

Legacy Graphs as Tools for Reflection and Formation of Engineering Identity

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Introduction

This Theory/Methods full paper proposes an asset-based reflective and visualization methodology called *legacy graphing* to identify and activate strengths and to advance formation of engineering identity among students. Supporting undergraduate students' professional identity development has become a central goal in science and engineering education, given its explicit and latent associations with persistence, motivation, well-being, and long-term career trajectories [1], [2]. Despite its recognized importance, much of the existing literature emphasizes what factors contribute to identity development (e.g., interest, recognition, self-efficacy) rather than how students actively interpret, integrate, and reconstruct their identities over time as they encounter new experiences, challenges, and opportunities. We theorize *legacy graphs* as a tool to help identify and activate students' assets while simultaneously supporting the ongoing construction of professional identity

Legacy graphs combine time (or temporality), developmental vectors (transitions, experiences, accomplishments), and context-rich narrative to derive trajectories of identity statuses among undergraduate students. This work is grounded in established developmental theories, including Marcia's Identity Status model [3], which distinguishes four identity statuses based on the strength of the individual's *exploration* of alternatives and their *commitment* to specific beliefs, values, or roles. These status trajectories represent different configurations of commitment and exploration that persist over time: identity *diffusion* (low exploration, low commitment), identity *foreclosure* (low exploration, high commitment), identity *moratorium* (high exploration, low commitment), and identity *achievement* (high exploration, high commitment). We posit that *legacy graphing* can provide a reliable way to characterize these identity status trajectories. Furthermore, aligned with social cognitive theory, the technique can act as an intentional intervention to foster self-efficacy, while also recognizing and mobilizing inherent individual and relational capacity and strengths (or assets) for developmental growth.

Background

To situate our work appropriately, we first outline the theoretical foundations of identity development, drawing on developmental perspectives originating in Erikson's theory of psychosocial development and Marcia's identity status model. We then review key frameworks and empirical work on professional identity formation, with particular attention to post-secondary science and engineering education contexts.

Foundational Identity Research: From Erikson to Marcia

The conceptual foundation of identity studies lies in the work of Erik Erikson, who characterized the primary developmental challenge of adolescence as the resolution of the tension between identity synthesis and role confusion. Erikson posited that identity represents a subjective sense of invigorating sameness and continuity, allowing an individual to integrate their past experiences with future aspirations in a coherent social framework. While Erikson's theories were profoundly influential, they were criticized for being difficult to measure empirically, often framing identity as a global, dichotomous outcome rather than a process of ongoing negotiation. James Marcia addressed this limitation by developing the identity status interview, which

operationalized identity development through two observable dimensions: exploration and commitment. Exploration refers to a period of active questioning, reflection, and engagement in searching among meaningful alternatives for goals, values, and beliefs. Commitment refers to the degree of personal investment an individual makes in a specific choice, manifesting as behaviors aligned with those values. By crossing these two dimensions, Marcia identified four distinct identity statuses that describe an individual's current position in the identity-formation process. This paradigm provided the first empirical scaffolding for Erikson's psychosocial theories related to identity work. Marcia's paradigm characterizes the pathways of self-discovery as fluid statuses that individuals may inhabit or transition through based on their environmental interactions, rather than a linear sequence of stages. The four statuses – achievement, moratorium, foreclosure, and diffusion – each represent a unique approach to the psychosocial tasks of adolescence and emerging adulthood (see typology in Table 1).

Table 1. Marcia's Four-Status Typology of Identity Development and Corresponding Psychosocial Manifestations

High Exploration	Identity Moratorium Individuals are actively exploring but feel anxious and emotionally tense. They are frequently passionate about social and moral issues but struggle to make firm choices.	Identity Achievement Characterized by high self-esteem, an internal locus of control, and high critical thinking skills. Individuals feel secure in their self-views and are better prepared for social and professional relationships.
	Identity Diffusion The least stable status, characterized by confusion and a lack of meaningful direction. Diffused individuals often feel out of control of their futures and are easily influenced by peers.	Identity Foreclosure Commitments are adopted without prior exploration, usually dictated by authority figures such as parents. These individuals are often conventional but may be rigid and fragile in their self-esteem.
	Low Commitment	High Commitment

The developmental maturity of these statuses is often evaluated in terms of their psychological correlates. For example, individuals in the *achievement* and *foreclosure* statuses, both characterized by high commitment, tend to exhibit higher wellness and lower psychological distress compared to those in moratorium or diffusion. However, *foreclosure* is considered less mature than *achievement* because it lacks the internal foundation of self-exploration. Research consistently shows that *achievement* is associated with higher levels of conscientiousness and emotional stability, while *diffusion* is linked to neuroticism and poor coping strategies.

In the decades following Marcia's original formulation, other researchers recognized that the two-dimensional model of exploration and commitment was insufficient to capture the intricacies of identity maintenance over time. This led to the development of expanded models, most notably by Luyckx and colleagues [4], [5], who decomposed exploration and commitment into five distinct processes: commitment making, identification with commitment, exploration in breadth, exploration in depth, and ruminative exploration. This refinement allows for a dual-

cycle understanding of identity, where the individual moves between a formation cycle (deciding on a path) and a maintenance cycle (validating and internalizing that path).

- *Commitment Making*: The act of settling on specific identity choices such as engineering major or a career path.
- *Identification with Commitment*: The extent to which an individual identifies with and feels certain about their choices. This is an important predictor of adjustment and well-being.
- *Exploration in Breadth*: Searching for different possibilities before making a commitment.
- *Exploration in Depth*: The evaluation of current commitments to determine if they still align with one's goals and values. This process is essential for long-term stability.
- *Ruminative Exploration*: A dysfunctional state where searching leads to increased uncertainty and distress rather than commitment. This often characterized the *troubled diffusion* cluster.

The introduction of these five dimensions (see Table 2) has allowed researchers to identify more nuanced clusters beyond Marcia's four statuses. These include *carefree diffusion* (low exploration and low commitment without distress) and *troubled diffusion* (high ruminative exploration and low commitment). This granular approach is particularly relevant for undergraduate students who may be highly committed to a major (*foreclosure*) but engage in little depth-based exploration to validate that choice.

Table 2. Processes of Personal Identity Formation

Identity Status	Function in Development	Psychological manifestation
Commitment Making	Establishing direction	Promotes stability and focus
Identification with Commitment	Internalization of self	Highest association with self-esteem and adjustment
Exploration in Breadth	Expanding horizons	Essential for avoiding early foreclosure
Exploration in Depth	Validating choices	Strengthens resilience & identity coherence
Ruminative Exploration	Maladaptive searching	Linked to anxiety and lack of self-clarity

Professional Identity Formation in Post-secondary Education

Professional identity (e.g., science identity, engineering identity) is increasingly recognized as a distinct yet overlapping domain of general or personal identity development [6], [7]. For undergraduate students, the college or university may serve as the primary site of professional socialization, where academic coursework, experiential learning opportunities, industry and/or research internships, and interactions with peers and faculty facilitate the transition from a student identity to a professional identity. The process of professional identity formation may also be shaped by the specific demands and social status of the chosen profession or discipline. In traditional engineering fields (e.g., electrical or mechanical engineering), students may often enter with high and stable professional identities, likely due to clear career pathways and high perceived social status. In contrast, students in less defined and/or interdisciplinary fields (e.g., biomedical engineering) may experience a decline in professional identity as they encounter the complexities and ambiguities of the role during their studies. For many students, professional identity is built through three primary factors: recognition (feeling that others see them as

competent), interest (a desire to engage in the field), and performance or competence (the belief in their ability to perform required tasks) [8]. When these factors are validated through authentic learning experiences, such as internships and/or other high-impact practices, students are more likely to achieve identity synthesis. While these constructs have advanced our understanding of identity-related outcomes, they often remain analytically separated from the lived, longitudinal narratives through which students experience professional growth. The undergraduate experience also introduces liminal spaces, i.e., periods of transition where students are betwixt and between roles [9]. These transitions (e.g., co-op or engineering design experiences) are important for identity work because they encourage students to renegotiate their connection to the discipline. Successful navigation of these spaces requires professional vision or knowledge of shared practices by which members see and articulate phenomena in their field.

Together, both developmental and professional identity theories emphasize identity as a dynamic, interpretive process shaped through experience over time. However, translating these frameworks into methodological approaches that can both capture and support identity development in engineering remains an ongoing challenge. In particular, existing methods often prioritize static measures or factor-based constructs and limit insight into how students themselves make sense of their professional trajectories. To address this gap, we next describe an approach that operationalizes these theories through visual and narrative tools designed to identify, interpret, and support professional identity development.

Approach

Grounded in developmental identity theory and professional identity formation frameworks, our approach, *Legacy Graphing*, emphasizes students' meaning-making as they reflect on experiences, navigate professional spaces, and negotiate evolving commitments. Adapted from systems thinking and cognitive engineering [10], *Legacy Graphs* are visual representations that enable students to represent how their experiences evolve and/or change over a period of time and to contextualize those changes through reflective storytelling.

Constructing and Applying Legacy Graphs

The application of *legacy graphs* follows a semi-structured sequence of activities that is designed to scaffold reflection while preserving students' interpretive agency. The activity typically begins with a brief, five-minute free-write responding to the prompt: "What sparked your interest in engineering?". This prompt is designed to orient students toward their lived and early identity-relevant experiences. The free-write also serves as a cognitive warm-up and helps students surface tacit motivations, formative influences, and early assumptions about engineering before engaging in visual representation. Importantly, this step foregrounds inherent assets such as curiosity, problem-solving tendencies, and/or linguistic and navigational capital [11].

Following the free-write, students are asked to define a temporal frame relevant to their engineering trajectory. This may include an academic term or year, a multi-year undergraduate experience, or even a decade. The x-axis represents the timeline of interest, and the y-axis represents observed behaviors (e.g., accomplishments, experiences, transitions) of interest to the student. This framing allows students to foreground aspects they perceive as meaningful for their professional development. Students have substantial freedom in designing their *legacy graphs*, including the time period of interest, the types of experiences to include, and the overall design

(e.g., shapes, trends, and colors). Importantly, *legacy graphs* are not intended to be standardized but rather meant to reflect the students' own perceptions of behaviors and their impact, in ways that are personally relevant and meaningful. A prototype of a *legacy graph* is shown in Figure 1.

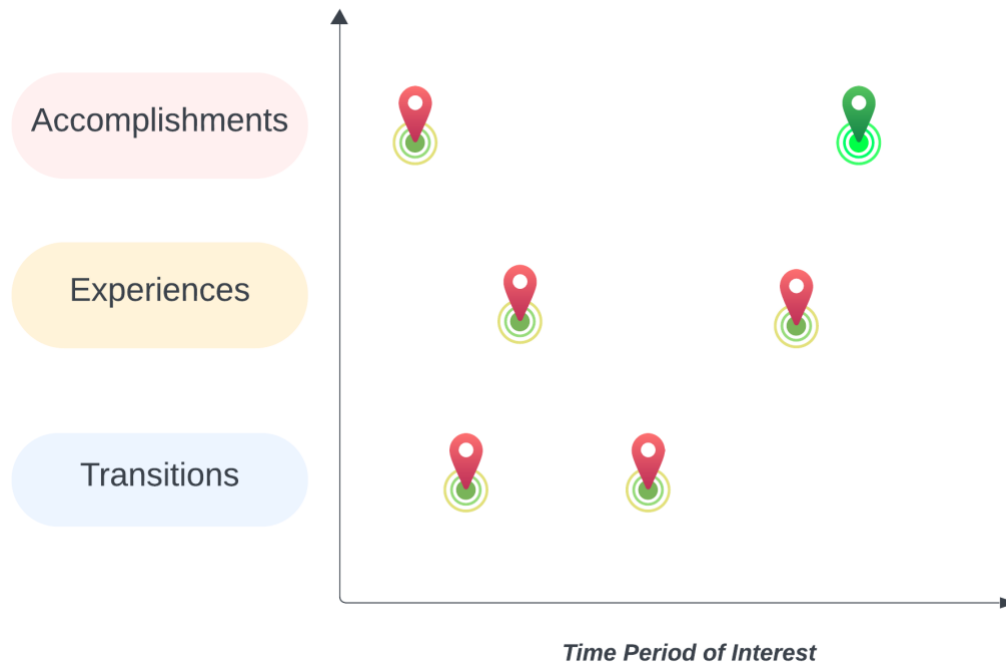


Figure 1. Prototypical Demonstration of a *Legacy Graph*

Students then revisit the observed behaviors from the free-write and organize them into three to four categories (e.g., experiences; milestones or accomplishments; transitions or turning points; moments of affirmation, challenge, and/or uncertainty). Students are encouraged to reflect on how these behaviors were interpreted and how they contributed to changes in their sense of themselves as engineers. Students map these behaviors and experiences onto the x-axis at points corresponding to when they occurred.

Using the identified time period and mapped behaviors, students sketch a two-dimensional *legacy graph*. Students are encouraged to focus on shape, inflection points, and relative change (e.g., growth, stability, or disruptions) rather than precision. This initial sketch functions as a provisional artifact that captures students' first-pass interpretations of their professional trajectories. Following the initial sketching activity, students are provided with tools and guidance to translate their draft into a digital *legacy graph*. This step allows students to refine their representations while maintaining ownership over content and interpretation.

Alongside the digital *legacy graph*, students engage in deeper reflection on each identified behavior or experience. This reflection may take the form of written narratives or short video reflections and is guided by prompts such as: What important elements have changed over time? How has a certain behavior changed over time? Did an experience reinforce, challenge, or reshape your professional goals or commitments? These professional identity narratives provide explanatory depth for the visual representation and attempt to reveal how students make meaning of experiences. Students are encouraged to explicitly link narrative reflections to specific regions

or inflection points on their *legacy graphs*. Together, the digital graph and accompanying narratives form an integrated artifact that captures both the temporal dynamics and interpretive processes of identity development.

Facilitation and implementation considerations

This method can be implemented flexibly across instructional, advising, and co-curricular contexts. A typical initial session requires approximately 30–45 minutes, including free-writing, initial graphing, and discussion. Follow-up reflections and digital graph development may be completed asynchronously. Facilitators are encouraged to (a) emphasize that there are no “correct” graphs or trajectories, (b) reinforce the interpretive and reflective purpose of the activity, and (c) create space for optional discussion or peer sharing, while respecting individual preferences. The approach is intentionally asset-oriented and adaptable to different student groups and institutional contexts.

From an analysis perspective, *legacy graphs* constitute rich qualitative artifacts that can capture longitudinal, non-linear identity trajectories. Analysis may include interpretive patterns such as examination of inflection points and turning moments, identification of recurring themes in meaning-making, and comparison of identity trajectories across time or contexts. Importantly, the focus is on understanding how students interpret experiences and construct professional identity over time. This structured application of *legacy graphs* serve both analytical and developmental purposes. Analytically, the artifacts reveal how students interpret experiences, recognize assets, and construct professional meaning over time. Developmentally, the process functions as an intervention by prompting intentional reflection, supporting identity exploration, and enabling students to articulate evolving commitments to engineering.

Study Setting

The methods described in this paper are being developed and applied within a larger, extramurally-funded, longitudinal project focused on undergraduate professional identity development and asset-based practices in engineering education. The project is situated at a public, land-grant, Hispanic-Serving Institution and is embedded within a co-curricular engineering program designed to support students’ professional growth. The program is organized around annual cohorts of approximately 12 undergraduate engineering students, with new cohorts formed each academic year. Students are drawn from multiple engineering disciplines, supporting cross-disciplinary dialogue. Participation in the program extends longitudinally and allows students to engage in recurring reflective activities, including further development and maintenance of *legacy graphs* and professional identity narratives. The cohort-based structure provides continuity while also enabling individual variation in timing, experiences, and identity trajectories. The cohort-based structure also provides opportunities for students to identify and reflect on their experiences and strengths collaboratively, allowing them to co-construct meaning and give constructive feedback to each other. Importantly, the setting emphasizes asset-based engagement, positioning students’ experiences, skills, and perspectives as resources for professional identity development.

Discussion

This paper advances a theory-informed approach for examining and supporting professional identity development among undergraduate engineering students. Drawing on developmental

identity theories and professional identity formation frameworks, we conceptualize identity as a longitudinal, interpretive process shaped through experience, reflection, and meaning-making [12]. The integration of *legacy graphs* with professional identity narratives provides a concrete mechanism for operationalizing this perspective.

Developmental theories emphasize exploration, commitment, and identity reconstruction over time, while sociocultural perspectives highlight participation, professional vision, and situated meaning-making. The *legacy graph* approach bridges these traditions by enabling students to visualize how they interpret their evolving participation in engineering contexts and how those interpretations shift across experiences and transitions, offering a methodological approach that both qualitatively captures and supports identity development. Rather than mapping directly onto predefined identity statuses, the graphs externalize these processes and allow students to represent periods of questioning, growth, stability, or disruption over time. Inflection points and shifts in trajectory, for example, can be understood as moments of exploration or reconsideration, while sustained patterns may reflect emerging or consolidated commitments. Thus, *legacy graphs* can translate abstract developmental constructs into temporally grounded, student-generated representations of identity formation. In doing so, the method offers an alternative to dominant factor-based models of professional identity formation. The longitudinal and versioned nature of the legacy graphs further supports identity reconstruction by allowing students to revisit, reinterpret, and reauthor their graphs and professional narratives over time.

Positionality

The development of the *legacy graph* methodology is informed by the authors' engagement in engineering education research, learning sciences, and asset-based practices. The approach emerged through iterative design and application within a longitudinal, co-curricular engineering program that prioritizes reflective practice, student agency, and professional growth. The authors approach identity development from a stance that views students as active constructors of professional meaning rather than passive recipients of disciplinary norms. This perspective shapes both the design of the tools and the facilitation strategies employed, emphasizing interpretive flexibility, student ownership, and respect for different pathways into and through engineering. While grounded in established identity theories, the methods were intentionally designed to remain open-ended, allowing students to define what aspects of identity mattered most to them and how those aspects evolved over time. The institutional context and setting provided a generative space for methodology development with attention to place, community, and culture.

Limitations

Several limitations of the proposed approach warrant consideration. *First*, the *legacy graph* methodology relies on self-reported, retrospective interpretation, which may be influenced by recall bias or present-oriented sensemaking. However, this limitation is also a feature of the method, as the goal is not to reconstruct objective histories but to understand how students interpret and re-interpret their experiences over time.

Second, the method is time-intensive relative to survey-based approaches and may require facilitation expertise to ensure that reflection remains supportive rather than evaluative. While the initial implementation is designed to be low-barrier, sustained longitudinal use benefits from institutional commitment and thoughtful integration into curricular or co-curricular structures.

Third, the study setting (a small, cohort-based co-curricular program) may limit direct generalizability to larger or less structured environments. Nevertheless, the core principles of the approach (e.g., visualizing temporal identity trajectories, integrating narrative reflection, and treating tools as developmental artifacts) can be adapted to a wide range of educational contexts, disciplines, and institutional types.

Future work may explore how *legacy graphs* function across different populations, how facilitation strategies influence identity sensemaking, and how longitudinal *legacy graphs* evolve as students transition into early professional practice. Additionally, empirical studies may examine how engagement with these tools intersects with persistence, agency, and professional decision-making.

References

- [1] B. E. Hughes, W. J. Schell, B. Tallman, R. Beigel, E. Annand, and M. Kwapisz, “Do I Think I’m an Engineer? Understanding the Impact of Engineering Identity on Retention,” presented at the 2019 ASEE Annual Conference & Exposition, Jun. 2019. Accessed: Jan. 26, 2026. [Online]. Available: <https://peer.asee.org/do-i-think-i-m-an-engineer-understanding-the-impact-of-engineering-identity-on-retention>
- [2] M. E. Lockhart and K. Rambo-Hernandez, “Investigating engineering identity development and stability amongst first-year engineering students: a person-centred approach,” *Eur. J. Eng. Educ.*, vol. 49, no. 3, pp. 411–433, May 2024, doi: 10.1080/03043797.2023.2262412.
- [3] J. Kroger and J. E. Marcia, “The Identity Statuses: Origins, Meanings, and Interpretations,” in *Handbook of Identity Theory and Research*, S. J. Schwartz, K. Luyckx, and V. L. Vignoles, Eds., New York, NY: Springer, 2011, pp. 31–53. doi: 10.1007/978-1-4419-7988-9_2.
- [4] K. Luyckx *et al.*, “Capturing ruminative exploration: Extending the four-dimensional model of identity formation in late adolescence,” *J. Res. Personal.*, vol. 42, no. 1, pp. 58–82, Feb. 2008, doi: 10.1016/j.jrp.2007.04.004.
- [5] K. Luyckx, S. J. Schwartz, L. Goossens, W. Beyers, and L. Missotten, “Processes of Personal Identity Formation and Evaluation,” in *Handbook of Identity Theory and Research*, S. J. Schwartz, K. Luyckx, and V. L. Vignoles, Eds., New York, NY: Springer, 2011, pp. 77–98. doi: 10.1007/978-1-4419-7988-9_4.
- [6] M. Head and S. B. Wilson, “Identifying differences in STEM self-efficacy, sense of belonging, and STEM professional identity statuses among diverse learners,” *Stud. High. Educ.*, vol. 0, no. 0, pp. 1–18, May 2025, doi: 10.1080/03075079.2025.2505927.
- [7] A. Patrick, M. Andrews, C. Riegle-Crumb, M. R. Kendall, J. Bachman, and V. Subbian, “Sense of belonging in engineering and identity centrality among undergraduate students at Hispanic-Serving Institutions,” *J. Eng. Educ.*, vol. 112, no. 2, pp. 316–336, 2023, doi: 10.1002/jee.20510.
- [8] A. Patrick and M. Borrego, “A Review of the Literature Relevant to Engineering Identity,” presented at the 2016 ASEE Annual Conference & Exposition, Jun. 2016. Accessed: Jan. 26, 2026. [Online]. Available: <https://peer.asee.org/a-review-of-the-literature-relevant-to-engineering-identity>
- [9] S. A. Claussen, J. Y. Tsai, K. Johnson, J. Blacklock, and J. A. Leydens, “Not an Engineer Yet: Manifestations of Liminal Engineering Identities,” *Stud. Eng. Educ.*, vol. 4, no. 2, Nov. 2023, doi: 10.21061/see.89.

- [10] L. Calancie, S. Anderson, J. Branscomb, A. A. Apostolico, and K. H. Lich, “Using Behavior Over Time Graphs to Spur Systems Thinking Among Public Health Practitioners,” *Prev. Chronic. Dis.*, vol. 15, p. E16, Feb. 2018, doi: 10.5888/pcd15.170254.
- [11] V. Subbian, G. N. Perera, A. Shivers-McNair, F. Lopez, and H. Budinoff, “Translating Evidence on Asset-based Pedagogies into Engineering Education Practice,” presented at the 2025 ASEE Annual Conference & Exposition, Jun. 2025. Accessed: Apr. 29, 2026. [Online]. Available: <https://peer.asee.org/translating-evidence-on-asset-based-pedagogies-into-engineering-education-practice>
- [12] S. Reissner and E. Armitage-Chan, “Manifestations of professional identity work: an integrative review of research in professional identity formation,” *Stud. High. Educ.*, vol. 49, no. 12, pp. 2707–2722, Dec. 2024, doi: 10.1080/03075079.2024.2322093.