engineer – Mentor through company	2.5 years
Valerie	Woman	Latina	Civil Engineer	1.5 years					
Xavier	Man	Black	Software Engineer	2.25 years					

Data Analysis

The interview transcripts were analyzed using thematic analysis [30], [31], [32], [33]. This process involved multiple rounds of close reading to clean transcripts and develop familiarity with the data, alongside analytic memo writing [34] to capture emerging insights, reflections, and interpretations throughout the analysis. The data were coded using a combination of deductive and inductive approaches: deductive coding was guided by the CIMER model of effective mentoring, Zerzan et al., (2009)'s strategies for mentees, and the workforce sustainability model, while inductive coding allowed patterns and concepts to emerge directly from the data. Following initial and focused coding of the data, excerpts were systematically organized and

compared using a cutting-and-sorting approach to develop categories and a proposed model that addressed the study's research questions [32].

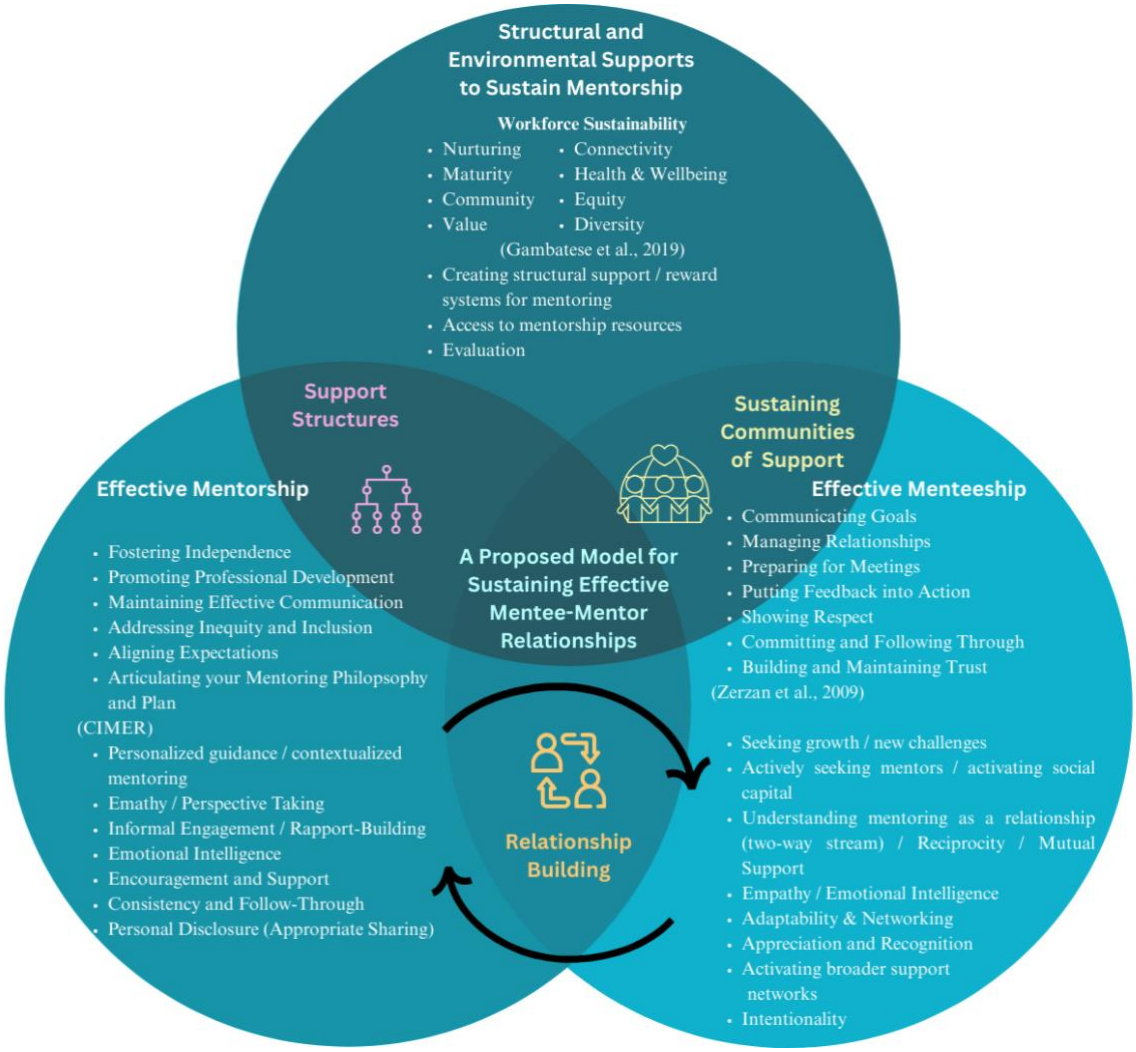
Data analysis occurred alongside data collection, enabling an iterative process in which interview prompts were refined and emerging codes and themes were shared with participants for clarification and deeper exploration. Data collection concluded upon reaching thematic saturation, when no new codes or themes appeared in the final three interviews and accompanying narratives [33]. To strengthen the trustworthiness and rigor of the findings, two participants with expertise in engineering education and qualitative research engaged in member-checking sessions [30], [35]. During these sessions, they reviewed and provided feedback on the emerging themes, conceptual model, and interpretations. Their input informed subsequent revisions to the model, themes, and implications [30], [35].

Findings

The following section presents the findings of this work in response to the guiding research question: **What factors enable early career engineers to sustain mentoring relationships across the transition into industry, including relationships begun during internships or college and those formed after hire?** The findings are organized into 3 major categories (i.e., effective mentorship, effective menteeship, and structural and environmental supports to sustain mentorship) and presented in Figure 1 as a model for Sustaining Mentee-Mentor Relationships.

Although each category presents distinct findings, it is important to emphasize that the model is conceptualized as a reciprocal and interconnected system necessary for sustaining effective mentoring relationships. In other words, the successful maintenance of mentoring relationships during early career engineers' transitions into industry requires the presence of all components: ***effective mentorship***, ***effective menteeship***, and the ***structural and environmental supports*** that enable mentorship to be sustained. These components do not operate in isolation; rather, they are mutually reinforcing and dynamically linked. Within this framework, mentoring is understood as a relational process that requires both advocacy and agency from mentors and mentees. Effective mentoring emerges not from unidirectional guidance, but from reciprocal engagement in which responsibility, learning, and support are shared. The findings further suggest that sustainable mentoring is best supported through multi-mentor ecosystems, where early career engineers draw on multiple mentoring relationships (e.g., mentors within their organization, past research mentors, family members, peers, mentors in professional organizations) and through environments that promote psychological safety, enabling open communication, trust, and growth for all participants.

Figure 1: A Proposed Conceptual Model for Sustaining Mentee-Mentor Relationships



Effective Mentorship

Effective mentorship encompassed all of the competencies outlined in the CIMER mentoring model, including fostering independence, promoting professional development, maintaining effective communication, addressing inequity and inclusion, aligning expectations, and articulating a clear mentoring philosophy and plan (CIMER). In addition to these established components, mentors identified as effective in this study described a set of relational and contextual strategies that were also emphasized by early career engineers.

These practices included providing personalized and context-specific guidance; demonstrating empathy and perspective-taking; engaging in informal interactions to build rapport; exercising emotional intelligence; offering consistent encouragement and support; following through on commitments; and engaging in appropriate personal disclosure. Together, these strategies

highlight the importance of mentoring approaches that are responsive to individual needs and grounded in trust, relational connection, and sustained engagement.

One early career participant, Steve, shared his experience transitioning into a new role after graduation and reflected on how much he "appreciated" the mentorship he received during this period, particularly as he relocated across the country. He described the transition as "significant", noting the importance of having "patient" and "supportive" mentors during the shift from college to professional practice:

> It was definitely a big move for me, a transition for sure. My family was very supportive of me. My significant other as well…they were very instrumental in getting me up to speed and like understanding that there is a learning curve to, going from college to working basically. So they're definitely very respectful [...] they're very supportive. And they still support me today"

Steve further emphasized the role of encouragement and psychological safety in his mentoring relationships, particularly the reassurance that he should feel comfortable asking questions and seeking help as he learned new systems, technologies, and professional practices:

> They [my most effective mentors] were very patient with me, encouraging me to know definitely not hesitate to ask questions, to help me understand better and to just learn the systems that I'm working with learn the new technologies, the new practices understanding that college doesn't teach you everything. So, they really encourage asking questions. … they keep in touch.

Steve identified his family members and his significant other, Valerie, another early career participant in this study, working in a different engineering discipline and approximately six months ahead of him in professional experience, as his most effective mentors during his transition into engineering practice. He reflected that, in addition to maintaining effective communication by "keeping in touch" and promoting professional development by encouraging him to "not hesitate to ask questions" and to "learn the systems that I'm working with learn like the new technologies, the new practices," his mentors provided substantial emotional support and encouragement. This included personal disclosure about how they navigated similar early career experiences, empathy grounded in having just been there, and reassurance that "understanding that college doesn't teach you everything" and experiencing a learning curve early in one's career is both normal and necessary.

Valerie, Steve's mentor, shared that mentorship is a core value guiding her professional practice, shaped by her own early experiences navigating engineering education without formal support as a first generation college student and engineer:

> At the beginning of my career, and as a student, I didn't have any mentorship. I didn't have anyone to look towards, I didn't have any knowledge of… I didn't have any knowledge of how the system works, of how universities work, how to apply for scholarships or anything like that. And when I actually got a mentor, and I… I knitted that together, and I started looking for mentors because of that. And when I got to a program that provided me with a mentorship. I just felt that that's exactly what I want to do. I want to help someone else. Don't go through that struggle. I know what it means to be in that position.

Valerie describes overcoming the obstacles of navigating engineering without a mentor and then realizing the benefits of mentorship as an asset she gained that made her more dedicated to her own mentorship practice and helped her develop empathy for others. She further reflected on her mentoring approach, emphasizing the importance of relational connection and sustained personal engagement. Valerie described intentionally cultivating long-term relationships with her mentees through regular check-ins and informal interactions:

> Personally, I just send them messages every now and then, see how they're doing, asking about their personal life, just making sure that they're okay. Yeah, I sometimes go out with them and just have a drink or eat something, just try not to make it so professional.

Similarly, another mentor, Persimmon, shared that personal relationships, and personalized and contextualized guidance were very important to her mentorship practice. Persimmon shared,

> Until you give them their first career opportunity, I don't know how they're supposed to do anything but school projects and school clubs and organizations. So I think that one of the biggest barriers right now is just maybe the mismatch between college expectation(s) within the classroom in an academic setting. Even in, like, a research lab type setting, I'm obviously saying compared to, like, industry of engineering, but my research lab was nothing like what my job is now, other than the theoretical practices of engineering. So I think that there's a missed opportunity in helping people identify pathways and opportunities for themselves, to, like gain a perspective of something that you've never seen, but unless I have a relationship with someone and they really are willing to open up and break down what they're feeling and what problems they're facing, it's hard to mentor to, like, a generic. Like, I really think mentorship is so much more impactful when it's for a person and the problems that they're facing, and so that's hard to do in a 45-minute coffee chat with someone that I met that day.

Another mentor, Soursop, echoed this perspective, emphasizing that personalized mentorship, specifically “just matching with the interest” of each mentee, is critical. They reflected that, despite having over 45 years of experience in engineering and management,

> Engineering's changing, I mean, it's changed a whole lot since I've been in school. Obviously, the technology now, everybody's talking about artificial intelligence, I just got a certification in that, I'm trying to keep up and make sure I understand what they're doing. So, for me, it's a challenge with, you know, trying to keep up with things that change so much, but…really just, helping them see the world outside of just what they studied. …

This mentor reflected on how rapidly engineering has evolved, particularly with the rise of new technologies such as artificial intelligence (AI), and describes the importance of putting in the effort required to stay current. They emphasize that effective mentoring involves not only keeping up with technical change, but also helping mentees broaden their perspective beyond their formal education and understand the wider professional and societal context of engineering practice.

The findings from this study indicate that while all components of the CIMER mentoring model are applicable within engineering industry settings, effective mentorship extends beyond these foundational practices. In particular, the data underscore the importance of providing personalized and context-specific guidance, demonstrating empathy, offering consistent encouragement and support, and engaging in appropriate personal disclosure by sharing one's own professional experiences. Together, these practices help early career engineers navigate the rapid pace of technological change and the broader realities of professional engineering work, supporting more sustainable and meaningful mentoring relationships.

Effective Menteeship

Effective menteeship in this study encompassed many of the components of Zerzan et al., (2009)'s strategies for mentees, including communicating goals, showing respect, and managing relationships. In addition to these strategies, our mentees and mentors reflected that being an effective mentee also entailed, taking action on advice provided, building and activating their mentoring network, seeking growth opportunities, and being intentional and empathetic.

Persimmon, an identified effective mentor, reflected that her own mentors shaped her understanding of the importance of acting on guidance and actively seeking opportunities for growth and challenge. She shared that taking action on her mentors' advice ultimately propelled her into a more senior leadership role where she was able to mentor others:

> I was working on projects that I had already done something similar to before, and so staying stagnant while it feels comfortable is not necessarily the best thing for your career. And it was her mentorship that kind of pushed me to look for a new role.

While mentors emphasized the importance of acting on guidance and support, early career engineers also described the active role they played as mentees in shaping these relationships. In particular, participants highlighted intentional relationship-building as a key strategy for developing professional and social capital. An early career engineer participant Sandy, actively reflected on how being intentional at cultivating relationships as mentee helped to build her career and social capital when she shared,

> Within work, we are encouraged to kind of get those informal mentors seek out mentorship […] being an early career engineer was making sure that I was connecting with people in my office and in my company that had shared identity. So if I saw, like a senior partner who was Black woman like I would reach out to them, or just like a woman like a senior partner who was a woman. So that's kind of how I was activating at that point like me. Making more connections. So that was me seeking them out. And then not it's kind of what I mentioned, like making sure I keep on checking in with them, and they check in on me, because, you know, that's a part of the Mentor Mentee relationship. And that's kind of how I've approached mentorship in the workplace. And then outside of the workplace […]

Sandy reflected that being intentional in seeking out mentors, particularly those who could help her navigate specific challenges or with whom she shared aspects of identity, was critical. She further emphasized that, beyond initiating conversations with potential mentors, she made a deliberate effort to cultivate ongoing relationships by checking in regularly and approaching these connections with intentionality, compassion, and consistency. Sandy went on to elaborate on specific strategies she engaged in to cultivate successful mentoring relationships as a mentee:

> Making an effort to increase my social capital within work and making sure I am harboring those mentor relationships and continuing to pour into the mentor relationships that I built during my internship. So checking in with my mentors, maybe informal mentors, maybe some lunches, coffee stuff like that to keep up those relationships and strengthen them as I move throughout my career, because the advice that they gave me when I was an intern will be very different from the advice they give me now as I'm transitioning to a more experienced engineer […] I do think it's important to keep on cultivating the relationships that I made within college. […] during college I relied on my girlfriends a lot for support and also advice. And even if we weren't all in the same going through the same curriculum. That was an important part of me, persisting because of social capital and also just like support systems are really important. So that has been a big thing in college and outside of college. Now I like still keep up with all my college friends and my family to my parents, played a big role and still do in creating like an a supportive environment, especially when work can get stressful or when school got stressful. they all played a big part in kind of getting me where I am today. And the

> activation. I kind of briefly mentioned within work It's me like seeking out mentors, but also strengthening those connections throughout my career, regardless of workload, and whatever else I have going on. I think it's very good to prioritize that still and then, outside of work activating with my friends, I feel like last year, and this year I've been traveling a lot just to see my friends, because we're all in different places now. So like intentionally making plans, keeping up, checking in, facetiming, going to visit them, them visiting me. That has all kind of kept me calm and more balanced, with everything going on at work. and then family same sort of thing like checking in. Yeah, making sure that I'm checking in with the people that I care about and that are in my community.

Sandy reflected on the value of "pouring into mentoring relationships," both those she experienced in the past and those she actively maintains in the present. She described the importance of "checking in" and continually cultivating the connections she established during college, reflecting on who is in her social network and the support they provide. Sandy emphasized the significance of sisterhood, as well as the guidance and encouragement she receives from her girlfriend's, family, and peers, in helping her navigate her engineering career. While acknowledging the stress and heavy workload common in engineering, she stressed that making time for mentoring relationships is always worthwhile. By investing in her mentoring network and broader community, Sandy gains knowledge, calmness, and balance despite workplace pressures, and she deeply understands the necessity of continually nurturing these relationships to thrive in the engineering industry.

From the data we found that effective menteeship is an active, intentional, and relational process in which early career engineers take ownership of their professional growth while engaging reciprocally with mentors. It involves seeking out mentors who can provide guidance on specific challenges, building connections with individuals who share aspects of identity or professional experience, and consistently cultivating those relationships through regular communication, reflection, and follow-through. Beyond professional skill development, effective menteeship emphasizes emotional intelligence, empathy, and relational care, recognizing that mentorship is not one-directional but a shared, mutually reinforcing process. By intentionally investing in their mentoring networks and communities, mentees gain not only knowledge and career guidance but also support, balance, and resilience, all of which are essential for thriving in the complex and evolving engineering industry.

Structural and Environmental Supports to Sustain Mentorship

Structural and environmental supports that participants reflected on in this study to help sustain mentorship encompassed all of the components of the Workforce Sustainability Model. Most notably, nurturing, connectivity, and maturity provided the foundational supports for effective mentoring to occur within organizations. In addition to these attributes, our mentees and mentors

reflected that access to mentoring training and resources, formal rewards and systems in place that encouraged and valued mentorship, and evaluation of mentorship and mentorship programs as strategies that might help to promote more impactful mentorship to occur from an organizational perspective.

Ocean reflected that, while he feels an intrinsic motivation to mentor others at this stage of his career, formal programs that provide the resources, time, and training to do so have been incredibly impactful. His organization offers opportunities to mentor early career engineers through success coaching, and he also engages in mentoring through his professional organizations. Ocean shared,

> When you talk about mentorship, I do believe that it's our responsibility as we get further along in our career. I mean, I'm not ready to retire yet, but I'm on the closer side of that, and I do believe that we have to give back to the profession, and we have to encourage and motivate and inspire the next generation of engineers, and that's how I got involved, sort of, in mentoring programs.

While Ocean and many other participants spoke positively about the impact of formal mentoring programs within their engineering organizations and professional associations, others suggested that institutional support could be strengthened by more explicitly valuing and rewarding mentorship. They emphasized that moving beyond statements of support to actually allocating resources, providing structured programs, and implementing evaluation mechanisms could further enhance the effectiveness and sustainability of mentoring initiatives. Clementine, an engineering education faculty member and identified effective mentor of early career engineers, shared,

> Maybe having that [mentoring evaluation] kind of built into either our… our expectation or, reward system, so that it's not just…like, are you a good researcher, are you a good teacher, but have you been, you know, effective as a supervisor or mentor? Have you taken on, kind of, the capacity building or professional development to do that? Because I think it's always a matter of, you know, access to that resource, and then access to the time to do it. And if it's not something that seems really rewarded or valued, but rather just something that's kind of an assumed responsibility, then I think there's always going to be less engagement in it. Whereas if it's something that is seen as really valued, and there's kind of engaging opportunities to develop that, then I think that can be more impactful. I think particularly when you're navigating a transition or an uncertainty is knowing where you can go to get, kind of, resources and guidance. But that, I think, in and of itself is… is a skill, because then you need to be able to communicate your needs effectively. You need to, kind of have the self-awareness to know where those… where those gaps are. You need to kind of have that interpersonal connection of just reaching

> out to somebody and, you know, explaining what you're hoping to get out of the exchange. And so I think those are very crucial skills.

Here Clementine emphasizes that mentorship should be formally recognized and rewarded within institutions, rather than treated as an assumed responsibility. Effective mentoring requires access to resources, time, and training, and institutional support can increase engagement and impact. They also highlight that navigating mentoring relationships, knowing where to seek guidance, communicating needs clearly, and building connections, is a critical skill for both mentors and mentees, particularly during transitions or periods of uncertainty.

This third and final component of the model, Structural and Environmental Supports to Sustain Mentorship, highlights that effective and sustainable mentorship requires more than just mentees and mentors putting in the effort or organizations valuing mentorship in principle. For engineering organizations, institutions, and broader economies to fully benefit from mentoring, structural changes are essential. These include implementing metrics and evaluation, providing training, allocating resources and time, and offering ongoing institutional support, practices that ensure mentorship can be meaningful, impactful, and sustained over time.

Limitations and Future Work

This study developed a conceptual model using qualitative data from interviews with 23 early career engineers (0–5 years of experience) and 8 mentors identified by participants as effective. Because mentors were nominated based on perceived effectiveness and agreed to participate, the model may foreground sustaining conditions and adaptive practices associated with positive mentoring and may underrepresent dynamics that contribute to misalignment, stalled relationships, or mentoring loss. Our dyadic focus provides depth on focal mentor–mentee ties, but it may not fully capture the mentoring portfolios and networked supports many engineers draw upon during transition. In addition, protecting confidentiality by not identifying organizations limits our ability to connect model pathways to specific organizational structures, policies, and onboarding contexts that likely shape mentoring opportunities and constraints. Finally, interview accounts emphasize participants' meaning-making and may not capture interaction-level practices that could be observed through complementary methods.

While we acknowledge that our sample overrepresented women, the purpose of qualitative research is not to produce statistically generalizable findings, nor was this study designed to examine gender differences. Participation was open to all who chose to respond to recruitment calls and recommendations for mentors, and the resulting demographics reflect those who opted to participate; we did not engage in selective sampling to examine gender. That said, across participants, mentoring practices and relational dynamics appeared largely similar regardless of gender in this study. While examining gender differences was beyond the scope of the present study, future research might explicitly explore how mentoring experiences and relational

dynamics vary across gender, identity, and other demographic dimensions to further enrich understanding of mentoring practices in engineering contexts.

The proposed conceptual model produced in this study should be interpreted as a theory-informed framework introduced by the authors that synthesizes existing literature and empirical findings to explain relationships among key constructs, and is offered as a foundation for future testing, refinement, or application. Future work should test and refine the model's boundary conditions by sampling cases in which mentoring was unavailable, difficult to sustain, or perceived as ineffective. Future work could explicitly focus on validating this model within structured college–industry partnership programs, systematically evaluating its effectiveness and scalability. Insights from these efforts will help establish best practices for creating durable and adaptable mentorship frameworks that seamlessly bridge academic and professional environments. Longitudinal designs that follow engineers from internships and entry into full-time roles through the early career period can illuminate turning points, renegotiations, and relationship evolution over time. Network-oriented approaches can document mentoring portfolios and differentiate functions across multiple mentors and sponsors. Even when organizations cannot be named, studies can categorize contextual features (for example, sector, firm size, remote/hybrid status, formal mentoring availability) to examine how pathways vary by setting. Finally, mixed-methods or quantitative research can operationalize model constructs into measures and support the design and evaluation of low-burden interventions that strengthen mentoring continuity and foster new mentoring relationships after hire.

Discussion

This research extends prior work on effective mentoring by integrating insights on effective menteeship and structural supports for mentorship, building on the CIMER mentoring competencies [3], [4] and the Workforce Sustainability Model [6]. While previous research has largely focused on the mentor's role in fostering mentee development, our findings highlight that sustaining effective mentoring relationships is a reciprocal and dynamic process, in which both mentors and mentees actively contribute.

This work aligns with recent calls to focus on strategies for effective mentorship, emphasizing the relational nature of mentoring, the importance of training mentors, assessing mentorship outcomes, and cultivating a mentoring culture [2].

Our study also extends the literature on effective menteeship, offering explicit strategies for early career engineers to maintain and leverage mentoring relationships during transitional phases, such as the move from school to professional practice [5]. These strategies include intentionally seeking mentors, engaging in ongoing communication, and reflecting on one's professional and personal needs. By emphasizing mentee agency, our findings highlight that mentees are not passive recipients but active participants who can sustain and enhance mentoring relationships.

Another key contribution of this work is the importance of clarification of the construct of nurturing within the Workforce Sustainability Model [6]. Nurturing does not imply that all mentors must act as friends or bear sole responsibility for relationship maintenance. Rather, nurturing can take the form of providing psychological safety, empathy, and consistent support, and it is most effective when it is reciprocal. This reframing emphasizes that both mentors and mentees exercise agency and advocacy, actively shaping mentoring relationships in ways that support professional growth, confidence, and resilience.

Importantly, while individual constructs, such as effective mentorship, effective menteeship, and structural supports, are critical, our findings demonstrate that the interplay among all components is essential for sustaining mentorship and preparing early career engineers to navigate professional challenges. Mentoring relationships are most impactful when they exist within broader mentoring ecosystems, where multiple mentors, peers, and organizational supports collectively foster growth and development. This aligns with research on mentoring networks and ecosystems [11], [36], [37] and the Learning Partnership Model [38], which underscore that both mentors and mentees engage in reciprocal learning, with each contributing to knowledge, skills, and professional identity development.

Our findings emphasize the importance of having mentors and sustaining relationships, particularly through the transition from college to industry. This aligns with evidence that collaborative mentoring, actively involving both mentors and mentees, produces better outcomes than top-down programs. Effective mentoring requires time, patience, and effort, and is far more valuable than formal programs that lack relevance to participants or the organization [19].

Findings from this study align with existing literature demonstrating that having a network of mentors can help sustain and support individuals during career transitions. Mentoring circles, for example, have been found to provide substantial support for women at every career stage [26]. However, prior research also highlights that mentors themselves, who are often leaders in their fields, can be stretched thin and at risk for burnout [1]. This may have been reflected in our study, where several identified mentors were unable to participate in interviews due to time constraints. Mentorship is typically viewed as a volunteer activity that extends beyond formal job requirements [1]. In engineering, where professionals are already often stretched thin, this can exacerbate workload and stress. Organizations should therefore consider structural supports, such as allocating time or adjusting workloads, to enable mentorship while mitigating burnout. Recognizing mentorship as real labor, rather than invisible labor, underscores the significant value mentors contribute, particularly to the development of early-career engineers. In order to reap the multitude of benefits from mentorship, organizations must invest not only in developing and sustaining early-career engineers but also in supporting the mentors who guide them.

Overall, this work contributes novel insights into mentoring dynamics by identifying a model of mentoring relationships that emphasizes reciprocity, nurturing, and multi-level supports. By

highlighting the agency of both mentors and mentees, the study provides a framework for designing mentoring programs and institutional policies that not only support individual growth but also strengthen the broader engineering workforce and prepare early career engineers for sustainable professional success.

College-Industry Partnerships

Students often encounter impactful mentors during college through personal connections, internships, or participation in student and professional organizations. In this study, the mentors identified as most effective were largely those relationships established during college that extended into students' early careers. This underscores the importance of sustaining mentoring relationships beyond college, helping to prevent a gap in support as students transition into industry. The conceptual model we present is designed as a flexible partnership framework that can be implemented across the continuum from college to industry, explicitly supporting the maintenance of mentoring relationships during this critical transitional phase which is critical to early career persistence and success in engineering [10], [11], [12].

Implications

This study highlights several important implications for college–industry partnerships aiming to strengthen mentorship programs for early career engineers. First, organizations should develop professional development programs and support structures specifically for mentors. Providing mentors with training, resources, and allocated time not only enhances their ability to guide mentees effectively but also helps mitigate the risk of burnout and acknowledges mentorship as valuable labor.

Second, both mentors and mentees benefit from education around roles, assumptions, and boundaries. Clear guidance can reduce role confusion and prevent the projection of expectations onto others, fostering healthier and more productive mentoring relationships. Reflection exercises and structured guidance can further support participants in navigating these dynamics, ensuring alignment between individual goals and program objectives.

Third, the model presented in this study can serve as a practical guide for implementing mentoring programs in college–industry partnerships. By using this framework, organizations can standardize mentoring practices, track and evaluate outcomes, and provide evidence-based support for both mentors and mentees. It is important to highlight that many of these mentors engaged through hybrid structures, including virtual mentoring, structured touchpoints, and phone or Zoom meetings. These approaches proved effective for maintaining meaningful connections even as mentees relocated to pursue engineering careers. Notably, the model does not rely on the continuous physical presence of industry mentors as this can be limited especially in this transitional phase; instead, it emphasizes sustained relational structures that support long-term professional development and growth.

Finally, college–industry partnerships should view mentorship as a strategic investment rather than a voluntary add-on. By integrating mentorship into professional development pathways, recognizing the contributions of mentors, and providing structured support, these partnerships can strengthen talent pipelines, enhance workforce readiness, and create sustainable networks that benefit both students and industry professionals.

Conclusion

This study presents a model for sustaining mentee-mentor relationships that supports early-career engineers as they transition into industry. By integrating individual, relational, and organizational strategies, the model highlights the reciprocal and evolving nature of mentorship, emphasizing both personal and professional support. Findings underscore the importance of cultivating mentoring communities, clarifying roles, and providing structural resources to sustain effective relationships. Ultimately, this framework offers a practical guide for engineering programs, professional organizations, and college–industry partnerships to strengthen mentorship, enhance workforce readiness, and foster long-term career development for early-career engineers.

Acknowledgments

We would like to gratefully acknowledge the contributions of our participants in interviews. This work was supported by the National Science Foundation under Grant no. 2429274. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

[1] R. Gotian, "Why you need a support team.," *Nature*, vol. 568, no. 7752, pp. 425–427, Apr. 2019.
[2] W. B. Johnson, S. Long, D. G. Smith, and K. A. Griffin, "Creating a mentoring culture in graduate training programs," *Training and Education in Professional Psychology*, vol. 17, no. 1, pp. 63–70, 2023, doi: 10.1037/tep0000404.
[3] A. E. Greenberg, "Entering Mentoring: A Mentor Training Seminar for REU Mentors," in *Best Practices for Chemistry REU Programs*, vol. 1295, 0 vols., in ACS Symposium Series, no. 1295, vol. 1295. , American Chemical Society, 2018, pp. 121–137. doi: 10.1021/bk-2018-1295.ch009.
[4] "Mentor Curricula and Training: Entering Mentoring – CIMER." Accessed: Apr. 10, 2024. [Online]. Available: https://cimerproject.org/entering-mentoring/
[5] J. T. Zerzan, R. Hess, E. Schur, R. S. Phillips, and N. Rigotti, "Making the most of mentors: a guide for mentees," *Acad Med*, vol. 84, no. 1, pp. 140–144, Jan. 2009, doi: 10.1097/ACM.0b013e3181906e8f.
[6] J. Gambatese, A. Karakhan, and D. Simmons, "Workforce Sustainability Report," *CPWR-The Center for Construction Research and Training*, Jan. 2019.
[7] A. Ilumoka, I. Milanovic, and N. Grant, "An Effective Industry-Based Mentoring Approach for the Recruitment of Women and Minorities in Engineering," *Journal of STEM*

Education: Innovations and Research, vol. 18, no. 3, Art. no. 3, Oct. 2017, Accessed: Nov. 20, 2020. [Online]. Available: https://www.jstem.org/jstem/index.php/JSTEM/article/view/2102

[8] G. W. Ivey and K. E. Dupré, "Workplace Mentorship: A Critical Review," *Journal of Career Development*, p. 0894845320957737, Sep. 2020, doi: 10.1177/0894845320957737.

[9] E. S. Volpe, D. R. Simmons, J.-L. Mondisa, and S. Rojas, "Effective mentoring strategies to support underrepresented students during a virtual summer research experience for engineering education undergraduates," *International Journal of Mentoring and Coaching in Education*, vol. ahead-of-print, no. ahead-of-print, Jan. 2024, doi: 10.1108/IJMCE-09-2023-0089.

[10] J. Trevelyan, "Transitioning to engineering practice," *European Journal of Engineering Education*, vol. 44, no. 6, pp. 821–837, Nov. 2019, doi: 10.1080/03043797.2019.1681631.

[11] J.-L. Mondisa, B. W.-L. Packard, and B. L. Montgomery, "Understanding what STEM mentoring ecosystems need to thrive: A STEM-ME framework," *Mentoring & Tutoring: Partnership in Learning*, vol. 29, no. 1, Art. no. 1, Jan. 2021, doi: 10.1080/13611267.2021.1899588.

[12] B. L. Montgomery, J.-L. Mondisa, and B. W.-L. Packard, "Promoting the cultivation and sustainability of mentoring ecosystems: results from a multi-institutional study," *Mentoring & Tutoring: Partnership in Learning*, vol. 32, no. 5, pp. 596–617, Oct. 2024, doi: 10.1080/13611267.2024.2389051.

[13] D. Jeske and C. Linehan, "Mentoring and skill development in e-Internships," *Journal of Work-Applied Management*, vol. 12, no. 2, Art. no. 2, Jan. 2020, doi: 10.1108/JWAM-09-2019-0028.

[14] J. P. Martin, P. Jensen, and * D. Suresh, "Perceptions of shared experiences in mentoring relationships: A collaborative autoethnography," *2022 ASEE Annual Conference & Exposition*, Jun. 2022, Accessed: May 25, 2023. [Online]. Available: https://par.nsf.gov/biblio/10345583-perceptions-shared-experiences-mentoring-relationships-collaborative-autoethnography

[15] J.-L. Mondisa, "The Role of Social Capital in African American STEM Mentoring Relationships," *JWM*, vol. 26, no. 2, Art. no. 2, 2020, doi: 10.1615/JWomenMinorScienEng.2020022267.

[16] A. Tuladhar, C. Queener, J. L. Mondisa, and C. Okwudire, "Informal community spaces, mentoring and representation: unpacking factors that influence African American engineering undergraduates," *International Journal of Mentoring and Coaching in Education*, vol. ahead-of-print, Jun. 2021, doi: 10.1108/IJMCE-06-2020-0032.

[17] V. Washington and J.-L. Mondisa, "A need for engagement opportunities and personal connections: Understanding the social community outcomes of engineering undergraduates in a mentoring program," *Journal of Engineering Education*, vol. 110, no. 4, pp. 902–924, 2021, doi: 10.1002/jee.20422.

[18] E. Volpe, D. R. Simmons, and M. Polmear, "Balancing what Drains and Sustains: Factors Influencing Early-Career Women's Persistence in STEM Fields," *Journal of Career Development*, vol. 52, no. 5, pp. 563–579, Oct. 2025, doi: 10.1177/08948453251363225.

[19] K. Kram, "Improving the Mentoring Process.," *Training and Development Journal*, 1985.

[20] "CIMER – Center for the Improvement of Mentored Experience in Research." Accessed: Dec. 28, 2022. [Online]. Available: https://cimerproject.org/

[21] V. Y. Womack *et al.*, "Culturally aware mentorship: Lasting impacts of a novel intervention on academic administrators and faculty," *PLOS ONE*, vol. 15, no. 8, Art. no. 8, Aug. 2020, doi: 10.1371/journal.pone.0236983.
[22] A. M. Rynearson and C. A. Pantoia, "Mentoring Undergraduate Researchers Through Entrepreneurial Mindset," in *2023 IEEE Frontiers in Education Conference (FIE)*, College Station, TX, USA: IEEE, Oct. 2023, pp. 1–5. doi: 10.1109/FIE58773.2023.10343323.
[23] E. S. Volpe, D. R. Simmons, J.-L. Mondisa, and S. Rojas, "Effective mentoring strategies to support underrepresented students during a virtual summer research experience for engineering education undergraduates," *International Journal of Mentoring and Coaching in Education*, vol. ahead-of-print, no. ahead-of-print, Jan. 2024, doi: 10.1108/IJMCE-09-2023-0089.
[24] H. Adams, "Mentoring for Professional Development: Mentor/Protégé Orientation Handbook." HG Adams & Associates., 1998.
[25] M. Bruce and J. Bridgeland, *The Mentoring Effect: Young People's Perspectives on the Outcomes and Availability of Mentoring. A Report for Mentor: The National Mentoring Partnership*. Civic Enterprises, 2014. Accessed: Nov. 20, 2020. [Online]. Available: https://eric.ed.gov/?id=ED558065
[26] M. Bustillo and R. Gotian, "A mentoring circle supports women anaesthesiologists at every career stage," *British Journal of Anaesthesia*, vol. 124, no. 3, pp. e190–e191, Mar. 2020, doi: 10.1016/j.bja.2019.12.014.
[27] I. Gutu, D. T. Agheorghiesei, and A. Tugui, "Assessment of a Workforce Sustainability Tool through Leadership and Digitalization," *Int J Environ Res Public Health*, vol. 20, no. 2, Art. no. 2, Jan. 2023, doi: 10.3390/ijerph20021360.
[28] E. Volpe and D. Simmons, "AI's Visual Representation Gap: Redefining Civil Engineering Workspaces for Early-Career Women," in *2024 ASEE Annual Conference & Exposition Proceedings*, Portland, Oregon: ASEE Conferences, Jun. 2024, p. 46536. doi: 10.18260/1-2--46536.
[29] K. Charmaz and L. L. Belgrave, "Grounded Theory," in *The Blackwell Encyclopedia of Sociology*, American Cancer Society, 2015. doi: 10.1002/9781405165518.wbeosg070.pub2.
[1] R. Gotian, "Why you need a support team.," *Nature*, vol. 568, no. 7752, pp. 425–427, Apr. 2019.
[2] W. B. Johnson, S. Long, D. G. Smith, and K. A. Griffin, "Creating a mentoring culture in graduate training programs," *Training and Education in Professional Psychology*, vol. 17, no. 1, pp. 63–70, 2023, doi: 10.1037/tep0000404.
[3] A. E. Greenberg, "Entering Mentoring: A Mentor Training Seminar for REU Mentors," in *Best Practices for Chemistry REU Programs*, vol. 1295, 0 vols., in ACS Symposium Series, no. 1295, vol. 1295. , American Chemical Society, 2018, pp. 121–137. doi: 10.1021/bk-2018-1295.ch009.
[4] "Mentor Curricula and Training: Entering Mentoring – CIMER." Accessed: Apr. 10, 2024. [Online]. Available: https://cimerproject.org/entering-mentoring/
[5] J. T. Zerzan, R. Hess, E. Schur, R. S. Phillips, and N. Rigotti, "Making the most of mentors: a guide for mentees," *Acad Med*, vol. 84, no. 1, pp. 140–144, Jan. 2009, doi: 10.1097/ACM.0b013e3181906e8f.
[6] J. Gambatese, A. Karakhan, and D. Simmons, "Workforce Sustainability Report," *CPWR-The Center for Construction Research and Training*, Jan. 2019.

[7] A. Ilumoka, I. Milanovic, and N. Grant, "An Effective Industry-Based Mentoring Approach for the Recruitment of Women and Minorities in Engineering," *Journal of STEM Education: Innovations and Research*, vol. 18, no. 3, Art. no. 3, Oct. 2017, Accessed: Nov. 20, 2020. [Online]. Available: https://www.jstem.org/jstem/index.php/JSTEM/article/view/2102
[8] G. W. Ivey and K. E. Dupré, "Workplace Mentorship: A Critical Review," *Journal of Career Development*, p. 0894845320957737, Sep. 2020, doi: 10.1177/0894845320957737.
[9] E. S. Volpe, D. R. Simmons, J.-L. Mondisa, and S. Rojas, "Effective mentoring strategies to support underrepresented students during a virtual summer research experience for engineering education undergraduates," *International Journal of Mentoring and Coaching in Education*, vol. ahead-of-print, no. ahead-of-print, Jan. 2024, doi: 10.1108/IJMCE-09-2023-0089.
[10] J. Trevelyan, "Transitioning to engineering practice," *European Journal of Engineering Education*, vol. 44, no. 6, pp. 821–837, Nov. 2019, doi: 10.1080/03043797.2019.1681631.
[11] J.-L. Mondisa, B. W.-L. Packard, and B. L. Montgomery, "Understanding what STEM mentoring ecosystems need to thrive: A STEM-ME framework," *Mentoring & Tutoring: Partnership in Learning*, vol. 29, no. 1, Art. no. 1, Jan. 2021, doi: 10.1080/13611267.2021.1899588.
[12] B. L. Montgomery, J.-L. Mondisa, and B. W.-L. Packard, "Promoting the cultivation and sustainability of mentoring ecosystems: results from a multi-institutional study," *Mentoring & Tutoring: Partnership in Learning*, vol. 32, no. 5, pp. 596–617, Oct. 2024, doi: 10.1080/13611267.2024.2389051.
[13] D. Jeske and C. Linehan, "Mentoring and skill development in e-Internships," *Journal of Work-Applied Management*, vol. 12, no. 2, Art. no. 2, Jan. 2020, doi: 10.1108/JWAM-09-2019-0028.
[14] J. P. Martin, P. Jensen, and * D. Suresh, "Perceptions of shared experiences in mentoring relationships: A collaborative autoethnography," *2022 ASEE Annual Conference & Exposition*, Jun. 2022, Accessed: May 25, 2023. [Online]. Available: https://par.nsf.gov/biblio/10345583-perceptions-shared-experiences-mentoring-relationships-collaborative-autoethnography
[15] J.-L. Mondisa, "The Role of Social Capital in African American STEM Mentoring Relationships," *JWM*, vol. 26, no. 2, Art. no. 2, 2020, doi: 10.1615/JWomenMinorScienEng.2020022267.
[16] A. Tuladhar, C. Queener, J. L. Mondisa, and C. Okwudire, "Informal community spaces, mentoring and representation: unpacking factors that influence African American engineering undergraduates," *International Journal of Mentoring and Coaching in Education*, vol. ahead-of-print, Jun. 2021, doi: 10.1108/IJMCE-06-2020-0032.
[17] V. Washington and J.-L. Mondisa, "A need for engagement opportunities and personal connections: Understanding the social community outcomes of engineering undergraduates in a mentoring program," *Journal of Engineering Education*, vol. 110, no. 4, pp. 902–924, 2021, doi: 10.1002/jee.20422.
[18] E. Volpe, D. R. Simmons, and M. Polmear, "Balancing what Drains and Sustains: Factors Influencing Early-Career Women's Persistence in STEM Fields," *Journal of Career Development*, vol. 52, no. 5, pp. 563–579, Oct. 2025, doi: 10.1177/08948453251363225.
[19] K. Kram, "Improving the Mentoring Process.," *Training and Development Journal*, 1985.

[20] "CIMER – Center for the Improvement of Mentored Experience in Research." Accessed: Dec. 28, 2022. [Online]. Available: https://cimerproject.org/
[21] V. Y. Womack *et al.*, "Culturally aware mentorship: Lasting impacts of a novel intervention on academic administrators and faculty," *PLOS ONE*, vol. 15, no. 8, Art. no. 8, Aug. 2020, doi: 10.1371/journal.pone.0236983.
[22] A. M. Rynearson and C. A. Pantoia, "Mentoring Undergraduate Researchers Through Entrepreneurial Mindset," in *2023 IEEE Frontiers in Education Conference (FIE)*, College Station, TX, USA: IEEE, Oct. 2023, pp. 1–5. doi: 10.1109/FIE58773.2023.10343323.
[23] E. S. Volpe, D. R. Simmons, J.-L. Mondisa, and S. Rojas, "Effective mentoring strategies to support underrepresented students during a virtual summer research experience for engineering education undergraduates," *International Journal of Mentoring and Coaching in Education*, vol. ahead-of-print, no. ahead-of-print, Jan. 2024, doi: 10.1108/IJMCE-09-2023-0089.
[24] H. Adams, "Mentoring for Professional Development: Mentor/Protégé Orientation Handbook." HG Adams & Associates., 1998.
[25] M. Bruce and J. Bridgeland, *The Mentoring Effect: Young People's Perspectives on the Outcomes and Availability of Mentoring. A Report for Mentor: The National Mentoring Partnership*. Civic Enterprises, 2014. Accessed: Nov. 20, 2020. [Online]. Available: https://eric.ed.gov/?id=ED558065
[26] M. Bustillo and R. Gotian, "A mentoring circle supports women anaesthesiologists at every career stage," *British Journal of Anaesthesia*, vol. 124, no. 3, pp. e190–e191, Mar. 2020, doi: 10.1016/j.bja.2019.12.014.
[27] I. Gutu, D. T. Agheorghiesei, and A. Tugui, "Assessment of a Workforce Sustainability Tool through Leadership and Digitalization," *Int J Environ Res Public Health*, vol. 20, no. 2, Art. no. 2, Jan. 2023, doi: 10.3390/ijerph20021360.
[28] E. Volpe and D. Simmons, "AI's Visual Representation Gap: Redefining Civil Engineering Workspaces for Early-Career Women," in *2024 ASEE Annual Conference & Exposition Proceedings*, Portland, Oregon: ASEE Conferences, Jun. 2024, p. 46536. doi: 10.18260/1-2--46536.
[29] K. Charmaz and L. L. Belgrave, "Grounded Theory," in *The Blackwell Encyclopedia of Sociology*, American Cancer Society, 2015. doi: 10.1002/9781405165518.wbeosg070.pub2.
[30] E. Volpe and D. R. Simmons, "Foundational Methods for Inclusive Engineering Research: Reflexive Design Choices to Foster Participation and Broaden Impact," in *2025 ASEE Annual Conference*, ASEE, 2025.
[31] J. Creswell, *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*. SAGE Publications, 2020. Accessed: Dec. 10, 2020. [Online]. Available: https://www.google.com/books/edition/Qualitative_Inquiry_and_Research_Design/Ykruxor10cYC?hl=en&gbpv=1&dq=john+W.+Creswell.+%E2%80%9CQualitative+Inquiry+and+Research+Design:+Choosing+Among+Five+Approaches.&printsec=frontcover
[32] J. Saldaña, *The coding manual for qualitative researchers*, 2nd ed. Los Angeles: SAGE, 2013.
[33] V. Braun and V. Clarke, "Using thematic analysis in psychology," *Qualitative Research in Psychology*, vol. 3, no. 2, Art. no. 2, Jan. 2006, doi: 10.1191/1478088706qp063oa.
[34] M. Birks, Y. Chapman, and K. Francis, "Memoing in qualitative research: Probing data and processes," *Journal of Research in Nursing*, vol. 13, no. 1, Art. no. 1, Jan. 2008, doi: 10.1177/1744987107081254.

[35] J. W. Creswell and D. L. Miller, “Determining Validity in Qualitative Inquiry,” *Theory Into Practice*, vol. 39, no. 3, Art. no. 3, Aug. 2000, doi: 10.1207/s15430421tip3903_2.
[36] B. W.-L. Packard, B. L. Montgomery, and J.-L. Mondisa, “Taking stock of campus mentoring ecosystems: a peer assessment dialogue exercise,” *IJMCE*, vol. 13, no. 1, pp. 17–33, Feb. 2024, doi: 10.1108/IJMCE-09-2022-0072.
[37] B. W.-L. Packard, B. L. Montgomery, and J.-L. Mondisa, “Synergy as a strategy to strengthen biomedical mentoring ecosystems,” *Front. Educ.*, vol. 10, Feb. 2025, doi: 10.3389/feduc.2025.1474063.
[38] M. B. B. Magolda and P. M. King, Eds., *Learning Partnerships: Theory and Models of Practice to Educate for Self-Authorship*. New York: Routledge, 2023. doi: 10.4324/9781003445685.