The Mentorship Method: An Out-of-School Pre-College Mentorship Program (RTP)

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ABSTRACT

Pre-college students in engineering pathways often excel technically but lack clarity of purpose, identity formation, and ownership of learning, gaps that eventually contribute to disengagement and attrition. Research in adolescent development and self-efficacy theory highlights the importance of purpose and agency in sustaining motivation, yet few pre-college engineering initiatives systematically integrate these elements into mentorship models. This paper introduces a student-centered and evidence-based system informed by self-efficacy theory and grounded in positive psychology. Unlike typical skills-based programs, The Mentorship Method (established over the last eight years at educational startup Hugo Mentors, with over 500 successful mentorships completed) embeds purpose development as a measurable construct and comprises six principles—*narrative over numbers, purpose as compass, iterative metacognition, learning ownership, scholar–mentor partnership,* and *supported growth*—that together provide a foundation for academic exploration.

The Mentorship Method™ (TMM) is presented with a literature review grounding its six principles in foundational and current research. Using an exploratory multimethod approach, we analyze pre- and post-mentorship survey data alongside qualitative student reflections from 196 structured mentorships pairing pre-college students with university research faculty. Originated and verified through sequential mixed-methods and incorporating the Claremont Purpose Scale, our surveys assess clarity of academic goals, ownership of learning, and confidence in problem-solving, while open-ended responses capture evolving interests, strengths, career plans, and motivations.

Findings indicate the TMM-structured approach fosters significant gains in self-efficacy and purpose development, particularly around societal contribution with ethical awareness, curiosity, and alignment between personal purpose and academic pursuits. Further analysis illustrates how student-informed mentorships guide students' development, purpose, and self-efficacy across engineering fields, ranging broadly from biomedical engineering, renewable energy, to systems design. Results suggest that TMM offers a scalable pathway for cultivating self-efficacy and purpose among pre-college students. When focusing solely on engineering mentorships, findings

remain consistent, suggesting that our system successfully nurtures a learning identity with potential applications to engineering identity. Future work will explore TMM's impact on pre-college engineering identity development, offering the potential to extend Godwin's framework beyond college-level engineering identity.

I. INTRODUCTION

A.The Pre-College Engineering Pipeline: A Developmental Problem

Despite decades of concerted effort, the engineering pipeline is still a major area of concern with attrition rates of 30 - 40% nationally and in Europe [1], [2], [3]. Some gains have been made in developing pre-college students' technical skills and exposure, but students still disengage because they lack purpose, struggle with identity formation, and ownership of learning [4], [5], [6], [7], [8], [9], [10], [11], [12]. Out of the hundreds of pre-college engineering programs available to students in the U.S., few explicitly go beyond skills and situational interest development to integrate these pillars of adolescent development into their mission and goals [13], [14], [15], [16], [17], [18]. A holistic approach to shoring up the engineering student pipeline may lie in self-efficacy theory, as research in adolescent development emphasizes the importance of purpose and agency in sustaining motivation [19], [20], [21], [22], [23], [24], [25], [26], [27], [28].

B. Identity, Motivation, & Adolescent Development in Engineering

Research in adolescent psychology has shown that the idea of the self also evolves to become an important source of value and intrinsic motivation [21], [29]. Compared to previous generations, young people today are prioritizing meaning and purpose in their lives, especially when it comes to work and work/life balance [30], [31]. A growing pool of research indicates that personal interest and engineering identity are the most important factors in young adults' career choice and retention [32], [33], [34]. Whether guided or not, young adults will attempt to integrate their emerging identities with their chosen field of study [14]. When engineering students' process of sense-making is internally consistent with engineering culture and identity, it can lead to retention [7], [8], [35]; when it falters, attrition [35], [36]. There is promise for intervention; in cases when students exhibit a flexible growth mindset, whether due to drawing on extramural engineering experiences or relying on the wisdom of a mentor, students can overcome de-identification with their generalized concept of engineering by making interdisciplinary connections [8], [36], [37], [38], [39].

C. Mentorship as a Mechanism

More generally, the powerful effects of mentorship on STEM students have been widely documented across demographics [40], [41], [42]. Formation of an expert-novice pair allows for the emerging engineer to quickly build deeply interconnected knowledge that is nuanced and multimodal in nature [29], [43], [44]. When done properly, this instructional scaffolding can bypass some of the friction associated with deep technical learning, giving young engineers an early taste of both the struggle and the successes that define an authentic engineering experience [42], [45], [46], [47], [48], [49]. Accessing these authentic experiences accelerates the development of engineering identity, which, when formed earlier in life, sustains students through the gauntlet of undergraduate, graduate, post-graduate, and professional life [35], [37]. While mentorship is widely recognized as beneficial, less attention has been paid to how pre-college mentorship environments can be intentionally designed to support students' agency, identity, and purpose development [50], [51], [52].

D. Purpose & Agency: Missing Design Elements

Purpose and agency are theoretically grounded but inconsistently operationalized in pre-college engineering contexts. Developing these traits alongside skill development, rather than as secondary or downstream outcomes, is critical to preventing attrition in the pre-college engineering pipeline; broadly speaking, mentees report that nurturing feelings of belonging and supporting identity development are the most meaningful forms of support. Large-scale and multigenerational studies suggest placing greater emphasis on supporting youth identity development and feelings of belonging [29], [53].

Pre-college engineering mentorship programs rarely integrate self-efficacy, learning ownership, and purpose as co-developing constructs. Here we introduce Hugo Mentors approach, The Mentorship Method ™ (TMM), as an intentionally developed 1:1 mentorship program designed to support adolescents in pursuing authentic, interest-driven engineering and research. Drawing on descriptive survey data and illustrative qualitative reflections, we examine how gains in academic self-efficacy, learning ownership, and purpose development were experienced and articulated by engineering-focused students. Rather than treating identity and purpose as outcomes that follow technical competence, this work explores how these constructs appear to develop alongside skill acquisition within an intentionally designed mentorship environment. Our findings contribute to ongoing conversations in engineering education by highlighting mentorship design as a critical lever for supporting adolescent identity development, agency, and sustained engagement in the pre-college engineering pipeline.

II. THE MENTORSHIP METHOD

The Mentorship Method™ (TMM) is a learner-centered mentorship system developed at Hugo Mentors over the past eight years, comprising more than 500 mentorship pairs centered across a wide range of engineering and non-engineering disciplines. Similar to others in the engineering education space [15], [36], [37], [54], [55], we approached program development using an endogenous view of learning from the perspective of the students participating. Therefore, it makes the most sense to initially describe our methods from the student perspective.

A. Program Sequence

Guided by the integrative framework of motivation theory proposed by Urhahane & Wijnia [56], TMM begins with the student broadly exploring topics of situational interest during initial intake and interviews (see Figure 1 below). One of the defining characteristics of TMM is that the student's study topic usually folds two or more seemingly orthogonal interests together, kickstarting the process of open-ended thinking and transdisciplinary research. A student reporting interest in engineering may also report a passion for music, which might then result in that student being paired with a mentor to build a violin-playing robot. Students routinely describe high-arousal states during these first encounters with their program coach (a “guide on the side” trained in adolescent psychology and educational best practices), leading us to name it the “Spark Session.” This semi-structured interview invites students to integrate multiple interests and a beyond-the-self component into the study or deliverable [57], [58], [59], [60], which is designed by the student with the help of both the program coach and mentor.

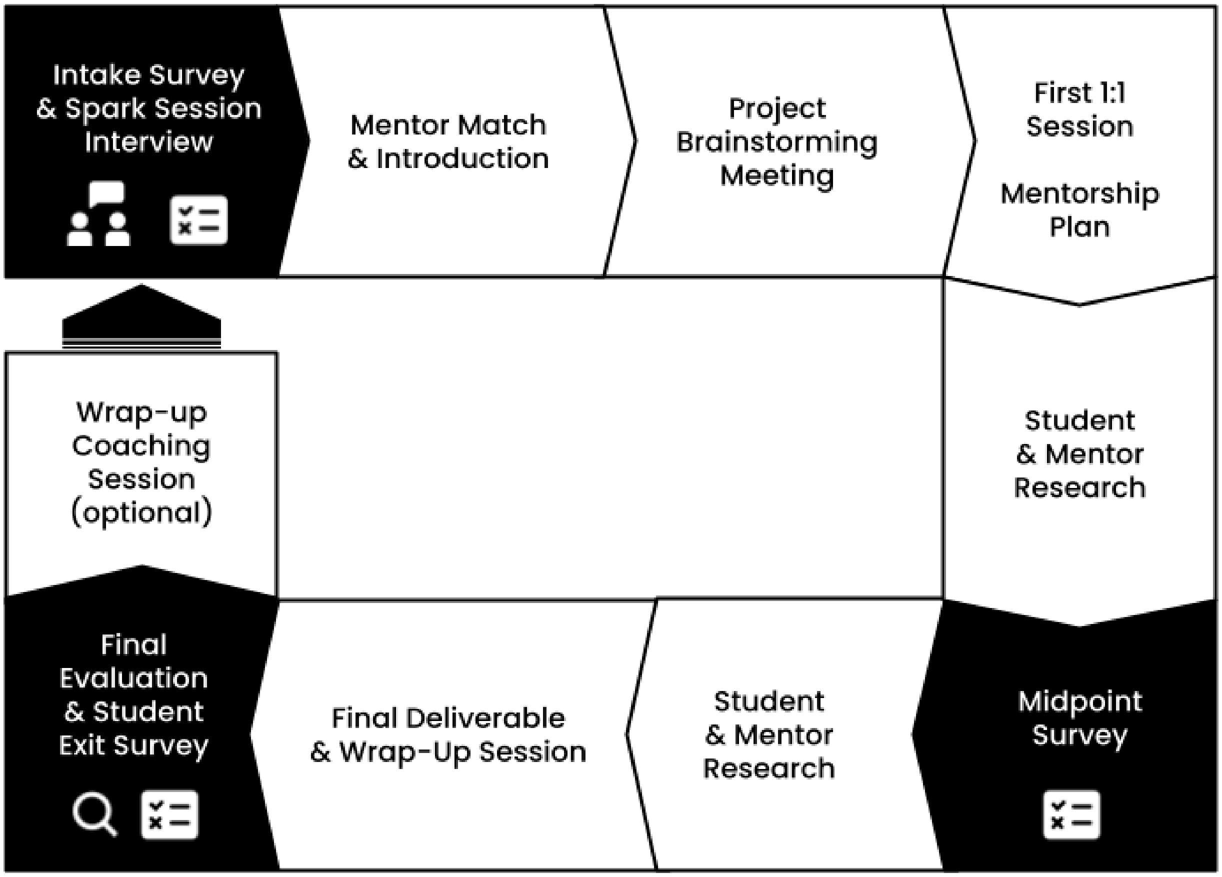

Figure 1. Student timeline within The Mentorship Method™ system, grounded on the general cognitive model of motivation [61]. Black boxes indicate stages where we collected student data.

From the students' point of view, all interactions within TMM center around their curiosity and zone of proximal development. In reality, the program balances building foundational academic and professional skills with project-based learning in niche and/or advanced fields, including mechanical, civil, biomedical, or computer engineering, among others. The flexibility of TMM allows activation of a range of competence-related behaviors, according to achievement-goal theory [62], [63], and the structure of requiring a final deliverable activates external motivation to help students integrated and identified regulations [64], [65], [66]. Identity is contextually emergent and multiply-authored [67], [68], [69], [70]. One's personal identity contains multitudes; an engineering professor will not speak, move, or interact with others the same way they will during evening hours when taking (or leading) a dance class. By fostering multimodal and interdisciplinary study, TMM encourages students to develop a robust personal identity that is inclusive of more narrow engineering identity concepts [71], [72], [73].

Since TMM has students research a highly specific or niche topic of interest, mentors are selected based on their area of expertise, precisely matched to students' self-reported interests. Because priority is given to finding a niche match for student-mentor pairings, TMM relies on a remote meeting structure to eliminate the constraints of geofencing a search. Over the course of ten one-on-one videoconference sessions, and in addition to email, phone, text exchanges, and asynchronous editing/comments, students and mentors explore a niche topic of mutual interest. This offers an authentic collaboration experience as it mirrors long-distance collaboration that professional peers engage in the real world. The experience concludes with the student's completion of a final deliverable, a formal written evaluation by the mentor and program coach, a final survey/reflection by the student, and a one-on-one wrap-up session between the mentor and student, and the student and program coach (as requested).

B. Six Principles of The Mentorship Method

TMM aims to develop pre-college, emergent adults' sense of purpose and identity–critical pieces of adolescent development known to contribute to thriving in personal, professional, health, and academic realms [74], [75], [76], [77]. The program was designed within the educational startup Hugo Mentors by cognitive science, educational psychology, and positive psychology experts, and in partnership with stakeholders including parents, students, college admissions counselors, school guidance counselors, and pre-college and university-level educators. Here we outline the six principles that shape TMM's novel approach to adolescent identity development.

1) Narrative before numbers: Beginning with the intake survey and a follow-up interview, TMM immediately centers upon student identity by using a richly informative narrative intake form and a semistructured live interview with their program coach. Rather than using test scores, GPA, and transcripts, which are limitedly informative and known to induce student anxiety and crises of identity [78], [79], [80], these qualitative assessments are designed to thoroughly describe student interests and personal epistemology, while also encouraging students to begin defining themselves [14], [81]. Harnessing ego-involvement from the outset, we initiate the process of introjected regulation as students internalize programmatic values when they assess their availability, capacity, learning styles, and motivations to dictate the shape of their mentorship [82].

2) Purpose as compass: During adolescence, the idea of the self evolves to become an important source of value and intrinsic motivation [21]. Research also shows a strong reinforcing link between identity and purpose, with purpose providing direction for identity, and identity reinforcing commitment to purpose in a cycle where one supports the other's development through a shared focus on meaningful beliefs and aims [60], [83]. After others, TMM defines purpose as a stable, long-term intention to achieve something that is both personally meaningful and has a positive impact on the world beyond oneself (ibid). By integrating purpose into goal-setting, TMM harnesses student emotional states to deliver active commitment, not just passive belief, thus providing direction, motivation, and resilience [84], [85], [86], [87].

Program coaches, who have backgrounds in psychology, medicine, or other STEM fields and are trained to guide student development, explicitly guide students through purpose identification and implementation during the Spark Session and mentorship planning meetings. Students' reported identity becomes the throughline as they articulate their project design, topic selection, and long-term exploration goals. Mentors pick up and continue these efforts throughout the learning experience, asking students to tie their experiences and learnings back to their larger goals and identity. Intake, progress, and exit surveys all ask students to reflect on their intentions beyond the self, as well as their motivations and active commitments.

3) Iterative metacognition: Since thoughtful reflection on actions, consequences, and feedback builds students' sense of self-efficacy [85], [88], [89], TMM offers many opportunities for student reflection. Students are prompted to complete short written and verbal reflections linking insights to next steps throughout the program. While mentorships begin at each student's level of readiness, projects may be rescoped as needed, especially when epistemic practices are misaligned. Depending on the degree of rescoping, and aiming for the most student-led solution, student, mentor, and parent input may be recruited in a transparent process guided by the program coach, but fully informed by the student's choices [14], [81]. At the end of the Hugo Mentors program (see Figure 1 above), a final evaluation written by the mentor and program coach includes student-specific suggestions for how mentees can pursue their interests, grow their skills independently, and further share their work. A final student survey and optional reflection meeting with their program coach asks students to reflect on their experience and future plans, and in some cases, students choose to engage in the program again.

4) Learning ownership: Since student questions and curiosities drive the direction of each mentorship, TMM includes no fixed curriculum. Ample work in academic motivation theory indicates that interest propels student motivation (see reviews in [90], [91], [92], [93]). TMM uses student interest or curiosity as the engine to propel student engagement. During the intake and planning phases, TMM harnesses situational interest triggered by environmental stimuli, nurturing and supporting it through programmatic design. Program coaches guide students through these phases with an emphasis on student "voice and choice" to further build student engagement, effort, intrinsic motivation, and performance [17], [94], [95], [96]. TMM further prioritizes student choice by encouraging students to creatively share their work in the format of their choice. The diversity and creativity of student projects is impressive; projects have ranged from traditional written collateral, which varies from formal peer-reviewed journal articles to pamphlets and policy briefs, to multimodal forms such as prototypes, computer programs and simulations, presentations, interactive toolkits, online course modules, social media video content, art installations, lesson plans, etc.

5) Scholar-mentor partnership: Related to the principle of learning ownership, each student collaborates directly with a professor or advanced researcher in mutual exploration, rather than rote instruction, which enhances autonomy and confidence, further bolstering motivation [24], [25]. Mentors and program coaches continuously invite and encourage students into dialogue, building on co-investigation over didactic teaching, mirroring the college engineering education experience and building student engineering identity [72], [97]. Since mentors are selected primarily on their topic of interest/expertise, and secondarily on their personality and teaching/mentorship style, Hugo Mentors provides ample support to ensure mentors structure their interactions in a way that develops mentees' purpose and agency. In addition to pre-program orientation materials, mentors have access to a library of troubleshooting tools, “one pager” style handouts that address common concerns (e.g., assigning independent work as SMART goals, etc.), and are in regular contact with program coaches. Mentors regularly update program coaches with meeting notes, which are submitted via templated forms that break down programmatic and learning goals.

6) Supported growth: To tightly couple student struggle with high-motivational states, wrap-around support is provided to offset the onerous tasks associated with research (i.e. scheduling, maintaining bibliographic research records, annotating sources, etc). This frees up mental and emotional resources for the constructive friction key to deep technical learning [98], [99]. Program coaches and mentors, who are themselves given resources and personalized coaching on best practices, offer ample support to keep their emergent researchers on track for their chosen final goal [100].

Designated program coaches provide responsive support to kickstart metacognition, helping students identify or clarify an initial direction, then transitioning into facilitative roles once mentorships are underway. Beyond offering skill development support, these program coaches use students’ reported identity as a throughline as they help students articulate their project design, topic selection, and long-term exploration goals. The role of the program coach is therefore central to TMM design. They monitor student progress from behind the scenes by directly communicating with mentors to monitor progress and potential misalignment in pacing, communication, or scope while aiming for the least invasive interventions possible. While mentors offer subject-matter expertise, ensuring an individualized learning experience, program coaches operate as a “sounding board” or “guide on the side” for mentees as they further align their personal and engineering identities, which may be loosely coupled [101]. These crucial players expand students’ zones of proximal development while also nurturing their metacognitive regulation [46], [102].

III. METHODS

The surveys used to collect student data originated and were verified by others through sequential mixed-methods. This earlier external evaluation was conducted by the Organizational Behavior Division of Behavioral and Organizational Sciences at Claremont Graduate University. The surveys include the Claremont Purpose Scale, which measures constructs such as self-efficacy, purpose, and academic identity [103].

Here, we employed an exploratory multimethod design integrating quantitative and qualitative data to examine changes in students' purpose development, self-efficacy, and perceptions of mentorship effectiveness. We chose a multimethod approach since these data were originally collected to triangulate outcomes and verify the efficacy of TMM during development, and to capture participants' lived experience of mentorship.

Participants were high school students engaged in structured mentorships (using TMM) with university faculty between 2020–2025. Students ranged in age from 14 - 18 years old, and had finished some or all of high school. A supermajority of students were from the US, and represented a broad diversity of learning abilities, including gifted and talented, those with specific learning disabilities, and those with neurodevelopmental or physical conditions (including ADHD, ASD, visual and hearing impairments), and/or mental health disorders (anorexia, depression, anxiety, etc.).

This project did not fall under formal Institutional Review Board oversight; however, all data collection and analysis procedures were conducted by personnel trained in psychometric ethics, following the ethical standards and participant protection protocols consistent with IRB expectations for educational research.

A. Quantitative Methods

In multimethod educational research, descriptive quantitative analyses can provide meaningful numerical context without overextending inferential claims, particularly when constructs are developmental or metacognitive in nature [104]. Accordingly, descriptive statistics were used in conjunction with qualitative analysis to examine patterns and support triangulated interpretation.

While inferential statistical testing was not included for reasons outlined in Study Limitations, quantitative analysis ultimately included descriptive statistics that summarized response distributions and informed integration with qualitative themes.

Because TMM is designed to encourage transdisciplinary thinking and research, we were not able to purely categorize students into engineering and non-engineering categories. We therefore provided descriptive statistics on students across all disciplines, and then focused on quotes and qualitative analysis for students who explicitly mentioned engineering in their responses.

B. Qualitative Methods

Open-ended survey responses were analyzed using an iterative qualitative coding process situated within a multimethod analytic framework. We first grouped survey questions by common topical focus, and initial codes were inductively generated from participant responses within each group. These codes were then examined across responses and clustered into higher-order themes that captured shared patterns of meaning. To support analytic rigor and methodological coherence, qualitative codes and emergent themes were systematically compared with descriptive statistical findings from the quantitative analysis. We then conducted a focused re-reading of qualitative responses with the quantitative results in mind, aligning participant comments with their corresponding survey items to examine convergence, divergence, and elaboration across data sources. Throughout the analysis, attention was given to consistency in coding decisions and transparency in theme development to strengthen the credibility of our interpretations.

IV. STUDY LIMITATIONS

Several limitations should be considered when interpreting our findings. Despite our robust sample size, inferential pre-post quantitative comparisons were not informative due to well-documented ceiling effects and cognitive bias effects [105], [106]. To control for recalibration bias and cognitive biases, we focused on questions that followed the retrospective pre-test design. The absence of inferential pre-post quantitative comparisons limits the ability to draw causal claims about change over time. Additionally, reliance on self-reported measures introduces the possibility that shifts in students' metacognitive awareness, rather than underlying constructs themselves, influenced survey responses [106], [107]. Because TMM includes structured midpoint surveys in addition to post program reflections (see Figure 1), future analyses will be able to examine recalibration effects in students' self-assessments across time, an opportunity not available in the present cross-sectional analysis. Midpoint data are particularly valuable for constructs such as self-efficacy and identity, as they allow researchers to distinguish genuine declines in confidence from better metacognition awareness of their place at the start of a long post-secondary educational journey as learners gain awareness of task complexity. While our current integration of qualitative data helps contextualize these patterns, results should be interpreted as indicative of developmental trajectories rather than definitive measures of magnitude or effect.

V. RESULTS

After data sanitation, 195 of the 246 surveys collected were retained for analysis. Since patterns were consistent across all students participating in TMM, descriptive statistics are reported for the full sample, with illustrative quotes drawn from the subset of 46 students who explicitly referenced engineering. Survey answers were rated on a 5-point Likert scale ranging from 1 to 5 , with higher scores indicating greater agreement with statements (Strongly Disagree - Strongly Agree) or assessment of magnitude of change (No Gain - Very Large Gain).

TABLE I

STUDENT-REPORTED OUTCOMES FOLLOWING PARTICIPATION IN TMM

Foundationals	% "Large & Very Large" Gains
Technical skills	95%
Research skills	85%
Writing skills	78%
College readiness	98%
Independent learning	94%
Problem-solving	89%
Purpose & contribution	93%

Results presented above are drawn from the entire sample of respondents, which includes students that studied topics across all disciplines. For clarity, we have converted Likert "4" and "5" (agree and strongly agree) to "large gain" and "very large gain" to summarize these descriptive statistics in one table.

Descriptive patterns summarized in Table 1 were consistent across disciplines and informed subsequent qualitative analysis. The sections below incorporate illustrative student reflections from engineering-focused mentorships to contextualize these patterns and highlight how students experienced and articulated gains in self-efficacy, learning ownership, and purpose.

A. Self-efficacy & academic readiness

Across disciplines, students reported substantial gains in skills foundational to academic success and persistence. As summarized in Table 1, a large majority of students indicated they made "large" or "very large" improvements in technical (95%), research (85%), and writing (78%) skills following participation in The Mentorship Method. These gains were accompanied by increased confidence in students' readiness for college-level work (98%), and their ability to work independently (94%), suggesting that skill development within TMM was closely linked to students' perceived academic self-efficacy.

Engineering-focused students frequently described skill development as directly contributing to increased confidence and preparedness for future academic work. One student noted, *"I went from not knowing how to code to becoming someone who had a strong grasp on the basics of coding."* Others emphasized gains in research and writing, explaining that, *"This way of creatively thinking and crafting a review paper will help me in the future when writing review or research papers because I am better able to understand what to look for and what to emphasize as being most important."*

Students also framed these goals in forward-looking terms, highlighting the transferability of skills beyond the mentorship itself. As one student reflected, *"If I do any scientific writing in the future (college and after), I will have the skills I learned during the mentorship as a foundation. Additionally, I have become more comfortable reading scientific literature which is very helpful in all science classes I will take in the future."* Another student similarly noted, *"I learned to take problems one step at a time, which I have been using to transition from high school to college (which has different types of assignments)."*

In addition to technical competence, students described increased confidence in their ability to navigate challenges independently. As one student explained, *"The problem solving skills I have developed as a result of this mentorship are invaluable and will help me this coming year and throughout the rest of my academic and non-academic life."* Another shared, *"When I had any challenges, [my mentor] would walk me through how to solve them, further improving my problem solving skills."*

Altogether, these findings suggest that gains in academic self-efficacy were not limited to discrete skill acquisition but extended to students' confidence in directing and sustaining their own learning.

B. Learning ownership & metacognition

Beyond gains in academic skills and confidence, students demonstrated increased ownership over their learning processes and greater metacognitive agency. As reflected in Table 1, a large majority of participants reported gains in their ability to work independently (94%), and to adapt or pivot when encountering challenges (89%). These findings suggest that participation in The Mentorship Method supported not only skill development but also students' capacity to direct, regulate, and sustain their own learning over time.

Students frequently described learning ownership in terms of autonomy, self-direction, and responsibility for decision-making. Several emphasized the experience of being positioned as the primary driver of their work: *"The most meaningful aspects were the feeling of being in the* *driver's seat"*, rather than a passive recipient of instruction. As one engineering-focused student explained, *"This program helped me create my own learning path, and my own goals. [It] allowed me to pursue the program I wanted."* Another similarly reflected, *"One of the most meaningful aspects of the mentoring experience was that I was able to pursue independent study as a high schooler."*

This sense of ownership was often accompanied by increased confidence in managing complex or open-ended tasks. Students described learning to pivot in response to obstacles, *"What was most valuable to me was learning to adjust my research [direction] based on the availability of information."* Others highlighted mentor support as facilitative rather than directive, emphasizing guidance that preserved student agency: *"[My mentor] knew exactly how to help me and support me in my next steps…further improving my problem-solving skills."*

Students also connected learning ownership to pride in their work and sustained engagement, *"I am planning on taking a greater leadership role in my school's STEM publication so that others who write research papers can get more acknowledgement and take more pride in their work."* One participant described the value of receiving feedback on their final project, stating: *"The most meaningful aspects of the mentoring experience to me was talking about my review paper and being able to get feedback and help on something that I was incredibly proud of and had spent a lot of time on."* Cumulatively, these reflections illustrate how TMM supported students in developing not only independent learning behaviors but also a sense of responsibility and investment in their academic work.

As students assumed greater ownership over their learning processes, many also began to articulate clearer connections between their work, their emerging identities, and their longer-term academic and societal goals.

C. Purpose & identity alignment

In addition to gains in self-efficacy and learning ownership, students reported increased clarity around their academic interests, emerging identities, and longer-term goals. As summarized in Table 1, a supermajority of students felt they gained clarification regarding academic areas of interest (96%) and future career plans (76%). Many students also reported heightened awareness of the value of their own contributions (93%), indicating growing alignment between personal interests, academic pursuits, and considerations beyond the self.

Engineering-focused students frequently described the mentorship experience as clarifying not only what they wanted to study, but how they understood themselves as learners, researchers, and emerging professionals. Students articulated a stronger identification with engineering or research as a result of engaging in authentic scholarly practices, *"What was most meaningful was the process of learning to actually scope the research, write scientifically, and communicate effectively with a mentor…[it] solidified my idea of what I want to pursue in college and beyond."* One student reflected, *"I was generally interested in engineering, but I am now more interested in civil engineering and urban studies,"* and yet another, *"The mentorship helped me be more confident in my ambitions as a researcher."*

Students also linked their academic work to ethical considerations and societal impact, indicating a development of purpose. Some students described learning to translate technical knowledge for broader audiences, explaining,*"Writing a policy brief with recommendations that could actually be implemented and being able to send it to the governor and DOT has changed my perspective,"* and, *“As I learned how to write scientific articles that are accessible to people with a non-scientific background, the skill of converting scientific concepts into easily comprehensible ideas will also be a very important part of my life.”* Others emphasized applying disciplinary knowledge to real-world problems: *“I can use the knowledge and things I learned about air pollution to try and make more changes in the future."*

For some students, this alignment culminated in a sense of agency and pride in their ability to contribute to the broader community: *“I have [realized] that I am able to create a [medical] protocol that could help dictate change" and "The most meaningful aspects of this program were learning about the field of CTE from someone who knows a lot about it and then being able to contribute to the knowledge of the field myself."*

The students' reflections directly illustrate how participation in TMM supported students in integrating identity, ethical awareness, and purpose via academic work. These findings suggest that students' purpose and identity development within TMM develop alongside, rather than after, gains in self-efficacy and learning ownership.

VI. DISCUSSION & IMPLICATIONS

This study examined how The Mentorship Method™ (TMM), a pre-college mentorship system developed by Hugo Mentors, supports adolescents' development of self-efficacy, learning ownership, and purpose. Across a large and diverse sample, students report substantial gains in academic readiness, independent learning, and confidence in navigating complex and multi-step tasks, gains accompanied by increased clarity around academic interests, emerging identity, and intention to contribute to society beyond the self that were demonstrated through qualitative responses that shared their intention for increased involvement: *"I plan on getting more involved with administration given the success with my policy document,"* and *"I plan to take a bigger part in dev club and look further into getting into data analysis options at my school."*

Rather than viewing purpose and identity development as downstream outcomes of technical competence, our findings suggest that they develop alongside skill acquisition when mentorship environments are structured to support agency, reflection, and student-authored goals. This generates personal identity that encompasses engineering identity, being more robust to outside pressures and influences. Indeed, students reported alignment of personal and engineering identity with personal ethics and hobbies when prompted about the impact of their mentorships: *"I plan to, and have signed up for an ethical hacking course next year at my school,"* and *"As a result of my [mentorship in forensic science] I now run the criminal justice club at my school."* For engineering-focused students in particular, engagement in authentic research practices paired with guided reflection and individualized support appeared to strengthen both academic self-efficacy and alignment between personal values and engineering pursuits. These findings extend existing research on motivation and adolescent development by illustrating how purpose, identity, and self-efficacy can be operationalized as co-developing constructs within pre-college engineering mentorship programs [93], [108]. Prior work emphasizes the role of interest, belonging, and identity in persistence [109], but many pre-college programs still emphasize skill exposure without systematically integrating purpose development into program design.

Like so many other pre-college engineering programs, students enter the Hugo Mentors ecosystem aware of contextual cues or situational stimuli (e.g. YouTube channels, podcasts, news articles, etc.) which have triggered their emotions (e.g. situational interest, curiosity, surprise, or concern) [17], [110]. TMM leverages established motivation and self-efficacy theory by intentionally activating situational interest, then harnessing high-motivational states to get students into sustained effortful engagement through scaffolded mentorship, reflection, and student ownership, embarking on long, large-scale, sometimes uninteresting, and difficult research tasks [56], [111], [112], [113], [114]. With an attrition rate of 2% (representing just 12 students, 4 of which withdrew due to close friend or relative's death or their own severe illness), TMM's whole-student approach successfully guides students through identity development that is embedded in individualized learning experiences.

Our results align with theoretical models suggesting that activating emotions such as curiosity and hope can support engagement in long-term, cognitively demanding tasks, particularly when learners perceive their work as meaningful and self-authored. Students confirmed this: *"I would say that if you have an interest you want to deepen, and you don't feel like you could do it totally on your own, but you don't think you need a [proscribed] environment to explore it, [this program] is very good"* and *"Super cool! ...I think it's a super unique and SUPER helpful experience, especially for people who do a lot of independent work, or want to skill-build like me."* In this way, TMM demonstrates how purpose as a design principle can shape how students engage with engineering learning from the outset. *"This experience is unforgettable and it always puts a smile on my face each time I think about it."*

A. Implications

The findings have several implications for educators and institutions seeking to strengthen the pre-college engineering pipeline. First, purpose-driven mentorship can support recruitment into engineering pathways by helping students connect technical interests to personal values and societal impact. Nearly 3 in 5 young adults report that they lack “meaning or purpose” in their lives, and half report that their mental health is negatively influenced by “not knowing what to do with my life” [29]. This underscores the urgency of designing experiences that support students' emerging sense of direction, identity, and contribution; purpose-driven mentorship models such as TMM may help address these challenges by supporting students in articulating why engineering matters to them, not solely what they can do. By explicitly linking technical learning to personal values and societal impact, TMM appears to strengthen students’ motivation to engage deeply with challenging material and persist through difficulty. Identity alignment may be particularly important given the well-documented identity tensions and attrition that occur when students struggle to reconcile personal meaning with engineering culture [14], [16], [39]. Students who can identify why engineering matters to them persist through rigorous coursework and identity challenges encountered later in formal engineering education [15]. The emphasis on learning ownership and authentic collaboration mirrors professional engineering practice, potentially easing students’ transition into undergraduate research and project-based learning environments that demand independence, sustained effort, and comfort with ambiguity. By normalizing struggle as part of authentic engineering experiences and embedding reflection throughout the learning process, TMM supports students’ development of adaptive problem-solving strategies and metacognition/awareness that are critical for long-term persistence of engineering identity [115].

Finally, integrating reflection and identity work into mentorship design may broaden participation by validating diverse motivations for engaging in engineering, including ethical, interdisciplinary, and community-oriented goals. Our findings suggest that integrating purpose and identity development into pre-college engineering mentorship is not ancillary to technical training, but may be a key driver lever for fostering sustainable engagement and retention.

While TMM results in strong developmental outcomes, its highly individualized structure presents inherent scalability and access constraints. As implemented, TMM primarily benefits students with the resources to participate in out-of-school-time (OST) enrichment programs. Although a scholarship program exists, the majority of students represented in this dataset came from higher socioeconomic backgrounds. Responses from scholarship-supported students did not meaningfully differ from those of full-pay participants; however, the incidence of scholarship participation was insufficient to support a formal statistical comparison. This limitation reflects a broader tension common to high-impact enrichment interventions: the design features most strongly associated with student growth–deep personalization, supported mentorship, and flexible, student-authored learning trajectories–are also the most resource-intensive. Accordingly, the outcomes reported here should be interpreted as evidence for what is possible within a depth-oriented mentorship model, rather than as a claim of broad population-level impact. This tradeoff is not unique to TMM but is characteristic of many high-touch learning programs.

Fortunately, several design elements of TMM may soon be scalable with recent advances in technology and AI; Hugo Mentors is currently building an interactive digital tool that will provide students with many of the personalized guided prompts and customized suggestions that students have found so useful and inspiring. The digital tool replicates TMM's narrative-based intake process, explicit purpose articulation, and structured reflection cycles that anchor student learning to identity and agency, and could be embedded within group mentorship models, hybrid programs, or school-based pre-college engineering initiatives. Isolating and adapting these components in lower-cost, broader-reach settings represents an important direction for future work aimed at expanding access while preserving developmental impact, and could allow institutions to retain many of the developmental benefits observed here while expanding access to more diverse student populations.

B. Future Work

While the current surveys were not written with the present study in mind, and therefore reflect the limitations outlined earlier, future work will focus on reconfiguring instruments to more precisely capture engineering identity development and related motivational constructs. In particular, upcoming survey iterations will align with retrospective pre-test designs and be grounded in established engineering identity frameworks, including Godwin's 2016 model. This refinement should allow for more nuanced examination of how identity, purpose, and self-efficacy evolve over the course of mentorship.

A key direction for future research involves leveraging midpoint survey data (see Figure 1) to formally examine recalibration effects associated with students' developing metacognition (including patterns consistent with the Dunning-Kruger effect). Traditional pre-post designs often obscure these dynamics, since learners' increasing awareness of task complexity can depress self-assessments even as competence improves [106], [107]. Because TMM includes structured midpoint surveys alongside post-program reflections, future analyses will be able to trace changes in students' self-perceptions across time, capturing transitions from unconscious incompetence toward conscious incompetence and finally conscious competence. Empirically documenting this trajectory in a pre-college engineering context represented a rare methodological opportunity, as few interventions collect sufficiently granular longitudinal self-report data to evaluate these effects directly [116].

The authors are uniquely positioned to conduct a longitudinal person-centered study examining engineering identity development across the full duration of students' mentorship experience and beyond. To our knowledge, such a study would represent only the second of its kind in this domain [15]. Beyond tracking engineering identity over time, future research has the potential to capture a more holistic view of adolescent identity development by integrating academic, personal and societal dimensions. Future studies will be able to draw on rich historical data that contextualizes students' experiences across multiple perspectives because Hugo Mentors already collects structured feedback from parents and mentors. These data will be complemented by thoughtful and detailed mentor evaluations that document students' co-learning processes, offering additional insights into how mentorship interactions shape identity agency and learning trajectories. Moreover, Hugo Mentors has begun collecting college and post-college outcomes through alumni surveys and publicly available professional data sources, including LinkedIn searches, enabling longer-term examination of education and career pathways. This should allow future research to move beyond cross-sectional outcomes toward a more comprehensive understanding of how purpose-centered mentorship influences engineering identity formation, calibration of development of metacognition, persistence, and engagement across critical developmental transitions.

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