From STEM Identity to Engineering Identity: A Critical Review of Theoretical Development and Emerging Research Directions

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Abstract
Engineering identity has become an important construct in engineering education research because of its influence on student engagement, persistence, belonging, and professional development. However, its theoretical foundations remain dispersed across psychology, sociology, science education, STEM education, and engineering education. This paper presents a structured critical review of engineering identity research by tracing its development from foundational identity theories through science and STEM identity frameworks to contemporary engineering identity models. Drawing on 49 core publications published primarily between 2000 and 2026, the review shows that engineering identity has gradually consolidated around three core dimensions: interest, performance and competence, and recognition. Contemporary scholarship, however, has expanded beyond this tripartite structure to include agency, belonging, emotional experience, developmental perspectives, contextual variation, and professional readiness. The review identifies key challenges in the literature, including conceptual fragmentation, methodological concentration, Western-centred evidence, and limited longitudinal understanding. Based on these findings, the paper proposes future research directions that emphasise contextualisation, ASEAN and Global South perspectives, industry readiness and employability, longitudinal inquiry, and more integrated identity frameworks. This review contributes by consolidating the theoretical evolution of engineering identity and clarifying opportunities for future conceptual and empirical development.

Keywords: Engineering Identity; STEM Identity; Science Identity; Engineering Education; Identity Development.

1. Introduction

Engineering identity has become an important concept in engineering education research because it helps explain how students develop a sense of belonging, confidence, and professional self-understanding within engineering. Beyond acquiring technical knowledge, students need to see themselves, and be recognised by others, as legitimate members of the engineering community. This identity formation process is important because it influences students' motivation, persistence, engagement, and long-term commitment to engineering pathways (Tonso, 2006a; Carlone & Johnson, 2007; Godwin, 2016; Patrick et al., 2018).

The growing interest in engineering identity reflects a broader shift in engineering education research. Earlier work in STEM education often focused on achievement, participation, and retention, but more recent scholarship has increasingly examined how students construct disciplinary and professional identities over time. Identity is no longer viewed only as an internal psychological trait. Instead, it is understood as a socially situated and relational process shaped by participation, recognition, belonging, and interaction within educational and professional communities (Gee, 2000; Wenger, 1998). From this perspective, becoming an engineer involves more than completing an engineering programme. It also involves gradually internalising the values, practices, expectations, and social meanings associated with engineering.

The theoretical roots of engineering identity research can be traced to broader scholarship on identity development, science identity, and STEM identity. Foundational work by Carlone and Johnson (2007) conceptualised science identity through the dimensions of competence, performance, and recognition. Their model was significant because it showed that disciplinary identity depends not only on what individuals know, but also on how they perform that knowledge and how they are recognised by others. Hazari et al. (2010) later extended this discussion within physics education by incorporating interest as a central motivational dimension linked to persistence. These models provided an important foundation for later engineering identity research because they established identity as a multidimensional construct shaped by both internal self-perception and external validation.

Building on this foundation, Godwin (2016) adapted the identity framework to engineering

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education by conceptualising engineering identity through three key dimensions: interest, performance and competence, and recognition. This model has become one of the most widely used approaches in engineering identity scholarship because it offers clear constructs for examining how students identify with engineering. Subsequent studies have continued to support the importance of these dimensions, particularly the roles of interest and recognition in shaping students' engineering self-identification and persistence (Godwin et al., 2016; Patrick et al., 2018; Verdín, 2021). However, while this model has provided important conceptual and empirical clarity, engineering identity research has also expanded beyond these original dimensions to include agency, belonging, emotional experience, gendered experience, and developmental progression.

Despite these advances, the literature remains theoretically and methodologically fragmented. Engineering identity has been examined through multiple lenses, including social constructivism, communities of practice, social cognitive career theory, possible selves theory, identity-based motivation, and social identity theory. Each of these perspectives contributes useful insight, but they are not always integrated into a coherent explanation of how engineering identity develops. Some studies emphasise motivation and self-efficacy, while others focus on recognition, belonging, participation, or sociocultural positioning. As a result, the field has developed a rich but uneven body of knowledge, where theoretical models and empirical findings sometimes operate in parallel rather than being critically synthesised.

Another important limitation is the strong concentration of engineering identity research within Western educational contexts. Many influential models and empirical studies have been developed and validated in North American or Western higher education systems. These studies have generated valuable insights, but their direct applicability to non-Western, collectivist, and policy-driven education systems remains underexamined. This is important because engineering identity does not develop in a cultural vacuum. Students' decisions, motivations, and professional self-understanding may be shaped by family expectations, institutional structures, national policy priorities, accreditation systems, labour market conditions, and broader societal perceptions of engineering. Therefore, models developed in individualistic educational settings may not fully explain engineering identity formation in contexts where collective expectations and structural conditions play a stronger role.

The current literature also shows methodological imbalance. Many engineering identity studies rely heavily on quantitative survey-based approaches, particularly because identity dimensions such as interest, performance and competence, and recognition can be operationalised through validated instruments. While this has strengthened measurement precision and allowed large-scale analysis, it may also reduce identity to measurable constructs and underrepresent lived experience, contextual meaning-making, and sociocultural negotiation. Earlier sociocultural and ethnographic studies showed that engineering identity is deeply shaped by institutional culture, peer norms, participation, and recognition. Therefore, future engineering identity research needs to balance measurement-based approaches with interpretive, contextual, and qualitative perspectives that can capture how identity is experienced and negotiated in specific educational settings.

In addition, engineering identity research has increasingly recognised that identity development is not static. Students' sense of becoming engineers evolves across educational and professional stages, from early STEM exposure to undergraduate participation, industrial training, postgraduate development, and professional practice. However, many existing studies examine identity at isolated stages rather than as a developmental continuum. This creates a gap in understanding how early interest, university experiences, social recognition, and professional exposure interact over time to support or weaken engineering identity. A more integrated understanding is needed to explain how identity develops across transitions from school to university and from university to the engineering profession.

Although several reviews have examined aspects of engineering identity, STEM identity, and engineering education, including definitions, measurement approaches, development factors, and higher education contexts (Patrick & Borrego, 2016; Morelock, 2017; Rodriguez et al., 2018; Co & Chen, 2025), limited attention has been given to synthesising the theoretical progression from STEM identity to engineering identity while critically examining the conceptual, methodological, and contextual challenges that continue to shape the field. This review addresses that gap by providing an integrated analysis of the development, consolidation, and future directions of engineering identity scholarship.

Given these gaps, this paper presents a critical review of the theoretical development of engineering identity research. The purpose of the review is to trace the conceptual progression from general identity theories and STEM identity frameworks to engineering-specific identity models, while critically examining how the field has evolved, consolidated, and expanded. Specifically, the paper aims to: (1) review the theoretical foundations informing STEM and engineering identity research; (2) examine the development of major engineering identity models and dimensions; (3) critically analyse conceptual, methodological, and contextual limitations in existing scholarship; and (4) propose future research directions for more contextually responsive engineering identity research.

This review contributes to engineering education scholarship in three ways. First, it synthesises the theoretical progression from STEM identity to engineering identity, clarifying how key constructs such as interest, performance and competence, and recognition became central to the field. Second, it critically examines the expansion of engineering identity research beyond the tripartite model by considering agency, belonging, emotion, gender, and developmental perspectives. Third, it highlights the need for more contextually responsive identity research, particularly in non-Western and Global South settings where sociocultural, institutional, and professional conditions may shape identity formation differently.

The paper is structured as follows. Section 2 explains the review methodology. Section 3 discusses the theoretical foundations of identity development relevant to engineering education. Section 4 traces the movement from STEM identity to engineering identity. Section 5 reviews major engineering identity models and dimensions. Section 6 critically analyses key limitations in existing scholarship. Section 7 outlines emerging research directions. The final section concludes by emphasising the need for more integrated, developmental, and contextually grounded approaches to engineering identity research.

2. Review Methodology

2.1 Review Design

This study employed a structured critical review approach to examine the theoretical development, conceptual evolution, and emerging directions of engineering identity research. Unlike systematic literature reviews that primarily focus on exhaustive identification and quantitative synthesis of studies, a structured critical review aims to critically analyse, interpret, and integrate theoretical and empirical scholarship to generate deeper conceptual understanding and identify research gaps. This approach was considered appropriate because the objective of the present review was not merely to catalogue existing studies, but to examine how engineering identity has evolved from broader identity traditions and to evaluate the strengths, limitations, and future directions of the field.

The review was guided by principles of transparency, relevance, and conceptual synthesis. Particular attention was given to studies that contributed significantly to the development of identity theory, STEM identity, science identity, and engineering identity scholarship. The review also considered contemporary studies that expanded or challenged existing understandings of engineering identity through new theoretical, methodological, or contextual perspectives.

2.2 Literature Search Strategy

The literature search was conducted using major academic databases commonly used in engineering education and educational research, including Scopus, Web of Science, ERIC, and Google Scholar. These databases were selected because they provide broad coverage of engineering education, STEM education, identity research, and higher education scholarship.

The search process utilised combinations of the following keywords and search terms:

- "engineering identity"
- "engineering student identity"
- "professional identity in engineering"
- "STEM identity"
- "science identity"
- "engineering education"
- "identity development"
- "engineering persistence"
- "engineering belonging"
- "engineering recognition"
- "engineering self-concept"

Additional studies were identified through backward and forward citation tracking of highly influential publications, particularly foundational works by Carlone and Johnson (2007), Hazari et al. (2010), Godwin (2016), Wenger (1998), and Gee (2000). This process enabled the identification of seminal studies that have significantly influenced the development of engineering identity scholarship.

2.3 Inclusion and Exclusion Criteria

To ensure relevance and quality, studies were selected based on several inclusion criteria. Included studies were:

1. Published in peer-reviewed journals, conference proceedings, academic books, or recognised research reports.
2. Focused on identity development within STEM, science, engineering, or related educational contexts.
3. Published primarily between 2000 and 2026, while allowing inclusion of earlier seminal theoretical works that informed contemporary identity scholarship.
4. Relevant to theoretical, conceptual, empirical, or methodological discussions of identity development.
5. Written in English.

Studies were excluded if they:

1. Focused exclusively on technical engineering content without discussion of identity-related constructs.
2. Addressed professional identity outside STEM or engineering contexts without clear conceptual relevance.

3. Were duplicate publications or non-scholarly sources.
4. Provided insufficient theoretical or empirical contribution to the objectives of the review.

The inclusion of both foundational and contemporary studies ensured that the review captured the historical development of engineering identity while also reflecting recent advances in the field.

2.4 Data Analysis and Synthesis

The selected literature was analysed through an iterative process of reading, comparison, categorisation, and thematic synthesis. Rather than treating studies as isolated sources of information, the review sought to identify patterns, theoretical continuities, conceptual shifts, and emerging trends across the literature.

The analysis proceeded through four stages. First, foundational theories relevant to identity development were identified and examined. These included Identity Theory, Social Identity Theory, Communities of Practice, Social Cognitive Career Theory, Identity-Based Motivation Theory, and related perspectives. Second, the evolution of STEM and science identity scholarship was analysed to understand how engineering identity emerged from earlier disciplinary identity research. Third, major engineering identity models and dimensions were compared and synthesised. Finally, recurring conceptual, methodological, and contextual limitations were identified to establish future research directions. Following the screening, selection, and synthesis process, 49 core publications were retained for detailed thematic analysis. These publications comprised foundational theoretical works, influential engineering identity frameworks, and recent empirical studies that collectively informed the critical synthesis presented in this review.

Throughout the analysis, emphasis was placed on identifying areas of convergence and divergence across studies, examining the contexts in which theories were developed and validated, and evaluating the extent to which existing frameworks addressed diverse educational and sociocultural settings.

2.5 Scope and Limitations of the Review

Although the review adopted a structured and transparent search strategy, it does not claim to represent an exhaustive systematic review of all engineering identity literature. Instead, the review prioritised influential, highly cited, and conceptually significant studies that contributed directly to the development of engineering identity scholarship. Consequently, some relevant studies may not have been included.

Nevertheless, the review provides a comprehensive synthesis of the major theoretical traditions, empirical developments, and emerging research directions that have shaped contemporary understanding of engineering identity. By integrating foundational theories, established models, and recent scholarship, the review offers a critical perspective on the evolution of engineering identity research and highlights opportunities for future conceptual and contextual advancement. The next section therefore examines the theoretical foundations that informed this development.

3. Theoretical Foundations of Engineering Identity Research

Engineering identity research is grounded in a broad theoretical tradition that spans psychology, sociology, science education, STEM education, and engineering education. Although contemporary engineering identity studies often focus on specific constructs such as interest, performance and competence, and recognition, these constructs did not emerge in isolation. They developed from earlier theories that explain how individuals form self-understandings, participate in social groups, imagine future selves, and gain recognition within communities of practice.

This section reviews the major theoretical perspectives that have shaped engineering identity scholarship. The discussion is organised thematically so that closely related theories can be examined together according to their shared assumptions about identity development. Identity Theory and Social Identity Theory are first discussed together because both explain identity through role internalisation, group membership, and social belonging. Communities of Practice and Situated Learning are then discussed together because both emphasise learning, participation, legitimacy, and identity formation within social contexts. The section then turns to motivational and developmental perspectives, including Social Cognitive Career Theory, Identity-Based Motivation Theory, and Possible Selves Theory, before discussing science and STEM identity foundations and the emergence of engineering identity as a discipline-specific construct.

To provide a structured overview of these theoretical perspectives, Table 1 summarises the major theories and frameworks informing engineering identity scholarship, including their core concepts, contributions, and key limitations. The key limitation column is included to highlight the conceptual boundaries, contextual constraints, and explanatory gaps within existing theories. These limitations help explain why engineering identity scholarship has continued to evolve and provide an important foundation for the critical analysis and future research agenda presented in this review.

Table 1. Summary of Major Identity Theories Relevant to Engineering Education

Theory / Framework	Key Authors	Core Concepts	Contribution to Engineering Identity Research	Key Limitation
Identity Theory	Burke & Stets (2009); Stryker (1980)	Identity meanings, role expectations, self-verification	Explains how individuals internalise and enact professional roles such as becoming an engineer. Highlights the relationship between role performance and self-concept.	Focuses primarily on individual role identities and provides limited attention to broader sociocultural influences.
Social Identity Theory	Tajfel & Turner (1979)	Social categorisation, group membership, social belonging	Explains how engineering students develop a sense of belonging through identification with engineering communities and peer groups.	Not specifically designed to explain professional identity formation within educational settings.
Communities of Practice and Situated Learning	Wenger (1998); Lave & Wenger (1991)	Participation, belonging, legitimate peripheral participation, community membership	Conceptualises engineering identity as developing through participation in engineering practices and communities. Widely used to explain learning and identity formation in engineering education.	Difficult to operationalise and measure quantitatively.
Science Identity Framework	Carlone & Johnson (2007)	Competence, performance, recognition	Provides the foundational disciplinary identity model from which engineering identity frameworks emerged. Emphasises recognition as a critical component of identity formation.	Developed within science education rather than engineering-specific contexts.
Physics Identity Framework	Hazari et al. (2010)	Interest, performance and competence, recognition	Introduces interest as a central motivational dimension and demonstrates the relationship between identity and persistence in STEM pathways.	Developed specifically within physics education and may not fully capture engineering-specific experiences.
Social Cognitive Career Theory (SCCT)	Lent, Brown, & Hackett (1994)	Self-efficacy, outcome expectations, goals	Explains how confidence, career expectations, and goal orientation influence engineering persistence and career decisions.	Emphasises individual cognitive processes and provides limited attention to social recognition and belonging.
Identity-Based Motivation Theory	Oyserman (2015)	Future selves, identity congruence, action readiness	Explains how students' perceptions of their future professional selves influence motivation, engagement, and persistence.	Less discipline-specific and relatively abstract when applied to engineering education.
Possible Selves Theory	Markus & Nurius (1986)	Future self-concept, aspirations, anticipated identities	Provides insight into how engineering students envision future professional identities and align current behaviour with future goals.	Focuses primarily on future-oriented cognition rather than social identity processes.
Engineering Identity Model	Godwin (2016)	Interest, performance and competence, recognition	Provides the most widely adopted engineering-specific identity model. Offers conceptual clarity and strong empirical support across engineering education studies.	Predominantly validated in Western higher education contexts and relies heavily on survey-based measurement approaches.
Critical Engineering Agency Framework	Godwin et al. (2016)	Agency, sociopolitical awareness, recognition, interest	Extends engineering identity beyond competence and recognition by incorporating societal contribution and empowerment.	Empirical applications remain relatively limited and concentrated within specific populations.
Gendered Engineering Identity Perspective	Wang et al. (2022)	Gender identity, emotional experience, resilience, engineering identity	Highlights emotional, psychological, and gender-related influences on engineering identity development.	Context-specific and not yet widely integrated into mainstream engineering identity frameworks.

3.1 Identity Theory and Social Identity Theory

Identity Theory, as articulated by Stryker (1980) and further developed by Burke and Stets (2009), provides one of the foundational perspectives for understanding how individuals internalise roles and attach meaning to who they are within social structures. From this perspective, identity is connected to role expectations, self-meanings, and the ways individuals verify their sense of self through action and interaction. In engineering education, this theory is useful because students do not simply learn engineering knowledge; they gradually negotiate whether the role of "engineer" becomes part of their self-concept. Becoming an engineer therefore involves more than academic achievement. It also involves adopting the values, expectations, and practices associated with the engineering profession.

Social Identity Theory (Tajfel & Turner, 1979) complements this role-based view by emphasising group membership and belonging. It explains how individuals define themselves in relation to social groups and how identification with a group can shape confidence, motivation, and participation. In engineering education, this is especially relevant because students often develop identity through their perceived membership in engineering communities. When students feel accepted by peers, lecturers, mentors, and professional communities, their sense of belonging to engineering may be strengthened. Conversely, weak recognition or exclusionary environments may weaken identification with the discipline.

Together, Identity Theory and Social Identity Theory show that engineering identity is both personal and social. It involves internal self-understanding, but it is also shaped by external recognition and group affiliation. This dual emphasis is important because engineering identity cannot be reduced to technical competence alone. A student may perform well academically but still fail to see themselves as an engineer if they lack recognition, belonging, or meaningful participation within the engineering community.

3.2 Communities of Practice and Situated Learning

Communities of Practice Theory and Situated Learning (Lave & Wenger, 1991; Wenger, 1998) provide another important foundation for engineering identity research. Lave and Wenger's theory of situated learning explains that learning occurs through participation in social practices rather than through knowledge acquisition alone. Wenger later extended this idea by arguing that identity develops through participation, mutual engagement, and alignment within communities of practice.

In engineering education, this perspective is highly relevant because students become engineers through participation in engineering-related practices. These practices may include design projects, laboratory work, teamwork, problem-solving, internships, capstone projects, professional communication, and engagement with industry expectations. Through these experiences, students learn not only technical content but also what it means to think, act, and communicate as engineers.

This perspective shifts engineering identity from a static personal trait to a socially mediated process. Identity develops when students are given opportunities to participate meaningfully in engineering practices and when their participation is recognised as legitimate. This explains why authentic learning environments, collaborative projects, industrial exposure, and mentorship are often associated with stronger engineering identity. Students are more likely to internalise an engineering identity when they experience themselves as active contributors rather than passive recipients of technical knowledge.

However, Communities of Practice Theory also has limitations. While it provides strong sociocultural insight, it is less easily operationalised into measurable dimensions. This makes it more suitable as an interpretive lens than as a direct measurement framework. Nevertheless, its contribution remains important because it reminds engineering education researchers that identity development is embedded in practice, interaction, and community membership.

3.3 Motivational and Developmental Perspectives

Engineering identity research has also been influenced by motivational and developmental theories, including Social Cognitive Career Theory (Lent et al., 1994), Identity-Based Motivation Theory (Oyserman, 2015), and Possible Selves Theory (Markus & Nurius, 1986). In engineering education, this theory helps explain why students persist or disengage from engineering pathways. Students who believe they can succeed in engineering and who perceive engineering as leading to meaningful future outcomes are more likely to sustain motivation and career commitment.

Identity-Based Motivation Theory and Possible Selves Theory further extend this discussion by focusing on future-oriented self-concepts. These perspectives suggest that students' current actions are influenced by how they imagine their future selves. If students can imagine themselves as future engineers, they may be more likely to engage in behaviours that support engineering persistence, such as participating in projects, seeking feedback, improving technical skills, and building professional networks.

These motivational theories are useful because they connect engineering identity to persistence, aspiration, and career direction. They explain why identity is not only a reflection of present experience but also a projection of future possibility. Students' sense of becoming engineers is shaped by whether

they see engineering as attainable, meaningful, and aligned with their future goals.

However, motivational theories are often more individualistic in orientation. They tend to emphasise self-efficacy, goals, and personal motivation, but may give less attention to broader social, cultural, institutional, and structural influences. This limitation is important because engineering identity is not formed only through individual confidence or aspiration. It is also shaped by recognition, family expectations, institutional culture, professional pathways, and sociocultural meanings attached to engineering.

3.4 STEM Identity and Science Identity Foundations

The movement from general identity theories to engineering identity was strongly shaped by science and STEM identity research. One of the most influential models is Carlone and Johnson's Science Identity Framework, which conceptualised science identity through competence, performance, and recognition. This framework was important because it showed that disciplinary identity requires more than knowledge. Individuals must be able to demonstrate competence and be recognised by themselves and others as legitimate members of the discipline.

Recognition is especially important in this framework. A student may be competent in science or engineering, but without recognition from teachers, peers, family, or professional communities, identity may remain weak. This insight became central to later engineering identity research because it highlighted the social nature of identity formation.

Hazari and colleagues extended this discussion in physics education by incorporating interest as an additional dimension. Their work linked identity to students' persistence intentions and showed that interest, performance and competence, and recognition were important predictors of STEM-related persistence. This development marked an important shift because it connected identity not only to social recognition but also to motivation and future participation.

Together, the science identity and physics identity frameworks provided the conceptual foundation for engineering identity research. They established identity as a multidimensional construct involving internal motivation, demonstrated ability, and social recognition. However, these frameworks were developed within science and physics contexts. Engineering differs from these fields because it is closely tied to design, problem-solving, professional practice, accreditation, teamwork, industry expectations, and societal application. Therefore, engineering identity required a more discipline-specific conceptualisation.

3.5 Emergence of Engineering Identity

Engineering identity emerged as a distinct construct when scholars began adapting STEM and science identity models to engineering education. Godwin's engineering identity model became one of the most widely adopted frameworks in the field. Building on earlier identity frameworks, Godwin conceptualised engineering identity through interest, performance and competence, and recognition.

Interest refers to students' personal engagement with engineering. It captures the extent to which students find engineering meaningful, enjoyable, and relevant. Performance and competence refer to students' confidence in understanding and performing engineering-related tasks. Recognition refers to whether students see themselves, and are seen by others, as engineering people. These three dimensions provide a clear and useful structure for examining how students develop identification with engineering.

The strength of Godwin's model lies in its operational clarity. It allows researchers to study engineering identity empirically and to examine how identity relates to persistence, belonging, motivation, and career intention. Subsequent studies have reinforced the importance of these dimensions, particularly recognition and interest. Many studies suggest that students' sense of being recognised as engineers can be as important as, or even more important than, technical ability alone.

Nevertheless, the model also has limitations. Much of the empirical validation has occurred within Western higher education contexts, and many studies have relied on survey-based measurement. While this has strengthened quantitative analysis, it may not fully capture how engineering identity is shaped in different cultural, institutional, and professional contexts. In collectivist or policy-driven education systems, for example, engineering identity may also be shaped by family expectations, national development priorities, accreditation structures, and industry readiness. These influences may not be fully explained by the original tripartite dimensions.

3.6 Synthesis of Theoretical Foundations

The theoretical foundations reviewed in this section indicate that engineering identity is a multidimensional, socially situated, and developmental construct. Identity Theory and Social Identity Theory explain the importance of role internalisation and group belonging. Communities of Practice and Situated Learning show that identity develops through participation in meaningful disciplinary practices. Motivational and developmental perspectives explain how self-efficacy, future goals, and possible selves influence persistence and career orientation. Science and STEM identity frameworks provide the conceptual bridge toward engineering identity by foregrounding competence, performance, recognition, and interest.

Taken together, these theories suggest that engineering identity cannot be understood through a single lens. It is not only a psychological construct, a social construct, or a motivational construct. Rather, it is formed through the interaction of personal interest, perceived competence, social recognition, disciplinary participation, future aspiration, and contextual influence. This explains why engineering identity research has become theoretically rich but also conceptually fragmented.

A key implication is that future engineering identity research must move beyond simply measuring identity dimensions. It must also examine how those dimensions are experienced, negotiated, and shaped within specific educational, cultural, and professional contexts. This is especially important in non-Western and Global South settings, where engineering identity may be influenced by sociocultural expectations, institutional systems, and labour market realities that differ from the contexts in which many dominant models were originally developed.

The next section builds on this theoretical foundation by tracing the progression from STEM identity to engineering identity and examining how major models have shaped the development of the field.

4. From STEM Identity to Engineering Identity

4.1 Origins of STEM Identity Research

The emergence of engineering identity research cannot be understood independently of broader developments within STEM identity scholarship. Before engineering identity became established as a distinct area of inquiry, researchers in science and STEM education had already begun investigating how learners developed a sense of belonging, participation, and identification within disciplinary communities. These studies shifted attention away from achievement alone and toward understanding how students came to see themselves as members of particular academic and professional domains.

Early identity research within STEM fields was influenced by sociocultural perspectives that viewed learning as a process of participation rather than simple knowledge acquisition. Within this tradition, identity became an important explanatory construct because it helped explain why some students persisted in STEM pathways while others disengaged despite comparable academic ability. Researchers increasingly recognised that academic performance alone could not fully explain participation patterns, particularly among underrepresented groups. Studies on STEM pathways, early engineering identity development, and STEM career aspirations further show that identity-related factors may emerge before university and are shaped by early exposure, self-concept, and perceptions of STEM professionals (Cannady et al., 2014; Capobianco et al., 2012; Capobianco et al., 2015; Chen et al., 2024). Instead, students' perceptions of themselves and their experiences of recognition within disciplinary communities appeared equally important.

This shift laid the foundation for disciplinary identity research, particularly within science education, where identity began to be examined as a multidimensional construct influenced by competence, participation, and social recognition. These developments ultimately provided the conceptual basis from which engineering identity scholarship emerged.

4.2 Science Identity as a Foundational Framework

A major milestone in disciplinary identity research was the work of Carlone and Johnson (2007), who proposed one of the most influential science identity frameworks. Their model conceptualised science identity through three interconnected dimensions: competence, performance, and recognition. Competence referred to an individual's understanding of disciplinary knowledge, performance reflected the ability to demonstrate that knowledge in socially meaningful ways, and recognition captured the extent to which individuals were acknowledged by themselves and others as legitimate participants within the discipline.

The significance of this framework extended beyond science education. By demonstrating that disciplinary identity depends not only on knowledge but also on social validation, Carlone and Johnson fundamentally changed how researchers conceptualised identity development. Their work showed that students may possess competence but still fail to develop a strong disciplinary identity if they are not recognised as legitimate members of the community.

Another important contribution of the framework was its emphasis on sociocultural context. Identity was not viewed as an internal psychological characteristic but as a socially negotiated construct shaped through interaction and recognition. This perspective later became highly influential in STEM and engineering identity research because it highlighted the importance of belonging, legitimacy, and community participation.

Despite its influence, the framework was developed within science education and focused primarily on women of colour in scientific settings. Consequently, questions remained regarding its applicability to engineering, where professional practice, design activities, teamwork, and industry engagement play a more prominent role.

4.3 Expansion Through Physics and STEM Identity Research

Building upon the science identity tradition, Hazari et al. (2010) extended identity research within physics

education by introducing interest as a central component of disciplinary identity. Their work retained the dimensions of performance and competence, and recognition, while emphasising the motivational role of interest in shaping persistence intentions.

This extension represented an important theoretical advancement because it linked identity directly to future educational and career decisions. Interest was shown to function not merely as an outcome of positive educational experiences but as an active driver of continued engagement with STEM pathways. Students who reported stronger interest, greater recognition, and higher confidence in their abilities were more likely to persist in STEM-related fields.

Hazari's framework therefore contributed two important developments. First, it strengthened the predictive capacity of identity research by linking identity to persistence and career intentions. Second, it introduced a more explicit motivational dimension that would later become central to engineering identity scholarship.

Nevertheless, the framework remained rooted in physics education. While many of its insights were transferable, engineering education presents unique characteristics that extend beyond those typically associated with science and physics disciplines. Engineering programmes place stronger emphasis on design, problem-solving, teamwork, innovation, professional practice, and interaction with industry. Consequently, scholars increasingly recognised the need for a discipline-specific identity framework capable of capturing these distinctive features.

4.4 Emergence of Engineering Identity as a Distinct Construct

The transition from STEM identity to engineering identity reflected broader developments within engineering education research. During the early 2000s, scholars began examining why some students remained committed to engineering while others left the discipline despite demonstrating adequate academic performance. Traditional explanations based on grades, retention statistics, and technical ability proved insufficient for explaining these patterns.

At the same time, sociocultural studies of engineering education highlighted the importance of participation, belonging, and professional socialisation. Research by Tonso (2006a, 2006b) and Stevens et al. (2008) demonstrated that students developed engineering identities through interaction with peers, engagement in engineering practices, and negotiation of professional roles within engineering communities. These studies suggested that engineering identity was shaped by both technical competence and social participation.

Consequently, engineering identity gradually emerged as a distinct construct that combined elements of STEM identity research with insights from engineering education. Scholars increasingly recognised that becoming an engineer involved not only acquiring technical knowledge but also developing a sense of professional legitimacy, belonging, and identification with engineering culture and practice.

4.5 Godwin's Engineering Identity Model

A major breakthrough occurred when Godwin (2016) adapted earlier STEM identity frameworks specifically for engineering education. Building upon Carlone and Johnson (2007) and Hazari et al. (2010), Godwin conceptualised engineering identity through three dimensions: interest, performance and competence, and recognition.

This model offered several important advantages. First, it provided conceptual clarity by translating identity constructs into an engineering-specific context. Second, it enabled empirical investigation through validated measurement instruments. Third, it established a common language that allowed engineering identity research to develop greater theoretical coherence.

Subsequent studies consistently demonstrated the importance of these dimensions. Interest was associated with motivation and engagement, performance and competence reflected students' confidence in their engineering abilities, and recognition functioned as a mechanism through which students gained legitimacy within engineering communities. Research also suggested that recognition and interest often exerted stronger influence on identity development than technical competence alone.

Despite its widespread adoption, the model is not without limitations. Most empirical validation has occurred within Western higher education environments, and much of the research relies on survey-based methodologies. Consequently, questions remain regarding how these dimensions operate within different sociocultural contexts and how broader influences such as family expectations, institutional structures, and professional systems interact with identity development.

4.6 Evolutionary Synthesis

The progression from science identity to engineering identity reflects a process of theoretical adaptation and disciplinary refinement. Science identity research established the importance of competence, performance, and recognition. Physics identity research expanded this structure by introducing interest as a motivational dimension linked to persistence. Engineering identity scholarship subsequently adapted these dimensions to engineering education while incorporating insights from

professional socialisation, participation, and disciplinary practice.

This evolution demonstrates that engineering identity did not emerge as an entirely new construct. Rather, it represents the culmination of several decades of theoretical development across identity research, STEM education, and engineering education. At the same time, the progression reveals important limitations within existing scholarship. Most dominant frameworks have been developed within Western contexts and validated through quantitative approaches, creating potential gaps in understanding how identity develops within diverse cultural, institutional, and professional environments.

These observations provide the foundation for the next section, which examines the major dimensions of engineering identity and evaluates how contemporary scholarship has expanded beyond the traditional tripartite structure. By reviewing these dimensions in greater detail, it becomes possible to understand how engineering identity has evolved from a relatively focused framework into a broader and increasingly multidimensional construct.

To illustrate the theoretical progression discussed in this section, Table 2 summarises the major identity frameworks that have influenced the development of engineering identity scholarship. In addition to highlighting the evolution of key dimensions and contributions, the table identifies important limitations associated with each framework. These limitations provide the basis for the critical evaluation presented throughout this review and help justify the need for broader conceptual, methodological, and contextual development within future engineering identity research.

Table 2. Evolution of Identity Frameworks from Science to Engineering

Framework	Key Authors	Core Dimensions	Major Contribution	Key Limitation
Science Identity Framework	Carlone & Johnson (2007)	Competence, Performance, Recognition	Established disciplinary identity as a multidimensional construct and highlighted recognition as a critical component of identity formation. Provided the theoretical foundation for later STEM and engineering identity models.	Developed within science education and focused primarily on women of colour in science contexts. Limited engineering-specific applicability.
Physics Identity Framework	Hazari et al. (2010)	Interest, Performance and Competence, Recognition	Extended science identity by incorporating interest as a motivational dimension. Demonstrated the relationship between identity and STEM persistence intentions.	Developed within physics education and may not fully capture engineering-specific learning experiences and professional practices.
Engineering Identity Model	Godwin (2016)	Interest, Performance and Competence, Recognition	Adapted STEM identity dimensions to engineering education. Provided a discipline-specific framework and enabled large-scale empirical investigation of engineering identity.	Predominantly validated in Western higher education settings and heavily dependent on survey-based measurement approaches.
Critical Engineering Agency Framework	Godwin et al. (2016)	Agency, Recognition, Interest, Sociopolitical Awareness	Expanded engineering identity by integrating agency, empowerment, and societal contribution. Emphasised engineering as a vehicle for social impact.	Limited empirical application across diverse cultural and educational contexts.
Belonging-Oriented Engineering Identity Research	Rohde et al. (2019); Kajfez et al. (2019); Ortiz et al. (2019)	Identity, Belonging, Community Participation	Highlighted the importance of belonging, peer relationships, and participation in shaping engineering identity development.	Belonging is often treated as a related construct rather than a fully integrated component of engineering identity frameworks.
Gendered and Emotional Engineering Identity Perspectives	Hoch et al. (2020); Wang et al. (2022)	Identity, Emotional Experience, Resilience, Gender Identity	Extended engineering identity research beyond cognitive and social dimensions by incorporating emotional and gender-related experiences.	Empirical evidence remains concentrated in specific populations and Western university contexts.
Contemporary Developmental and Contextual Perspectives	Lockhart & Rambo-Hernandez (2024); Liquete et al. (2025); Treadway et al. (2025)	Developmental Identity, Contextual Experience, Affective Engagement	Conceptualises engineering identity as a dynamic process evolving across educational and professional stages. Highlights contextual and affective influences on identity formation.	Longitudinal and cross-cultural evidence remains limited, particularly outside North America and Europe.

5. Major Engineering Identity Models and Dimensions

5.1 Introduction

As engineering identity scholarship has matured, several dimensions have emerged consistently across theoretical and empirical studies. While early research focused primarily on participation and belonging within engineering communities, subsequent scholarship increasingly sought to identify the specific constructs that explain how individuals come to see themselves as engineers. This effort resulted in the stabilisation of several core identity dimensions, particularly interest, performance and competence, and recognition. These dimensions have become central to contemporary engineering identity research and have been repeatedly validated across different educational settings and student populations.

At the same time, more recent scholarship has expanded beyond these foundational constructs by incorporating agency, belonging, emotional experience, and developmental progression. These developments reflect growing recognition that engineering identity is not a static attribute but a dynamic process shaped by motivational, social, emotional, and contextual influences. This section reviews the major dimensions that currently define engineering identity scholarship and examines how they contribute to understanding identity formation within engineering education.

5.2 Interest

Interest is widely recognised as one of the most influential dimensions of engineering identity. It refers to an individual's intrinsic attraction toward engineering activities, concepts, and career pathways. Interest influences how students engage with engineering-related experiences and often serves as an entry point into identity development. Students who find engineering personally meaningful are more likely to participate actively in learning activities, pursue engineering opportunities, and persist despite academic challenges.

The importance of interest became particularly evident through the work of Hazari et al. (2010), who identified interest as a significant predictor of persistence within STEM pathways. Godwin (2016) subsequently incorporated interest into the engineering identity framework, where it became one of the three foundational dimensions. Subsequent studies consistently demonstrated that students with stronger interest in engineering tend to report higher levels of identity salience, motivation, and persistence. Related studies also show that engineering identity is associated with students' career interests, professional expectations, and confidence in pursuing engineering-related pathways (Choe & Borrego, 2020; Choe et al., 2019; Godwin & Kirn, 2020).

Interest also interacts closely with other identity dimensions. Recognition from peers, lecturers, and family members may strengthen interest by reinforcing students' perceptions that engineering is an appropriate and attainable pathway. Similarly, successful performance experiences often increase interest by enhancing confidence and enjoyment. Consequently, interest functions not only as a motivational factor but also as a mechanism through which students begin to internalise engineering as part of their developing self-concept.

However, interest should not be viewed as a stable trait. Research suggests that interest evolves through exposure, participation, and meaningful educational experiences. Design projects, industry engagement, authentic engineering tasks, and mentorship opportunities may all contribute to strengthening students' engineering interest over time.

5.3 Performance and Competence

Performance and competence represent students' perceptions of their ability to understand, apply, and demonstrate engineering knowledge and skills. Although these concepts were originally treated separately within science identity research, they are commonly combined within engineering identity scholarship because both relate to students' confidence in performing engineering-related tasks.

Competence refers to students' understanding of engineering concepts and their belief that they possess the knowledge necessary to succeed within the discipline. Performance refers to the ability to demonstrate that knowledge through engineering activities, problem-solving tasks, design projects, communication, and professional practice. Together, these constructs contribute to students' perceptions that they are capable of functioning effectively as engineers.

Empirical studies consistently indicate that performance and competence play a significant role in engineering identity development. Students who experience success in engineering coursework, laboratory activities, and project-based learning environments often develop stronger engineering self-concepts. Positive performance experiences reinforce beliefs about capability and strengthen identification with engineering.

Nevertheless, research also suggests that performance and competence alone are insufficient for sustaining a strong engineering identity. Students may achieve high levels of academic success while still failing to identify strongly with engineering if they do not experience recognition or belonging. This observation highlights an important distinction between academic achievement and identity formation. Competence contributes to identity

development, but it does not automatically produce identity.

Recent scholarship further suggests that students' interpretations of competence may be shaped by contextual factors such as institutional culture, assessment practices, peer comparison, and educational expectations. Consequently, performance and competence should be understood not only as individual capabilities but also as socially interpreted experiences that contribute to identity construction.

5.4 Recognition

Recognition is widely regarded as the most distinctive and influential dimension within engineering identity scholarship. Recognition refers to the extent to which individuals perceive themselves, and are perceived by others, as legitimate members of the engineering community. It captures the social validation necessary for identity internalisation and reflects the relational nature of identity development.

The importance of recognition was first highlighted by Carlone and Johnson (2007), who argued that competence and performance become meaningful only when recognised by others. This insight has been repeatedly supported within engineering identity research. Studies consistently demonstrate that recognition from family members, peers, lecturers, mentors, and industry professionals significantly influences whether students come to view themselves as engineers. Recent work has further shown that recognition experiences vary across race, gender, and first-generation student backgrounds, indicating that recognition is not experienced uniformly across student groups (McIntyre et al., 2024; Verdín et al., 2024).

Recognition operates at multiple levels. Self-recognition reflects students' internal acceptance of an engineering identity, whereas external recognition reflects affirmation from social and professional communities. Both forms of recognition are important because identity development involves ongoing interaction between personal self-understanding and social validation.

Research further suggests that recognition often exerts stronger influence on engineering identity than technical competence alone. Students who receive encouragement, affirmation, and validation are more likely to persist within engineering pathways and develop stronger professional identification. Conversely, environments characterised by exclusion, limited feedback, or weak support structures may hinder identity development even among academically capable students.

These findings reinforce the view that engineering identity is fundamentally social. Becoming an engineer requires more than acquiring knowledge; it also requires being recognised as an engineer by oneself and by others.

5.5 Agency and Societal Contribution

The Critical Engineering Agency framework proposed by Godwin et al. (2016) expanded engineering identity scholarship beyond the traditional tripartite structure by incorporating concepts related to agency and societal contribution. Agency refers to students' perceptions that they can use engineering knowledge and skills to influence society, solve meaningful problems, and contribute to positive change.

The Critical Engineering Agency framework introduced this perspective by emphasising the relationship between engineering identity and sociopolitical awareness. From this perspective, engineering identity is not limited to technical competence or professional recognition. It also involves beliefs about purpose, impact, and responsibility.

The incorporation of agency represents an important conceptual expansion because it acknowledges that students often develop stronger identification with engineering when they perceive engineering as meaningful and socially relevant. Students who believe their work can improve communities, address societal challenges, or contribute to sustainable development may experience stronger motivation and deeper professional commitment.

Although agency has not yet achieved the same empirical stability as interest, performance and competence, and recognition, it provides valuable insight into how identity intersects with purpose, values, and social responsibility. As engineering increasingly addresses global challenges such as sustainability, climate change, and technological transformation, agency may become an increasingly important component of engineering identity development.

5.6 Belonging and Community Participation

Belonging has emerged as another important extension of engineering identity research. While closely related to recognition, belonging refers specifically to students' feelings of acceptance, inclusion, and connection within engineering communities. It captures the emotional and relational aspects of participation that influence whether students perceive themselves as legitimate members of the discipline.

Studies examining design teams, project-based learning environments, mentoring relationships, and learning communities consistently demonstrate that belonging contributes positively to engineering identity development. Belonging has also been shown to interact with social relationships, design experiences, peer support, and persistence-related constructs, particularly among students from underrepresented backgrounds (Rohde et al., 2019; Kajfez et al., 2019; Ortiz et al., 2019; Polmear et al.,

2024; Verdín et al., 2018; Earle et al., 2024). Students who feel connected to peers, lecturers, and professional communities are more likely to participate actively and persist within engineering programmes.

Communities of Practice Theory provides an important explanation for this relationship. Identity develops through participation, and participation is more likely when individuals feel accepted within the community. Consequently, belonging functions as both a psychological outcome and a mechanism that supports identity formation.

Belonging may be particularly important for students from underrepresented groups, who often face additional challenges related to legitimacy, inclusion, and representation. In such contexts, supportive communities and inclusive learning environments may play a critical role in strengthening engineering identity.

5.7 Emotional and Developmental Dimensions

Recent research increasingly recognises that engineering identity is influenced by emotional experiences and developmental processes. Recent studies have examined these issues through gendered, affective, developmental, and context-sensitive perspectives, showing that engineering identity may be shaped by emotional experience, resilience, gender, stability, and educational transition (Hoch et al., 2020; Wang et al., 2022; Lockhart & Rambo-Hernandez, 2024; Lockhart et al., 2025; Liquete et al., 2025; Treadway et al., 2025). Earlier models tended to emphasise cognitive, motivational, and social dimensions, but contemporary scholarship highlights the importance of affective experiences such as confidence, anxiety, resilience, stress, and emotional engagement.

Engineering students continuously interpret successes, failures, feedback, and challenges. These interpretations shape how they understand their competence, belonging, and future potential within engineering. Positive emotional experiences may reinforce identity development, whereas repeated negative experiences may weaken confidence and increase disengagement.

At the same time, engineering identity is increasingly viewed as developmental rather than static. Identity evolves across educational stages, beginning with early STEM exposure and continuing through undergraduate study, postgraduate development, industrial experience, and professional practice. Different dimensions may become more or less important at different stages. For example, interest may dominate early identity formation, while recognition, belonging, and professional validation become increasingly significant as students progress toward professional practice.

This developmental perspective highlights that engineering identity should not be understood as a fixed outcome. Rather, it is an evolving process shaped by accumulated experiences, opportunities for participation, and ongoing negotiation of professional self-understanding.

5.8 Synthesis of Engineering Identity Dimensions

The literature reviewed in this section demonstrates that engineering identity has evolved from a relatively narrow focus on interest, performance and competence, and recognition toward a broader multidimensional construct. While the traditional tripartite structure remains the most widely adopted framework, contemporary scholarship increasingly recognises the importance of agency, belonging, emotional experience, and developmental progression.

Taken together, these dimensions suggest that engineering identity is best understood as a dynamic process involving motivation, capability, recognition, participation, purpose, and professional self-understanding. No single dimension is sufficient on its own. Rather, engineering identity emerges through the interaction of multiple factors that collectively shape how individuals perceive themselves and are perceived by others as engineers.

This multidimensional understanding provides a more comprehensive foundation for examining engineering identity development. However, the expansion of engineering identity dimensions has also introduced new theoretical, methodological, and contextual challenges. As the field continues to grow, critical examination is needed to determine how these dimensions relate to one another and whether existing frameworks adequately capture the complexity of identity development across diverse educational settings. These issues are examined critically in the following section.

6. Critical Analysis of Current Engineering Identity Scholarship

6.1 Introduction

Engineering identity research has expanded significantly over the past two decades. The field has progressed from small-scale sociocultural investigations toward more structured theoretical models and large-scale empirical validation studies. Core dimensions such as interest, performance and competence, and recognition have become relatively stabilised, and engineering identity is now widely recognised as an important construct for understanding student engagement, persistence, belonging, and professional development.

Despite these advances, important challenges remain. A critical examination of the literature reveals several recurring limitations that constrain theoretical development and practical application. These

challenges include conceptual fragmentation across competing theoretical perspectives, methodological concentration around survey-based approaches, strong dependence on Western educational contexts, limited understanding of identity development over time, and ongoing difficulties in integrating contextual influences into existing frameworks. Collectively, these issues suggest that engineering identity scholarship has reached a stage where further advancement requires greater theoretical integration, methodological diversification, and contextual sensitivity.

6.2 Conceptual Fragmentation

One of the most significant challenges within engineering identity research is conceptual fragmentation. Although engineering identity is frequently discussed as a unified construct, the literature reveals considerable variation in how identity is defined, operationalised, and interpreted.

Some scholars conceptualise engineering identity primarily through the dimensions of interest, performance and competence, and recognition. Others emphasise belonging, agency, motivation, participation, professional identity, emotional experience, or career aspirations. While these perspectives provide valuable insights, they often operate independently rather than being integrated into a coherent conceptual framework.

This fragmentation partly reflects the interdisciplinary nature of engineering identity scholarship. The field draws from psychology, sociology, STEM education, science education, and engineering education, each of which contributes different assumptions about how identity develops. As a result, engineering identity is sometimes treated as a psychological construct, sometimes as a sociocultural process, and sometimes as a motivational mechanism. These different perspectives are not necessarily contradictory, but they are not always theoretically integrated.

The consequence is that researchers may use the same term, "engineering identity," to describe substantially different phenomena. This creates challenges for theory building, comparison across studies, and cumulative knowledge development. Future research therefore requires greater conceptual clarity regarding the relationships between identity dimensions, identity processes, and contextual influences.

6.3 Methodological Concentration

A second limitation concerns the methodological concentration of engineering identity research. Since the widespread adoption of Godwin's (2016) engineering identity model, much of the literature has relied heavily on survey-based methodologies and quantitative measurement approaches.

The popularity of these approaches is understandable. Survey instruments allow researchers to examine large populations, compare institutions, and test statistical relationships between identity and outcomes such as persistence, academic performance, and career intentions. Several studies have contributed to this measurement tradition by developing or validating instruments for examining engineering identity among undergraduate and postgraduate students (Borrego et al., 2018; Lockhart et al., 2025). These studies have contributed significantly to the empirical validation of engineering identity dimensions and have strengthened the reliability of measurement practices.

However, the dominance of survey-based research also introduces limitations. Identity is fundamentally a meaning-making process shaped by lived experience, social interaction, and contextual interpretation. Survey instruments may capture patterns and relationships, but they cannot fully explain how students interpret recognition experiences, negotiate belonging, respond to institutional expectations, or construct professional self-understandings.

Consequently, important aspects of identity development may remain underexplored. Qualitative approaches, including interviews, focus groups, ethnography, narrative inquiry, and longitudinal case studies, offer opportunities to examine the complexity of identity formation in greater depth. Greater methodological diversity would therefore strengthen the field by providing richer understanding of how identity develops across different educational and professional contexts.

6.4 Western Dominance and Contextual Limitations

A third challenge concerns the geographical and cultural concentration of engineering identity scholarship. Many of the most influential theories, frameworks, and empirical studies have been developed within North American or Western higher education systems.

This concentration has generated valuable knowledge and contributed substantially to the development of the field. However, it also raises questions regarding contextual applicability. Educational systems differ in their institutional structures, cultural expectations, professional pathways, and relationships between education and employment. Consequently, identity dimensions that function effectively within one context may operate differently in another.

The issue is particularly important in collectivist societies where family expectations, community obligations, and social relationships may exert stronger influence on educational and career decisions. Similarly, policy-driven education systems may shape engineering identity through accreditation requirements, national development priorities, and labour market expectations. These contextual

influences are often discussed as background variables rather than being incorporated directly into engineering identity frameworks.

Recent scholarship has begun to acknowledge these limitations, yet empirical evidence from non-Western settings remains relatively limited. Emerging studies from Asian, Malaysian, and other culturally diverse contexts indicate that engineering identity may be shaped by gender, ethnicity, family, professional practice, and local educational structures in ways that require further contextual investigation (DeBoer et al., 2019; Espino et al., 2024; Mastam et al., 2025; Koul, 2018). Engineering identity research therefore risks presenting theoretically robust but contextually incomplete explanations of identity development. Expanding research beyond dominant Western contexts is essential for establishing whether existing models possess broader explanatory relevance or require contextual adaptation.

6.5 Limited Understanding of Identity Development Across Time

Although engineering identity is frequently described as developmental, much of the literature examines identity at a single point in time. Cross-sectional studies dominate the field, providing valuable snapshots of students' identity perceptions but offering limited insight into how identity evolves across educational and professional transitions.

Identity development is unlikely to occur as a linear or stable process. Students encounter multiple experiences that may strengthen, weaken, or transform identity over time. Early STEM exposure, university entry, design experiences, internships, industrial training, postgraduate study, and workplace transition may each contribute differently to identity formation. Yet relatively few studies examine these transitions longitudinally.

The lack of longitudinal evidence creates important gaps in understanding. It remains unclear how identity trajectories develop, which experiences are most influential at different stages, and whether identity dimensions change in importance across educational pathways. Addressing these questions would significantly strengthen theoretical explanations of engineering identity development.

Future research should therefore move beyond isolated educational stages and examine identity as a developmental continuum extending from early education to professional practice.

6.6 Future Conceptual Challenges

Beyond the limitations discussed above, several broader conceptual challenges remain unresolved. First, existing frameworks continue to prioritise individual-level dimensions while providing limited explanation of how institutional, cultural, and structural influences shape identity development. Second, the relationship between engineering identity and related constructs such as belonging, professional identity, agency, and employability remains insufficiently clarified. Third, the increasing expansion of identity dimensions raises questions regarding conceptual boundaries and theoretical coherence.

As the field continues to evolve, researchers must balance conceptual expansion with theoretical clarity. The addition of new dimensions may enrich understanding, but excessive expansion risks creating fragmented frameworks that lack explanatory coherence. Future scholarship should therefore focus not only on identifying additional identity influences but also on explaining how these influences interact within broader identity development processes.

Ultimately, the future of engineering identity research depends on its ability to integrate individual, social, cultural, institutional, and professional influences into more comprehensive explanatory frameworks. Such integration would allow engineering identity scholarship to move beyond isolated dimensions toward a more holistic understanding of how engineers come to see themselves, and are recognised by others, as members of the engineering profession.

6.7 Synthesis of Critical Challenges

The critical analysis presented in this section suggests that engineering identity scholarship has achieved considerable theoretical and empirical maturity, yet several important limitations continue to constrain the field. The issues discussed in this section, including theoretical inconsistency, methodological concentration, geographical imbalance, limited longitudinal evidence, and unresolved conceptual challenges, indicate that engineering identity research remains an evolving area of inquiry.

These observations do not diminish the contributions of existing scholarship. Rather, they highlight opportunities for future advancement. The next section builds upon these insights by proposing emerging research directions that may contribute to more integrated, contextually responsive, and theoretically robust approaches to engineering identity research.

7. Emerging Research Directions

7.1 Introduction

The critical analysis in the previous section indicates that engineering identity research has reached an important point of development. The field has established strong foundational dimensions, particularly interest, performance and competence, and recognition. It has also expanded to include agency, belonging, emotional experience, and developmental progression. However, several limitations remain, especially in relation to contextual

applicability, methodological diversity, longitudinal understanding, and theoretical integration.

This section outlines emerging research directions that can strengthen future engineering identity scholarship. Rather than proposing a completely new model, the section identifies areas where existing models can be extended, refined, and contextualised. These directions are particularly important for advancing engineering identity research beyond dominant Western contexts and toward more inclusive, developmental, and globally relevant understandings of identity formation.

7.2 Contextualising Engineering Identity

Future engineering identity research should give greater attention to contextual influences. Existing models have contributed significantly to understanding identity dimensions, but they often give limited attention to how cultural, institutional, and professional environments shape identity development. This is important because engineering identity does not develop in isolation from the educational systems and social structures within which students learn.

Contextualising engineering identity means examining how identity is shaped by family expectations, institutional culture, accreditation systems, national development priorities, labour market conditions, and professional pathways. In some contexts, students may enter engineering because of personal interest. In others, their decisions may be shaped strongly by family encouragement, social mobility aspirations, or national workforce demands. These differences suggest that engineering identity frameworks should not assume a universal pathway of identity development.

Future studies should therefore examine how established dimensions such as interest, performance and competence, and recognition operate within specific cultural and institutional settings. Rather than simply applying existing instruments across contexts, researchers should investigate whether the meanings of these dimensions vary across educational systems. For example, recognition may come not only from lecturers and peers, but also from family members, community expectations, industry mentors, or professional bodies. Similarly, competence may be interpreted not only through academic performance, but also through employability, communication, teamwork, and readiness for professional practice.

7.3 Expanding Global South Perspectives

A second important direction is the expansion of engineering identity research within Global South contexts. Much of the existing literature has been developed within North American and Western European settings. While these studies are valuable, they do not fully represent the diversity of engineering education systems worldwide.

Engineering education in Global South contexts may be shaped by different economic priorities, cultural values, institutional capacities, and professional expectations. In many developing or rapidly industrialising countries, engineering is closely linked to national development, infrastructure growth, technological modernisation, and social mobility. These conditions may influence how students understand the meaning and value of becoming engineers.

Expanding Global South perspectives would help determine whether dominant engineering identity models are universally applicable or require contextual adaptation. Such research could also reveal new identity influences that are less visible in Western-centred studies. These may include collectivist family expectations, community responsibility, religious or moral values, national development narratives, and industry readiness concerns.

Importantly, expanding Global South scholarship should not be treated merely as adding more geographical cases. It should involve theoretical contribution. Studies from Asia, Africa, Latin America, and other underrepresented regions can challenge existing assumptions and help develop more globally responsive engineering identity frameworks.

Within this broader Global South agenda, ASEAN countries represent a particularly important context for future engineering identity research. Although ASEAN nations differ in their educational systems, economic development, and industrial priorities, many share common characteristics, including policy-driven higher education reforms, rapid industrialisation, strong emphasis on graduate employability, and collectivist cultural values. These characteristics may influence how engineering students develop professional identities, experience recognition, and perceive their future roles as engineers. Regional initiatives related to engineering mobility, accreditation, and workforce development also provide opportunities to examine how engineering identity develops across diverse yet interconnected educational environments. Consequently, ASEAN countries offer a valuable setting for extending and testing engineering identity frameworks beyond the Western contexts in which most dominant models were originally developed.

7.4 Industry Readiness and Employability

Another important research direction concerns the relationship between engineering identity, industry readiness, and employability. Existing engineering identity literature often focuses on students' experiences within educational institutions, but identity development is also shaped by students' understanding of professional practice and workplace expectations.

Engineering is a practice-oriented profession. Engineering outreach, industry-academia engagement, and employability-oriented learning experiences may therefore contribute to identity development by connecting students' academic learning with professional expectations and workplace realities (Balakrishnan & Azman, 2017; DeBoer et al., 2019). Therefore, students' identity development may be strengthened when they experience authentic engineering work through internships, industrial training, capstone projects, site visits, industry mentoring, and professional engagement. These experiences allow students to connect academic learning with real-world engineering practice and may help them see themselves more clearly as future engineers.

Future research should examine how employability-related experiences contribute to engineering identity development. This includes not only technical competence, but also communication, teamwork, ethical judgment, leadership, problem-solving, adaptability, and professional confidence. Industry readiness may function as a bridge between academic identity and professional identity, helping students move from "studying engineering" to "becoming engineers."

Regional accreditation and professional registration systems may also shape engineering identity by defining what counts as legitimate engineering competence and performance. For example, in Malaysia, the Board of Engineers Malaysia and Washington Accord-aligned accreditation expectations emphasise outcome-based competencies such as problem analysis, design ability, ethical responsibility, communication, teamwork, and lifelong learning. These requirements can influence how students understand the performance and competence dimensions of engineering identity by connecting academic learning with externally recognised professional standards. In practical terms, accreditation expectations may shape curriculum design, capstone assessment, industrial training requirements, and graduate attribute evaluation, thereby making competence and performance visible through both academic and professional benchmarks. In this sense, accreditation and professional bodies do not merely regulate engineering programmes; they also help define the qualities through which students learn to recognise themselves, and be recognised by others, as future engineers.

Greater attention should also be given to the role of industry professionals, professional bodies, and accreditation systems in shaping engineering identity. Recognition from lecturers and peers remains important, but recognition from industry mentors and workplace supervisors may carry particular significance as students approach graduation and professional practice.

7.5 Identity Across Educational and Professional Stages

Future research should also examine engineering identity as a developmental continuum rather than a fixed outcome. Current studies often focus on specific educational stages, such as first-year students, undergraduate students, or postgraduate students. While these studies provide useful insights, they do not fully explain how identity develops across transitions.

Engineering identity may begin before university through early STEM exposure, school experiences, family encouragement, and informal learning. It may then be strengthened or weakened during undergraduate education through coursework, projects, peer interaction, assessment, and industrial exposure. Later, it may continue to develop during postgraduate study, professional training, and workplace practice.

Longitudinal research is needed to understand how engineering identity changes across these stages. Such research could examine which experiences are most influential at different points, how recognition changes over time, and how students respond to challenges, failure, or uncertainty. It could also explore how students move from aspirational interest to academic participation and eventually to professional self-identification.

Understanding engineering identity development across stages would help educators design more effective interventions. Early exposure may support interest, undergraduate experiences may strengthen competence and belonging, while industry engagement may reinforce professional recognition and employability confidence.

7.6 Toward Integrated Engineering Identity Frameworks

The future of engineering identity research also requires more integrated frameworks. Existing studies have identified many important dimensions, including interest, performance and competence, recognition, agency, belonging, emotion, motivation, and professional readiness. However, these constructs are not always clearly connected.

An integrated framework should explain how these dimensions interact rather than treating them as separate variables. For example, interest may motivate participation, participation may produce competence, competence may invite recognition, recognition may strengthen belonging, and belonging may reinforce long-term professional identification. Similarly, industry exposure may transform academic identity into professional identity by providing authentic recognition and practice-based confidence.

Integrated frameworks should also connect individual, social, institutional, and professional levels of identity development. At the individual level, students develop interest, confidence, motivation, and future self-concepts. At the social level, they experience

recognition, belonging, mentorship, and peer validation. At the institutional level, curricula, assessment, pedagogy, and university culture shape opportunities for identity practice. At the professional level, industry exposure, accreditation expectations, and employability demands influence how students understand engineering as a future career.

Such integration would help move engineering identity research beyond isolated constructs and toward a more holistic explanation of how engineering identity develops.

7.7 Methodological Directions

Future engineering identity research should also adopt more diverse methodological approaches. Quantitative studies have provided valuable evidence regarding identity dimensions and their relationships with persistence, belonging, and career intention. However, qualitative and mixed-methods approaches are needed to understand how students interpret identity-related experiences.

Qualitative studies can capture the meanings students attach to recognition, belonging, competence, and professional expectations. Longitudinal qualitative work can reveal how identity develops across time and transitions. Mixed-methods studies can combine the strength of measurement with the depth of lived experience. Comparative cross-cultural studies can also examine whether engineering identity dimensions operate similarly or differently across educational systems.

Greater methodological diversity would strengthen the field by allowing researchers to examine both patterns and processes. This is especially important for understanding identity development in contexts where existing instruments may not fully capture local meanings.

7.8 Synthesis of Future Directions

The future of engineering identity research lies in moving from established dimensional models toward more contextual, developmental, and integrated understandings of identity formation. Existing models remain valuable, but they should be extended through research that examines cultural context, Global South perspectives, industry readiness, educational transitions, and methodological diversity.

These directions do not reject existing engineering identity frameworks. Rather, they build upon them by asking how identity dimensions operate across different settings, stages, and systems. Such work can help develop more inclusive and globally relevant understandings of what it means to become an engineer. The concluding section synthesises these contributions and reiterates the importance of more integrated and contextually responsive engineering identity research.

8. Conclusion

Engineering identity has emerged as one of the most influential constructs in engineering education research because of its ability to explain students' engagement, persistence, sense of belonging, and professional development. As engineering education increasingly seeks to prepare graduates who are not only technically competent but also professionally committed and socially responsive, understanding how engineering identity develops has become an important area of scholarly inquiry.

This review traced the theoretical progression of engineering identity research from broader identity theories through science identity and STEM identity scholarship to contemporary engineering identity frameworks. The review demonstrated that engineering identity is grounded in a diverse set of theoretical traditions, including Identity Theory, Social Identity Theory, Communities of Practice, Social Cognitive Career Theory, Identity-Based Motivation Theory, and Possible Selves Theory. These perspectives collectively contributed to the development of engineering identity as a multidimensional construct shaped by individual, social, and contextual influences.

The review further highlighted the significant contributions of Carlone and Johnson's (2007) Science Identity Framework, Hazari et al.'s (2010) Physics Identity Framework, and Godwin's (2016) Engineering Identity Model. Together, these frameworks established the dimensions of interest, performance and competence, and recognition as central components of engineering identity development. Over time, however, engineering identity scholarship has expanded beyond this traditional tripartite structure to include agency, belonging, emotional experience, and developmental perspectives, reflecting a growing appreciation of the complexity of identity formation.

Despite substantial progress, several challenges continue to constrain the field. The review identified conceptual fragmentation, methodological concentration, contextual limitations, and limited longitudinal understanding as recurring issues within the literature. Engineering identity is often examined through different theoretical lenses and research approaches, creating difficulties in integrating findings across studies. Furthermore, much of the existing evidence remains concentrated within Western educational contexts, raising important questions regarding the broader applicability of dominant frameworks across diverse cultural, institutional, and professional environments.

In response to these challenges, this review proposed several future directions for engineering identity research. These include greater attention to contextual influences, increased representation of Global South perspectives, stronger integration of industry readiness and employability considerations,

expanded longitudinal research, and the development of more holistic and integrated identity frameworks. Collectively, these directions can help advance engineering identity scholarship toward more comprehensive and contextually responsive understandings of identity development.

The main contribution of this review is that it consolidates the theoretical development of engineering identity into a clearer and more integrated scholarly narrative. Specifically, the review shows how engineering identity evolved from broader identity theories, science identity, and STEM identity research before becoming established around the dimensions of interest, performance and competence, and recognition. It also demonstrates that contemporary engineering identity scholarship has moved beyond this tripartite structure by incorporating agency, belonging, emotional experience, developmental progression, contextual variation, and professional readiness. By synthesising these developments, the paper provides a clearer foundation for future engineering identity research, particularly in non-Western, ASEAN, and Global South contexts where sociocultural, institutional, accreditation, and employability conditions may shape identity formation differently.

Ultimately, engineering identity should not be viewed as a fixed characteristic possessed by students. Rather, it is a dynamic and evolving process through which individuals develop interest, confidence, recognition, belonging, and professional self-understanding within engineering communities. As engineering education continues to respond to changing societal, technological, and workforce demands, a deeper understanding of engineering identity will remain essential for supporting the development of future engineers who are capable, committed, and prepared to contribute meaningfully to society.

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Conflict of interest

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