Exploring the Role of Mentorship within a Social Network to Develop Leadership in Engineering Educators

Stephen Mattucci, University of Guelph

Mattucci was raised in the traditional territories of the of the Mississaugas of the Credit First Nations, Anishinaabek and Haudenosaunee Peoples (Southern Ontario, Canada). He has strong core values around continuous personal improvement, and love for learning. His post-secondary education includes three technical engineering degrees (two mechanical, one biomedical). Mattucci's post-doctoral work shifted to focus on collaborative change management and communities of practice in engineering education at the national level in Canada, before beginning a faculty appointment in 2022 with a teaching focus. Mattucci's favourite courses to teach are engineering design, mechanics (solids), dynamics, and anything related to leadership and professional / transferable skills. His favourite things to do are backcountry camping, and going on adventures with his family.

Makary Nasser, University of Guelph

Nasser is a Biomedical Engineering Graduate student at the University of Guelph. His exploration in educational leadership initiated as he began working as a Graduate Teaching Assistant under Mattucci's guidance. This introduced him to Scholarship of Teaching and Learning (SoTL) providing fresh insights and highlighting learning processes in educational leadership.

Exploring the Role of Mentorship Within a Social Network to Develop Leadership in Engineering Educators

Stephen Mattucci, Makary Nasser

School of Engineering, University of Guelph, Guelph, ON, Canada

Abstract

Mentorship is one avenue of leadership and professional development that can be extended beyond a one-to-one interaction, instead involving multiple mentors and mentees within a social network. This work aims to explore characteristics of a 'mentorship social network' around a 'primary node' within the domain of engineering education. The specific objectives are to: identify characteristics indicative of thriving and successful mentorship practices within this network; recognize opportunities and barriers in future potential mentorship relationships; and identify potential lines of inquiry for future work on mentorship social networks. Aspects of interest include motivation for being a mentor or mentee, benefits of being a mentor or mentee, mentorship relationship patterns related to the domain of educational leadership, and types of mentorship methods. A survey featuring critical reflection prompts was distributed to ten individuals, including mentors, mentees, and peer mentors associated with the primary node, who also completed the same survey for each connection. Through thematic analysis of the twenty data entries, four distinct themes emerged from the generated codes: identity, traits, support behaviors, and outcomes. The code application patterns were interpreted to provide insight on the collective meaning within the network of being a mentee and a mentor, professional similarities and aligned values, and mentorship methods and motivations. The insights produced may not be generalizable to any mentorship social network, however they identify interesting characteristics which could lead to intriguing lines of inquiry for future work on this topic.

1 Introduction

The need for engineering students to develop and value leadership, transferable skills, and professional development alongside technical skills is gaining traction. Initiatives to develop leadership in engineering students has been gaining popularity in national communities including ASEE Leadership Division, and NICKEL (National Initiative on Capacity Building and Knowledge Creation for Engineering Leadership [1]) in Canada. However, the focus on student development often overlooks how educators are developing professionally and as educational leaders.

One common avenue for leadership and professional development is mentorship. Effective mentorship integrates both career and psychosocial aspects to develop professional identity and personal competencies [2]. Mentorship plays a role in shaping the cognitive and technical skills of future engineers as well as enhancing the transferable skills essential for leadership [3]. Mentorship can occur through prescribed means (e.g. a work program which pairs a mentor and a mentee), or can be more organic (e.g. approaching an experienced colleague for guidance).

Mentorship is particularly relevant within professional practices, such as engineering. Prior to larger-scale delivery models commonly seen in higher-education today, education in professional practices historically relied upon apprenticeship models to foster learning and competency development [4]. These models emphasize experiential learning and reflective practice, where apprentices apply their learnings to their own contexts with the support of someone with more

expertise – mirroring the essence of mentorship. To develop better engineers, this approach of learning through social relationships should be embraced as an essential component of professional practice and continuous improvement.

Mentorship is usually framed as one-to-one relationships, however, the authors recognize how people can have various mentors and mentees across their networks. These mentorship interactions can be seen as a web of connections between people within a network and play a critical role of both direct and indirect connections that underpin the development of professional relationships [5]. Mentorship relationships within a social network will then likely span various stages of career progression and professional ranks.

In a higher education context, traditional views of mentorship encompass relationships between staff, faculty, graduate students, and undergraduate students. Beyond professional roles, each person within a network will also identify as a mentor, mentee, and peer mentor depending on the relationship with another person. From a teaching perspective, the mentorship relationships between faculty members and graduate students are crucial in developing future educators and leaders [6]. This aspect of faculty mentorship is often undervalued and essential to enhancing the graduate educational experience. The role of social networks in these relationships and how various factors influence the leadership trajectory of engineering educators is worth further exploration.

Understanding how mentees and mentors are motivated to engage within this network may give perspective to strengthening existing relationships, and better identify future mentorship relationships with high potential for success. Organic mentorship relationships are inherently voluntary, highlighting the importance of strong motivation from both the mentor and the mentee. People are motivated to engage in actions that provide value, which can come in different forms. Intrinsic value is obtained simply through the enjoyment or satisfaction from performing a task – regardless of the outcome (e.g. an energizing conversation, playing a game without keeping score, etc.). Attainment value relates to the fulfillment of achieving a goal or developing mastery (e.g. ability to perform a complex task, achieving a personal best, etc.). Instrumental value is often confounded with extrinsic rewards, in that the accomplishment of a goal or task helps to achieve a more important goal (e.g. grades required for a scholarship, learning a skill to accomplish a specific task, etc.) [7], [8], [9].

2 Purpose

This work is driven by the authors' desire to enhancing quality improvement in professional development methods, with a specific focus on the phenomena of mentorship within social networks. This exploratory work seeks to explore the mentorship dynamics centered around Mattucci (or the "primary node" of the social network), within the domain of engineering education.

The specific objectives include:

i. Identify characteristics indicative of thriving and successful mentorship practices within this network,
ii. Recognize opportunities and barriers in future potential mentorship relationships,
iii. Identify potential lines of inquiry for future work on mentorship social networks.

The authors hypothesize that there may be rich insights related to specific characteristics, including: motivation for being a mentor or mentee, benefits of being a mentor or mentee, mentorship relationship patterns related to the domain of educational leadership, and types of mentorship 'methods'. These ideas stem from existing theories and frameworks that intersect with mentorship practices in this context.

3 Approach

3.1 Conceptual Framework

This work is set within the social reality of an Assistant Professor (Mattucci) in the School of Engineering at the University of Guelph, and his network of professional relationships with mentors and mentees – referred to herein as the 'Mentorship Social Network'. This study has been approved by the University of Guelph Research Ethics Board (REB# 24-03-007).

Mattucci is a white, straight, cis-gendered male who was raised in the traditional territories of the of the Mississaugas of the Credit First Nations, Anishinaabek and Haudenosaunee Peoples (Southwestern Ontario). He has strong core values around continuous personal improvement, and love for learning. His post-secondary education includes three technical engineering degrees, post-doctoral work in engineering education, before a faculty appointment with a teaching focus. His post-doctoral work focused on collaborative change management and communities of practice in engineering education at the national level, where Mattucci developed a large professional network across the country. In this role he often felt unfamiliar with the actors, priorities, and attitudes within the various contextual domains and the people he was working with. This role coincided with the initiation of his mindfulness and awareness practice, which led to him actively seeking 'contextual mentors' to help navigate the systems. This approach of intentionally seeking contextual mentorship has been ongoing for the last five years. Recently, he became more aware of the mentees in his network, and perceiving these relationships through a social network lens, which has inspired this work, and more broadly the interest in the idea of leadership development through mentorship.

Nasser, a biomedical engineering graduate student at the University of Guelph, initiated his exploration of educational leadership through a mentoring relationship with Mattucci. His initial interactions with Mattucci were characterized by curiosity and an abundance of questions. These interactions evolved towards deeper engagement, particularly when Nasser began working as a graduate teaching assistant under Mattucci's guidance. This partnership introduced him to Scholarship of Teaching and Learning (SoTL), where he can provide fresh insights and highlight the learning process inherent in educational leadership.

3.2 Theoretical Frameworks

Central to these explorations is Social Constructivism. Social and cultural factors play a critical role in cognitive development, often socially mediated, as knowledge and meaning are developed collaboratively between groups and communities of people [10]. The learning that happens through mentorship within a social network is inherently social in nature. The constructivist perspective on mentorship deepens the impact of mentors' beliefs, values, and attitudes on the shaping of effective learning environments and the outcomes of professional development. The interaction between the mentor and the mentee is essential in constructing a professional learning environment beneficial for growth and development [11]. This constructivist view describes both

mentor and mentees contributing to the learning process and recognizes complexities, facilitating open dialogue, mutual respect, and shared learning objectives [12]. This perspective reinforces the need for mentorship models to be adaptive and centered on shared experiences.

Social Network Theory models human relationships as a web of nodes (individuals) and ties (connections), where connections impact the actions and behaviors of one another [13]. With respect to education, the impacts of these connections are particularly meaningful, as learning and knowledge transfer primarily occurs through significant conversations characterized by privacy, mutual trust, and intellectual intrigue [14]. These interconnected networks can be used to appreciate the flow of knowledge and expertise across a larger system – not just across two connected nodes [13]. Guidance from one mentor then has the potential to benefit many others beyond the direct mentee.

Reflection-in-action involves learning from experience through active reflection on actions in the moment [4]. The approach of identifying why experiences are important, and how to leverage this learning in the future is ideally suited to any continuous improvement process [15]. Critical reflection also has deep ties to professional practice, such as engineering [4]. Engineers face rapidly changing technological environments and complex problems within unique contexts, so they must be adept at self-directed learning.

Many mentorship models exist with distinct contextual nuances. To identify and categorize distinct ‘methods’ of mentorship within the social network, we used a cognitive apprenticeship framework [16]. This model outlines six successful mentorship ‘methods’: modelling, coaching, scaffolding, articulation, reflection, and exploration. These methods progress from lower order, didactic demonstration (modelling), to higher order co-construction of mutual learning (exploration).

As teaching-focused faculty appointments become more prevalent, many institutions still struggle to define the expectations and differentiation of various scholarly aspects, which aren’t adequately captured by “research, teaching, or service”. The U21 Teaching Standards Framework [17], and a synthesized University of British Columbia version captures teaching duties as a broader educational leadership (EL) “landscape” across different dimensions of teaching, and forms of enactment (Figure 1). It includes topics like curriculum design, faculty development, and institutional strategy – broadening the definition of leadership beyond technical knowledge to include strategic contributions to the development of institutions.

		Forms of Enactment (Teaching Roles)		
		Practitioner (Do)	Leader (Influence / Develop)	Manager (Enable)
Dimensions of Teaching		Facilitate & support the learning of their students	Influence & support others to innovate or improve	Create policy & conditions to improve learning
Deliver Facilitate & support learning	Engaging, challenging, scaffolding, supporting, & providing feedback to students			
Design Course / Program Design / Development	Designing, developing & deploying resources, learning activities, assessments, etc.			
Develop Reflective Practive	Collection & interpretation of evidence to inform improvement			
Disseminate Scholarship & Public Dissemination	Engaging with & contributing to Scholarship of Teaching & Learning			

Figure 1. The U21 Conceptual Framework for Teaching is a four by three matrix which distinguishes four Dimensions of Teaching across three Forms of Enactment (or Roles) [17], [18]. It is a resource designed to help faculty categorize, articulate, and plan their activities in the empty boxes.

3.3 Methods

This work draws from the lived experiences of people within a social network to explore the idea of developing as an educational leader through mentorship. The primary node shares experiences with all other actors, each of whom are constructing meaning of the mentorship experience within the network through their own array of perceptions (Figure 2). Since everyone will not see or experience the same events in the same ways, the meaning of mentorship will be constructed socially [19]. This work aims to reveal and categorize the variation between people's experiences, so that mentors and mentees might intentionally adopt strategies to improve their own mentorship relationships in the future.

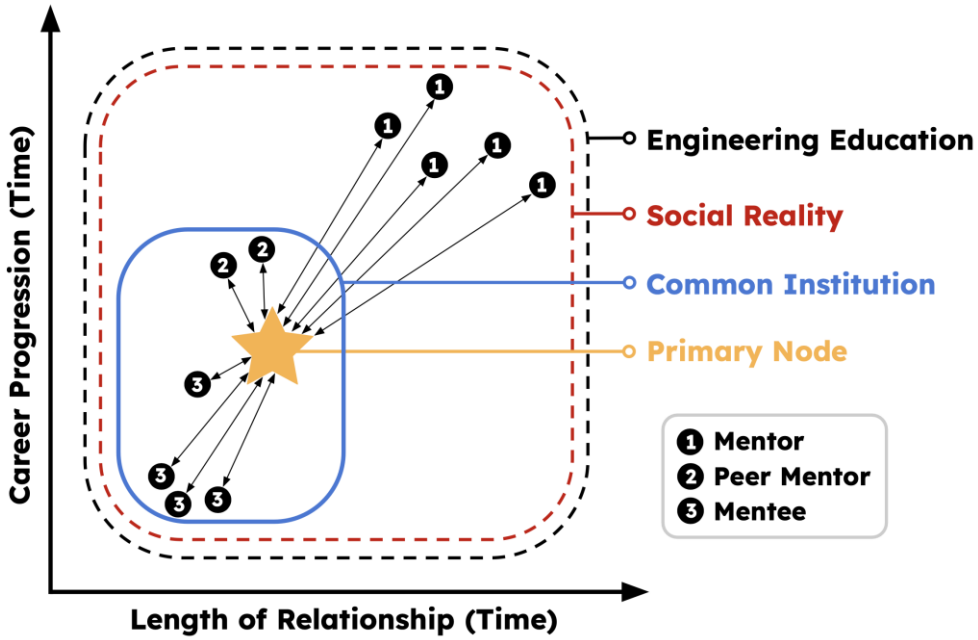

Figure 2. Visualization of the Mentorship Social Network. Nodes are based on the relationship with respect to the primary node and are plotted based on the length of time of relationship (x-axis) and career progression within an engineering education context (y-axis). The term "primary node" is inspired by astronomy, signifying the central body which others orbit, similar to the role of the central actor within this social network.

A survey was developed with six short-answer questions, and two numerical scoring questions (with optional comments) corresponding to relevant theoretical frameworks (Appendix A). Participants were asked to use Likert scale ratings to categorize the emphasis of each of the four dimensions of teaching present in the mentorship relationship and identify the three most common (of six total) methods of cognitive apprenticeship utilized in interactions. The survey was sent to ten people who the primary node felt he had ongoing mentorship relationships with – where the relationship exists within the domain of engineering education. Mattucci critically reflected upon his own relationship with each of the survey participants. Each tie in the social network therefore contains two critical reflections: one from the primary node, and one from the connecting node.

The data was thematically analyzed using Dedoose (version 9.0.107). Participant reflections were tagged with a descriptor to indicate the main type of relationship with the primary node (i.e. mentor, mentee, or peer mentor). Codes were first generated through a combination of inductive and deductive approaches. Many themes emerged from the question generation based on theoretical frameworks and were explicitly probed in the survey. As a result, findings were anticipated to have elements in these areas related to motivations, benefits, and mentorship methods. Both authors read all data entries and generated codes independently, before collaborating and negotiating meaning of a finalized set of codes. The codes were grouped into four main themes: identity, traits, support behaviors, and outcomes. Identity was further subdivided into: core values, motivations, career, and relationship. Both authors independently blind-coded the data entries with the finalized set of codes.

4 Findings and Discussion

The analysis examined 331 excerpts categorized by 56 distinct codes. Generated codes were removed if they were applied to less than three instances or did not contribute additional meaning to the emergent themes, resulting in 43 finalized codes (Appendix B). Half of the data entries are from the perspective of the primary node, who was also heavily involved in developing and applying the codes. Therefore, any insights gained from this work may only be relevant because the network is that of the primary node. In other words, findings cannot be generalized to be characteristics of any or all mentorship social networks. The following themes were identified by the application of codes, code co-occurrences, and quotes. Throughout this discussion, the codes that were associated with responses are italicized. The main insights are based on how the four emergent themes (identities, traits, support behaviors, and outcomes) characterize the social reality of the mentorship relationship (Figure 3).

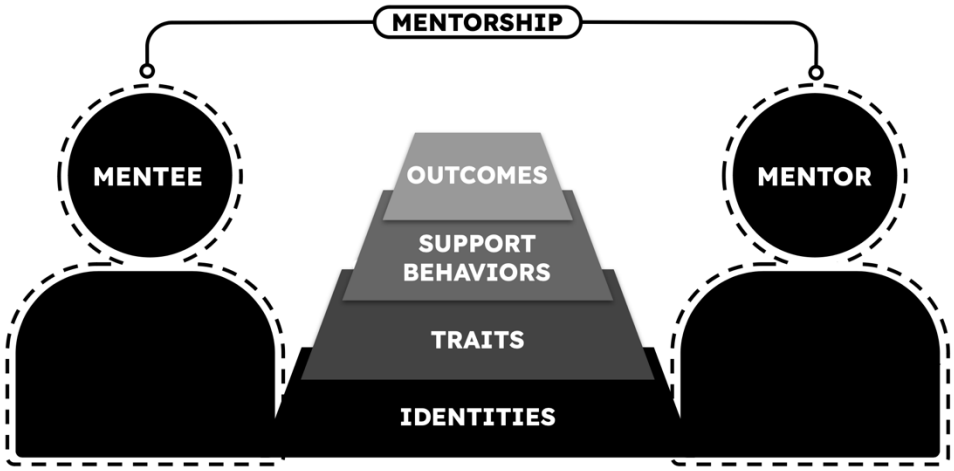

Figure 3. Relationship of emergent themes within the social reality under investigation. All aspects of the mentorship relationship depend on the identities of both the mentor and the mentee. With respect to the mentorship relationship, traits are the characteristics the people exhibit, support behaviors are the actions of each person, and outcomes are the results. Therefore, the mentorship relationship is more than just a conversation, but a product of both people as whole humans.

4.1 Mentee: characteristics, requirements, and common meaning

A recurring theme was the co-application of *benefit*, *guidance*, and *energizing*. These characteristics together provide different value to the mentee compared to the mentor. From a mentee's perspective, mentorship is the opportunity for professional growth, learning, and personal development. Mentees expressed a strong inclination towards seeking mentors who have the ability to provide guidance that incorporates broader professional and personal development aspects. This relationship offers an experience outside of traditional educational settings. The value for mentees lies in the motivation and inspiration they derive from the relationship. Witnessing a mentor's enthusiasm can inspire a mentees passion and commitment to their personal *career path*. Challenges arise in how mentees transfer the guidance received to fit their own unique context and career development paths. When faced with diverse advice from mentors, applying advice to one's own context becomes a critical skill. Drawing inspiration and motivation from mentors, mentees can *translate* this towards career *growth* opportunities. As

mentees navigate through their *career path*, the journey of mentorship serves as a valuable opportunity for *learning* and *growth*.

4.2 Mentor: characteristics, requirements, and common meaning

The benefits from a mentorship relationship are less obvious to the mentor. Interestingly, the most frequent type of motivation coded was *intrinsic*, indicating an emphasis on personal *benefit* from the support of a mentee's *growth*. Mentors value the mutual growth and insight gained from mentorship as "passing along wisdom and experiences with a mentee, but it goes beyond this… it is more of a shared journey." The mentor's perspective on mentorship connects *guidance* with *reflection*, often motivated by past experiences. Another emergent theme was how mentors found the relationship *energizing.* A key challenge for mentors is balancing between guidance and supporting mentees in their autonomy to make independent decisions, and learn from the outcomes. The exchange of knowledge and experience also supports mentors in their own professional *growth* and *career* progression. There is a clear pattern within this network between the mentors and intrinsic motivation, and feeling energized by the relationship, however, it remains to be seen whether these characteristics are generalizable to all mentors.

4.3 Within the network: professional similarities

There were frequent co-applications of *similarities* with *career path*, and *ambition*. This is unsurprising considering this network is contained within a professional domain, in this case engineering education. What is more interesting is how narrow the path appears for these individuals between ambitious grad students with a passion for teaching, and national leaders in engineering education. Since Mattucci was reflecting upon several relationships in parallel, patterns emerged: it is not coincidental that his mentorship network mostly consists of mentees that remind him of his past-self, and mentors who embody characteristics he strives for in his future-self. It occurred that his mentees shared especially similar characteristics from his stage as a graduate student: naïve, energetic, fun-loving, high-achieving, a passion for teaching, and naturally talented at teaching. His mentors have achieved success as leaders in the dimensions of teaching [18] related to his own ambitions: respect from students (deliver), large-scale curricular innovations (design), ability to make significant impact through leadership positions and impactful initiatives (develop), and established scholarly lines of inquiry (disseminate). Not all mentorship relationships in the network had strong "see yourself" qualities, however, it would be unsurprising if mentorship networks in general are predisposed to strong qualities of the primary node "seeing themselves" in their relationship counterparts.

4.4 Within the network: aligned values

A frequent observation related to similar *career path*, was *aligned values*. Each participant reflection was tagged for at least one of the core value codes. These values are core to the primary node of the network and were present at the same frequency as his ranking of the importance of these values: *growth*, *leadership*, *student focus*, and *social responsibility*. *Growth* contributed to more than 50% of the total core value application cases, and was the 3rd most applied code. This is unquestionably Mattucci's strongest personal value, relating to growth mindset, personal and professional improvement, continuous learning, grit, etc. *Growth* often co-occurred with *reflective*, which we loosely define as 'learning from experience', and in the mentorship context this learning can be from the mentee or the mentor's past lived experiences.

This presents the question of whether or not all mentorship relationships are underpinned by growth and reflection? Or are these themes central to this mentorship network because 'growth' is a core value within the primary node?

4.5 Demographic similarities

The emerged themes relating to similarities between mentor and mentee are unsurprising and align with the literature around how mentorship relationships form and develop. Demographic or surface similarity has been widely thought to influence mentorship dynamics, in particular at early stages, as people generally feel more comfortable with others similar to themselves, especially if the mentee identifies as a minority [20], [21], [22]. Deep-level similarity, which considers similarities based on shared values, attitudes and beliefs, can outweigh surface similarity if relationships have the opportunity to develop with continued interactions over time [20], [23]. Despite the success of the central node's relationships with his mentors being (believed to be) attributed to deep-level similarity, it cannot be ignored that many of these relationships are also demographically similar: white, straight, cis-gendered males. Further, while these relationships may currently be thriving based on deep-level similarity, this is likely also a product of the potential opportunities for mentorship available to Mattucci based on demographic similarity. It cannot be assumed that everyone has equal opportunities to foster mentorship networks.

4.6 Higher Order Mentorship Methods

We thought the cognitive apprenticeship methods [16] would emerge as codes, however this was not the case, except for *reflection* and *modeling.* More generally, *'support behaviors'* were captured as *'guidance'*. To gain more rich insight on how *'support'* is demonstrated in mentorship relationships, more nuanced prompts are likely needed. Participants were asked to indicate which three of the methods were most common and/or beneficial in their interactions with Mattucci, who also identified his perspective of the methods in the relationship. From his perspective, the higher order methods were more frequently identified in the relationships with mentors than mentees, despite mentees indicating these higher order methods were present. Most participants (7/10) identified *'exploration'*, where Mattucci only indicated two instances. This could be due to an undervaluing of the methods and benefits that he provides to his mentees. Further, the duration of the relationship with all mentees was shorter than with any of the mentors, and so in comparison, the mentee relationships have not had the same amount of time and opportunity to *evolve* into the higher order methods. Mattucci and his mentees are typically in a period of relatively rapid career transitions: finishing degrees, changing institutions, changing roles, etc. Mattucci's mentors (who were included in this investigation) were maintained through these transitions, due to intentionality on his part as the mentee, and normalization of virtual meetings throughout the pandemic.

4.7 Methods: Modeling

There was some disagreement between the presented definitions of cognitive apprenticeship methods from Collins, et. al (1991) [16]. In particular, Mattucci has a very different interpretation of *modeling*, which can be differentiated from 'demonstrating', which involves showing how to perform a particular task. *Modeling* is viewed as more an omnipresent demonstration of behavior and conduct in general. "I would argue I am continuously modeling

behavior for all of my mentees, while also continuously preceptive of behavior of my mentors. In fact, this behavior of my mentors is likely a key reason I keep them in high regard." Erosion of this perception would likely deteriorate the relationship. Modelling can be beneficial to a mentee that can learn from both positive and negative outcomes of behavior – for example, how not to act, cause-and-effect relationships between actions and outcomes, etc. – we can all learn from other people's mistakes.

4.8 Motivations

Participants were explicitly asked "What motivates you as a mentor/mentee in your professional relationship with S. Mattucci?", and *intrinsic* value was identified in almost all participant responses (80% code presence), where *instrumental* (30%) and *attainment* (10%) were mentioned less frequently. *Instrumental* value was often related to how the outcomes of a mentorship relationship led to skill development, benefits and impacts on work – which are usually a precursor to attainment value in the form of career progression and growth. Interestingly, four of the mentors in the network clearly identified *intrinsic* value from mentoring others (beyond just Mattucci). Since the perceived benefits in a mentorship relationship often favor the mentee, it makes sense that in successful relationships a mentor would be motivated by the satisfaction of helping someone else, particularly when they recognize the potential value they bring to the mentee.

4.9 Educational leadership and scaffolding

We anticipated the dimensions of teaching and forms of enactment from the educational leadership framework to arise more frequently in the data, considering one of the questions was scaffolded to this framework. Since the framework was developed primarily for educators to articulate their contributions for the purpose of promotional advancement, it may need to be more explicitly probed to uncover how mentorship directly benefits development in these dimensions. For the mentor, mentorship can best be characterized in this framework as the reflective practice (develop) dimension, and the leader (influence and develop) form of enactment. For the mentee, this is best captured as the reflective practice (develop) dimension, however, the outcomes of the mentorship relationship could benefit the mentee in any of the teaching dimensions.

The potential for growth in the teaching dimensions also depends on some baseline experience from which to reflect and build upon. This idea can be connected to interpretations of Vygotsky's Zone of Proximal Development [10], [24]: the proportional relationship between competence and challenge, and the proper balance required to optimize learning. With more competency, a mentee can utilize more nuanced and specialized guidance and support from a mentor to accomplish more challenging tasks. Without this baseline experience, mentoring can resemble direct training, with more scaffolding, and missed opportunities to challenge perspective and engage in dialogue. For example, with Mattucci's mentees, there is a gap related to educational theory and teaching practice, likely due to minimal formal training in this area. A formal teaching training program might consist of dozens of hours – which is substantial time to make up in small mentorship interactions alone. In many of these cases the mentoring benefits – both ways – could potentially be more valuable, and allow both to reach higher order mentorship methods, as they could explore ideas more deeply.

4.10 Intentionality

Most social networks form organically, but in this case the primary node was very intentional about initiating and developing the relationships with his mentors. Mattucci reflects:

> "In education, I am acutely aware of the power of significant conversations and social learning, so I am proactive about leveraging these types of approaches. Not only do I seek relevant contextual mentorship, I am intentionally fostering relationships with all of my professional colleagues, usually by investing socially – coffees, lunches, etc. Really, I am trying to build deeper connections with other humans over shared interests. Unsurprisingly, the intentionality of me developing this mentorship social network coincided with my national coordinator change agent role, where I was leveraging communities of practice and social networks to support educators in shifting online during the pandemic. The success of those initiatives has caused me to adopt these social learning approaches into my own practice."

It is important to acknowledge the mentee's critical role in developing a successful mentorship dynamic: 'managing up' [25]. This is originally connected within the corporate setting, where mentees influence the trajectory of their development and the productivity of the mentorship relationship. 'Managing up' calls for the mentee taking an active leadership role in the relationship, guiding and facilitating the mentor's efforts to provide support. This addresses common drawbacks in mentorship such as incompatible expectations by allowing mentees to communicate their needs and shape the agenda. Framing mentorship as a mentee-driven, 'managing up' approach can enhance mentorship outcomes through encouraging a more engaged, responsible, and productive mentor-mentee dynamic.

5 Conclusion

The authors began this exploratory journey around 'leadership and mentorship', unaware of what they did not yet know about in this domain. This learning-on-the-go approach has been exhilarating as the authors began to better understand the phenomena of mentorship, however, the early stages of this journey also risk overseeing some fundamental existing theories and missing meaningful connections with the data.

Several characteristics of thriving and successful mentorship practices were identified within this network. Mentors consistently mentioned intrinsic motivations as a main benefit of mentorship. While the mentee appears to be the main benefactor for professional and leadership development, the mentee is also primarily responsible for driving the relationship. The health of the mentorship relationships seems to be fueled by the mentee's drive to seek guidance from a mentor, who in turn is intrinsically energized by the opportunity to provide mentorship, which enhances the mentee's learning, and further motivates the mentee to steer the relationship – a positive feedback loop. These characteristics are likely embedded in organic mentorship relationships, leading to successful outcomes. However, they are also likely harder to foster in prescribed mentorship relationships, making it more challenging to ensure success of organizational mentorship initiatives.

Similarities were obvious between mentors and mentees, particularly with respect to career path, and common values, referred to in the literature as deep-level similarity. When reflecting on the

nature of the relationships within the network, Mattucci had a realization that he could see his past-self in his mentees, and his future-self in his mentors. However, these similarities also made the demographic similarities clear as well, which can be a precursor to mentorship success. This is concerning from an equity standpoint, indicating there is less mentorship support available to equity-deserving groups.

Like any worthwhile endeavor, this work identified several potential lines of inquiry for future work on mentorship social networks, particularly as it relates to generalizability. How many of these identified characteristics and emergent themes of mentorship social networks are a reflection of the attributes of the primary node and the domain? How do mentorship networks look in other domains, especially engineering industry contexts or academic research contexts? Does the professional nature motivate engineers to seek mentorship more deliberately in comparison to other disciplines? Does the alignment of values across ties within a network provide further evidence that mentorship relationships are deeply characterized by the values of both the mentor and mentee?

Finally, this work was a tremendous exercise in gratitude. This process has been extremely fulfilling, inspiring, intellectually intriguing, and fun. Mattucci and Nasser are now hyper-aware of how privileged they are to have this network, and motivated to leverage these opportunities for continued growth in educational leadership and professional development.

6 References

[1] "NICKEL - National Initiative on Capacity Building and Knowledge Creation for Engineering Leadership," https://www.engineeringleaders.ca.

[2] N. S. Hartman, S. J. Allen, and R. F. Miguel, "An exploration of teaching methods used to develop leaders," *Leadership & Organization Development Journal*, vol. 36, no. 5, pp. 454–472, Jan. 2015, doi: 10.1108/LODJ-07-2013-0097.

[3] T. D. Allen, L. T. Eby, and E. Lentz, "Mentorship behaviors and mentorship quality associated with formal mentoring programs: Closing the gap between research and practice.," *Journal of Applied Psychology*, vol. 91, no. 3, pp. 567–578, 2006, doi: 10.1037/0021-9010.91.3.567.

[4] D. Schön, *The reflective practitioner: how professionals think in action*. Basic Books, 1983.

[5] A. Sih, S. F. Hanser, and K. A. McHugh, "Social network theory: new insights and issues for behavioral ecologists," *Behav Ecol Sociobiol*, vol. 63, no. 7, pp. 975–988, 2009, doi: 10.1007/s00265-009-0725-6.

[6] A. K. Hund *et al.*, "Transforming mentorship in STEM by training scientists to be better leaders," *Ecol Evol*, vol. 8, no. 20, pp. 9962–9974, Oct. 2018, doi: 10.1002/ece3.4527.

[7] S. Ambrose, M. Bridges, M. DiPietro, M. Lovett, and M. Norman, *How Learning Works: 7 Research-Based Principles for Smart Teaching*. 2010. Jossey-Bass.

[8] A. Wigfield and J. S. Eccles, “The development of achievement task values: A theoretical analysis,” *Developmental Review*, vol. 12, no. 3, pp. 265–310, Sep. 1992, doi: 10.1016/0273-2297(92)90011-P.

[9] A. Wigfield and J. S. Eccles, “Expectancy–Value Theory of Achievement Motivation,” *Contemp Educ Psychol*, vol. 25, no. 1, pp. 68–81, Jan. 2000, doi: 10.1006/ceps.1999.1015.

[10] L. S. Vygotsky, *Mind in Society*. Harvard University Press, 1980. doi: 10.2307/j.ctvjf9vz4.

[11] O. Parylo, S. J. Zepeda, and E. Bengtson, “The different faces of principal mentorship,” *International Journal of Mentoring and Coaching in Education*, vol. 1, no. 2, pp. 120–135, May 2012, doi: 10.1108/20466851211262860.

[12] A. Shapiro, “Constructivism and Mentoring,” in *The Wiley International Handbook of Mentoring*, Wiley, 2020, pp. 65–78. doi: 10.1002/9781119142973.ch5.

[13] A. Kezar, “Higher Education Change and Social Networks: A Review of Research,” *J Higher Educ*, vol. 85, no. 1, pp. 91–125, 2014, doi: 10.1353/jhe.2014.0003.

[14] T. Roxå and K. Mårtensson, “Significant conversations and significant networks – exploring the backstage of the teaching arena,” *Studies in Higher Education*, vol. 34, no. 5, pp. 547–559, Aug. 2009, doi: 10.1080/03075070802597200.

[15] T. Borton, *Reach, touch, and teach; student concerns and process education*. McGraw-Hill, 1970.

[16] A. Collins, J. S. Brown, and A. Holum, “Cognitive Apprenticeship: Making Thinking Visible,” *American Educator: The Professional Journal of the American Federation of Teachers*, vol. 15, 1991. Available: https://api.semanticscholar.org/CorpusID:263308120

[17] U21 Educational Innovation Steering Group (U21 EISG). (2018). U21 Teaching Standards Framework – Full Description. Universitas 21. Available at: U21 Teaching Indicators

[18] “UBC Centre for Teaching, Learning and Technology,” https://ctlt.ubc.ca/ .

[19] G. Cousin and F. Deepwell, “Designs for network learning: a communities of practice perspective,” *Studies in Higher Education*, vol. 30, no. 1, pp. 57–66, Feb. 2005, doi: 10.1080/0307507052000307795.

[20] P. R. Hernandez, M. Estrada, A. Woodcock, and P. W. Schultz, “Protégé Perceptions of High Mentorship Quality Depend on Shared Values More Than on Demographic Match,” *The Journal of Experimental Education*, vol. 85, no. 3, pp. 450–468, Jul. 2017, doi: 10.1080/00220973.2016.1246405.

[21] D. B. Turban, T. W. Dougherty, and F. K. Lee, “Gender, Race, and Perceived Similarity Effects in Developmental Relationships: The Moderating Role of Relationship Duration,” *J Vocat Behav*, vol. 61, no. 2, pp. 240–262, Oct. 2002, doi: 10.1006/jvbe.2001.1855.

[22] B. R. Ragins, “Antecedents of Diversified Mentoring Relationships,” *J Vocat Behav*, vol. 51, no. 1, pp. 90–109, Aug. 1997, doi: 10.1006/jvbe.1997.1590.

[23] D. A. Harrison, K. H. Price, and M. P. Bell, “Beyond Rational Demography: Time and The Effects of Surface and Deep-Level Diversity on Work Group Cohesion.,” *Academy of Management Journal*, vol. 41, no. 1, pp. 96–107, Feb. 1998, doi: 10.2307/256901.

[24] J. Dziczkowski, “Mentoring and Leadership Development,” *Educ Forum*, vol. 77, no. 3, pp. 351–360, Jul. 2013, doi: 10.1080/00131725.2013.792896.

[25] J. T. Zerzan, R. Hess, E. Schur, R. S. Phillips, and N. Rigotti, “Making the Most of Mentors: A Guide for Mentees,” *Academic Medicine*, vol. 84, no. 1, 2009. doi: 10.1097/ACM.0b013e3181906e8f

Appendix A: Survey Questions

Topic	*Question*
Relationship Background	What is your name? Briefly describe when you first met S. Mattucci. What does 'mentorship' mean to you? Both in terms of the mentor and mentee.
Motivation and Benefits	What motivates you as a mentor/mentee in your professional relationship with S. Mattucci? How do you benefit from the mentor/mentee relationship with S. Mattucci?
Influence on Mentorship	What experiences as a mentee have influenced your approach in mentorship?
Characterization	What are 4 – 6 key words that you would use to characterize the nature and dynamics of this relationship?
Educational Leadership Dimensions	To what extent would you say your discussions cover these dimensions of educational leadership? 1 - never, 5 - often (UBC Centre for Teaching and Learning) - Activities to facilitate and support learning (deliver) - Course/Program Design/Development (design) - Scholarly Reflection, Professional Growth (develop) - Scholarship and Public Dissemination (disseminate) Do you have any additional comments or justification for the domains of educational leadership?
Beneficial Mentorship Methods	Which of the following 2 - 3 methods are most common and/or beneficial in your mentorship interactions with S. Mattucci? (Collins, Brown, and Holum – 1991) Please select at most 3 options. 1. Modeling–mentor demonstrating a behavior or performance of a task 2. Coaching–observing the mentee and offering targeted feedback for improvement 3. Scaffolding–mentor provides tools or resources to support the mentee 4. Articulation – mentee describes in detail their processes. Knowledge, rationale, past or future, etc. 5. Reflection – comparing mentee/mentor problem solving processes, identifying critical aspects, abstracting concepts, and applying to other contexts. 6. Exploration – mentee more independently problem solves, as supports fade. Do you have any additional comments or justification for the most common methods?

Appendix B: List of Themes and Codes

Code	*Description*
Identity	The core of who we are as unique human beings
Core Values	Fundamental beliefs and principles that influence all actions
Growth	Personal or professional development characterized by learning and knowledge
Leadership	Having the ability to influence others through achieving common goals
Social Responsibility	A sense obligation to make the world a better place for all
Student Focus	Prioritizing the student experience
Motivations	Factors that drive a person to pursue a task
Intrinsic	Motivation that comes from personal satisfaction
Instrumental	Motivated by a goal which is a lever to another goal
Attainment	The achievement of reaching a s specific outcome either tangible or a milestone
Career	Progression of one's professional experience over time
Career Path	Sequence of roles, positions, actions and consequences in one's career so far
Ambition	Desire to achieve self-defined success
Goals (Milestones)	Measurable targets that people aim to achieve
In Relation	Factors that are associated with the relationship between a mentor and mentee
Aligned Values	Personal or professional principles are in agreement
Career Gap	Difference in professional advancement progression
Evolution	The process of gradually changing over a period of time
Similarity/Commonality	Having similar interests or characteristics with an individual
Traits	Characteristic qualities that define one's personality
Approachable	Accessible and not judgmental
Collaborative	Being able and willing to work with others toward a common goal
Energizing / Inspiring	Invigorating. A renewed passion or sense of drive.
Personable	Engaging demeanor that makes others feel comfortable
Reciprocal	Mutual exchange where both parties benefit
Social Connection	The relationships and networks that are built with each other
Trust	Confidence and reliability in someone
Support Behaviors	Actions or characteristics that show encouraging, assistive, and understanding value
Communication	Exchange of information between people
Curiosity	Desire to learn and explore new things
Guidance	Providing advice or direction to help navigate a person
Meaningful/Thoughtful	Intentionality around purpose or providing value
Modeling	Demonstrating a skill or attitude for other to learn from
Outcome	The result of an action, event, or decision
Validation	Recognition or acknowledgment of the significance of someone or something
Benefit	An advantage or gain obtained from a situation or relationship
Co-learning	A process where all parties learn from each other encouraging mutual growth
Impact	Realized change on a person or the environment
Potential	The opportunity to realize growth or benefits
Reflective	Critical analysis to learn from experience
Rewarding	Providing satisfaction, fulfillment, or benefit
Transform	To make an everlasting change in perspective or nature
Translation	Applying concepts, ideas, or skills to different contexts