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A Review of the Literature Relevant to Engineering Identity

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A Review of the Literature Relevant to Engineering Identity

The aim of this review is to summarize the use of identity in theory and practice in the existing literature and make suggestions for areas of future work in engineering education. Identity is complex, multi-faceted and changes over time. Intersectional identities of gender and race also complicate what it means to identify as an engineer. Furthermore, identity development and its relation to academic and career outcomes are important lenses for studying engineering student recruitment and retention, the impact of interventions, and diversity of a competitive STEM workforce. However, the usefulness of engineering identity is dependent on maintaining a clear definition of what the framework is (and is not), distinct from other identity theories. Researchers do not always make a clear distinction between "identity" and other more rigorously studied constructs such as self-efficacy. The use of the term "identity" as it relates to this review spans studies in psychology, sociology, education, cultural studies, anthropology, and social linguistics and culminates with more recent research in physics, math and engineering education. Relating factors that contribute to identity across these different bodies of literature is even more confusing when terms including agency, utility, motivation, beliefs, values, and attitudes are used seemingly interchangeably with engineering identity. Consistency in the language of engineering identity such that the construct can be used consistently and coherently is an apparent need. Despite the existence of validated scales on instruments such as Sustainability and Gender in Engineering (SaGE), engineering identity has not been conceptualized or measured directly to date. Increased attention to the connection between both qualitative and quantitative studies will further strengthen the character of engineering identity work.

Introduction

The central motivation for conducting this review was the need to identify and synthesize prior work and theory relevant to engineering identity in order to inform future work. Even though there is a large, broad history of identity in the literature, use and discussion of identity theories in STEM education (including engineering education) is still relatively narrow and underdeveloped. This creates an opportunity for researchers to refocus and rethink the meaning of identity in STEM, leading to a much richer understanding of identity in STEM and particularly engineering. Studies show that a lack of identification with engineering and by engineers often motivates students to migrate out of engineering into other majors.[1] Attempts to define identity in the context of engineering education necessitate a deeper understanding of the term "identity." While definitions of identity vary across disciplines, *how* identity is formed is still a central and driving question. For example, what are the components that predict engineering identity and what does engineering identity predict?

We posit there is more to engineering identity than just feeling like an engineer or seeing oneself as an engineer. This definition is limited and does not take into account the various facets of personal identity that contribute to "being." Moreover, identity is not developed in isolation. We as engineering education researchers need to be aware of the rich and nuanced nature of engineering identity and development that accompanies the intersectionality of multiple identities including race, gender, sexual orientation, and affinity towards engineering. This idea is surfacing in the literature but has yet to be addressed fully in engineering education. Greater consistency with what we refer to as both identity and engineering identity will better ground the research moving forward. This effort needs to be driven from within the engineering education community. Recruitment and persistence in engineering, both in academia and the professional environment, is still a problem, and this review is one way of understanding why identity has gained popularity within and beyond engineering education.

This review is organized as follows. First, we describe the methods for selecting and categorizing identity studies. Second, we present the use of identity in theory and practice by field including working definitions of identity. Next, we summarize how identity is measured in STEM including details on quantitative and qualitative studies. We then summarize the findings of identity studies; specifically what factors and characteristics predict identity and what identity predicts. This paper ends with a discussion and implications for future research.

Methods

In compiling the literature for this review, we began by searching multiple databases using terms such as *identity*, *engineering*, *development* and *student*. Relevant studies were retained if the abstracts conceptually related to identity formation and/or development.
Then, we conducted forward and backward citation searches to gather studies that were relevant, which proved to be more fruitful than keyword searching. Many of the included articles were theoretically similar to identity but did not surface in the initial search because they employed more traditional terms such as self-efficacy. Similarly, many studies began by emphasizing the importance of engineering identity but did not actually follow through theoretically. For these reasons, a review based solely on sources labeled "identity" would have been of limited use. The criteria for inclusion are listed below. Qualifying articles had to:

1. Include identity or a theoretically similar construct
2. Focus on engineering or STEM students as population of interest
3. Contain engineering identity, STEM identity, or career interests/choice in either domain
4. Be published as a journal article or conference paper in English

Identity Versus Other Conceptual Frameworks

Among the 55 qualifying studies listed in Table 1, few if any discussed identity in isolation from more established theories of self-efficacy, motivation, and expectancy value. This section of the review lists the variety of identity frameworks at use in research relevant to engineering identity in addition to the origins of these identity frameworks in the broader literature. To be fair, in the broader literature there have only been a few claims that identity is explicitly distinct from other constructs such as self-efficacy[2] or the expectancy-value theory of achievement motivation.[3] However, in the last five years some have made this distinction. For example, Lent, R. W., Brown, S. D., & Hackett, G.[4] expand on Bandura's theory of self-efficacy to the extent of illuminating the importance of self-efficacy in academic persistence. While this is not explicitly identity, self-efficacy is a theoretically relevant construct that had to be taken into consideration in this review as it is often associated with identity measures.

Table 1 Categorization of Identity Studies by Methodological Approach. (Only first authors are listed. "mm" denotes mixed methods approaches.)

Theory	**Quantitative**	**Qualitative**
Arnett (2000; 2004; 2007)[5; 6; 7]	Arnett (1994)[21]	Brickhouse (2000; 2001)[40; 41]
Bandura (1997)[2]	Capobianco (2012)[22]	Calabrese Barton (1998;2008)[42;43]
Burke (1980)[8]	Cass (2011)[23]	Carlone (2007)[44]
Calhoun (1994)[9]	Chemers (2011)[24]	Furman (2006)[45]
Eccles (1983)[3]	Cribbs (2015; 2016)[25; 26]	Matusovich (2009; 2011)[46; 47]
Gee (2000)[10]	Estrada (2011)[27]	Olitsky (2006)[48]
Lave (1991)[11]	Fleming (2013)[mm,28]	Powell (2009)[49]
Lent (1994)[4]	Godwin (2013a;b)[29; 30]	Rahm (2007)[50]
Li (2009)[mm,12]	Hutchison (2006)[31]	Smith (2012)[51]
Mead (1934)[13]	Hazari (2010)[32]	Stevens (2005)[52]
Shanahan (2009)[14]	Jones (2014)[33]	Tan (2008a;b)[53; 54]
Stets (2000)[15]	Kier (2014)[34]	Tate (2005)[55]
Stryker (1968; 1980; 2000)[16; 17;18]	Lent (2008)[35]	Tonso (2006)[56]
Holland (2001)[19]	Marra (2009)[36]	
Erikson (1994)[20]	Meyers (2012)[37]	
	Pierrakos (2010)[38]	
	Sheppard (2010)[39]	

Sheppard et al. incorporates various motivation beliefs into the concept of identity.[39] The authors separate identity from skill, education, and workplace. In their model, other factors such as academic persistence and confidence are incorporated into education and skills respectively. Chemers et al. distinguish identity from self-efficacy in the exploration of underrepresented minority students' identity in science career commitment.[24] Additionally, Estrada et al. make the distinction between self-efficacy, identity, and value to a similar end: integration into the scientific community.[27] In both studies, the constructs are treated as separate components that contribute to the outcome of career commitment or integration. More recently, Godwin et al. used the constructs of agency and identity through the lens of critical engineering agency in the development of a model of engineering career choice.[29] They found that agency and identity are separate components that contribute to career choice. Jones et al. used the MUSIC Model of

Academic Motivation to show the relationship between first-year engineering students' course perception and other constructs, namely: engineering identification and utility, and program belonging and expectancy.[33] From this model, those and other factors are treated as components of engineering identification.

In these studies, identity work is not necessarily a reinvention of the wheel but rather an expansion and piecing together of various conceptual frameworks that contribute to grounding the studies. Table 2 lists the studies that explicitly stated their definition of identity. Although this list is by no means exhaustive, it does illustrate the various ways identity is being defined and what theories are anchoring the work. In an effort to illuminate any cohesiveness existing in identity work, the final column lists citations used in the original authors' explicit definition of identity. The variation in Table 2 demonstrates how the use of identity in engineering/STEM is not only scattered but also used in various forms even when the same source is being cited. Particularly in engineering education, the definition of identity tends to boil down to seeing oneself as or feeling like an engineer. This narrow definition is heavily dependent on recognition but excludes other important components identified in the literature, i.e., interest, performance/competence, agency, motivation, and expectancy values.[29; 32; 33] Moreover, this narrow definition does not give credence to social-cultural and environmental factors that shape "becoming" in the process of "doing" engineering.

Table 2. Theory and Definition of STEM Identity with corresponding source citation. Only 20 of 55 studies offered or cited definitions

Author	**Theory**	**Definition (direct quotation when available)**	**Source cited**
Cribbs (2016)[26]	Core identity (developed from Multiple Identity Theory)	"how students see themselves with respect to mathematics, based upon their perceptions and navigation of everyday experiences with mathematics" (p. 165)	Gee (2000)[10], Cobb (2010)[57]
Cribbs (2015)[25]	(no specific Identity theory)	"a student's desire or curiosity to think about and learn mathematics" (p. 1052)	Carlone (2007)[44], Hazari (2010)[32]
Tonso (2014)[1]	Cultural Worlds Sociocultural Theory	Identity is a concept that figuratively combines the intimate or personal world with the collective space of cultural forms and social relations (p. 267)	Holland (2001)[19]
Jones (2014)[33]	Domain Identification	The extent to which a first-year engineering student ''defines the self through a role or performance in engineering" (p. 1342)	James, W. (1892/1968)[58]
Fleming (2013)[28]	Academic and Social Integration Multiple Identity Theory	"We focus on the cultural context in which the identity develops, namely the MSI campus. Researchers have conducted studies on identity development of engineering students, specifically. They found that three factors influence the development of an engineering identity, (1) how engineering is understood as a science, (2) the rules that govern the behavior of an engineer, and (3) the environmental setting of the institution in which one learns to become an engineer. It is this latter factor that we have examined in this study."	Gee (2000)[10], Carlone (2007)[44]

Godwin (2013a;b)[29; 30]	(no specific Identity theory)	Identity is composed of students' perceptions of their performance/competence, recognition, and interest in a domain. (p. 1)	Hazari (2010)[32], Cass (2011)[23], Potvin (2011, 2012)[59; 60]
Meyers (2012)[37]	Identity Stage Theory	The development of engineering identity, modeled as a stage theory of development that takes place over time. (p. 120)	Erikson(1994)[20], Arnett(2004)[5]
Capobianco (2012)[22]	Multiple Identity Theory	There are four important ways to view young women's identities in becoming engineers (1) their self-beliefs in who they are as students (academic identities); (2) their affiliation or attachment to their respective engineering programs, courses, or university (institutional or school identities); (3) their beliefs in who they are as women and how their gender is mediated in an academic program (gendered identities); and (4) someone they aspire to be or how others encourage and support them (role models) (p. 701)	Gee (2000)[10], Brown (2005)[61]
Matusovich (2011)[47]	Multiple Identity Theory	Describing one's self as an engineer or using professional descriptors related to future engineering career rolls	Jackson (1981)[62], Gee (2000)[10]
Chemers (2011)[24]	Identity Stage Theory	Identity is framed as an integration of one's multiple identities including social, personal, and academic.	Erikson(1994)[20], Arnett(2004)[6]
Cass (2011)[23]	(no specific Identity theory)	Student identity is social, personal, and domain specific. Within the domain: identity defined as performance, competence, recognition, and interest.	Hazari (2010)[32]
Pierrakos (2010)[38]	Organizational Identity Grounded Theory	The relationship between social, organizational, and personal identity, as well as how they interact, to ultimately form a cohesive identity. (p. S3C-2)	Dutton (1994)[63]

Hazari (2010)[32]	(no specific Identity theory)	Four components, identified in the above literature review, act as key contributors to students' identification with physics in high school: competence, performance, recognition, and interest. (p. 982)	Carlone (2007)[44], (Fouad 1996, 2002; Lent 1994,1996)[4;64;65;66]
Pierrakos (2009)[67]	Social Identity Theory Communities of Practice	Rather than being just a personality issue (self-categorization), organizational, institutional, and situational factors play a central role in shaping identity. (p. M4F-3) "Collective identity"	Stryker (2000)[18], Tajfel (1986)[68], Wenger (1999)[69]
Matusovich (2009; 2010)[46; 70]	Eccles' Expectancy Value Model	This model highlights ability beliefs, *how people judge their ability for a particular activity,* and value or important beliefs, *how important an activity is to a person*. (p. 2, 2009)	Eccles (1983)[3]
Stevens (2008)[71]	Sociocultural Theory Communities of practice	Identity in these formulations is understood as formed out of a double-sided process of positioning ourselves and being positioned by others.	Lave (1991)[11], Holland (2001)[19], Skinner (2001)[72]
Carlone (2007)[44]	Grounded theory	The model illustrates that the three dimensions of science identity—competence, performance, and recognition—overlap. (p. 1190)	Informed by Gee (2000)[10]
Gee (2000)[10]	Multiple Identity Theory	Being recognized as a certain "kind of person" in a given context (p. 100)	(this is an original, highly cited source)

The dominant theoretical framework for each study is provided in the second column of Table 2. It is important to outline the distinctions between these various theories, as while many theories appear to be similar in name, nuances in their development and use makes relying on name alone deceiving. Sociocultural theory emerged from the work of Lev Vygotsky, a Russian psychologist.[73] This theory focuses on how individuals, primarily children, learn not only as individuals but also through cultural beliefs and attitudes. Terms closely related to this theory salient to this review are *cultural worlds* and *community of practice*, both of which come from a perspective that individuals are not practicing and participating in isolation of their environment and norms of that environment. Similarly, social identity theory is an individual's self-concept in relation to membership in a group. Identity stage theory emerged from the work of Erik Erikson, a German psychologist, the premise being that identity develops in stages as a function of reconciling the inner individual and outer forces (i.e., culture).

Domain identification is more focused on the performance of an individual in a given domain. However, this idea comes from the symbolic interactionalist perspective in sociology where the attention is on how humans interact with their reality. These types of interactions help author one's self. Mead and Mind's *Mind, Self and Society* is a highly cited version of this theory.[13] Tinto's academic and social integration model is also a sociological perspective.[74] The model can be thought of as a type of identity theory that focuses on how students transition and adopt values in college.

Gee, a psychosocial-linguist, postulated multiple identity theory based on the social and cultural factors that influence identity. The theory centers on four modes of identity: nature identity, institutional identity, discourse identity and affinity identity, any of which can be more or less salient to the individual depending on their situation. In organizational theory, "members assess the attractiveness of [work organization] images by how well the image preserves the continuity of their self-concept, provides distinctiveness, and enhances self-esteem."[63] This notion of continuity of self-concept in the midst of a functional environment echoes sentiments of the socioculturalist theories described above. Although these distinctions are notable, we encourage readers and researchers to consider the collective value of these theories in their pursuit of future research. Taking any one theory in isolation from the others reinforces the fracturing in the literature suggested by Table 2 and the rest of this review.

The Use of "Identity" in Theory and Practice

In the Social Sciences

Most theories of identity in the social sciences are centered on communities of practice and cultural worlds, which collectively fall under sociocultural theory, social identity theory, and multiple identity theory. Each of these will be discussed in the following paragraphs. In some instances the theories connect to each other but the work is not necessarily sequential as different fields of study developed conceptions of identity in their own ways. However, it is important to include these theories in this review because all have been applied to STEM identities including engineering (Table 1 and 2). It is also relevant to consider how certain theories may be useful to engineering education researchers in the future and whether these theories are actually distinct. If understood and applied properly, these theories may be useful as framework tools to to measure engineering identity at the primary, secondary, post-secondary, and professional level, which would in turn help further develop engineering identity theory.

The exploration of identity in the social sciences has been ongoing for several decades. Over time definitions of identity have evolved. These definitions have changed to accommodate the expanding variety of identity frameworks in the literature. Specifically, theories of identity development utilize a communities-of-practice framework[11] and closely related cultural production theory[74; 75], both of which maintain arguments for considering identity not only as who one is but also who one wants to become. These theories maintain a greater focus on how individuals are shaped by their communities and their personal beliefs.

Identity theory from a social perspective, such as that employed by Tonso's exploration of campus engineering as a figured world is a popular theory particularly for those in cultural studies.[56] This work is centrally inspired by Holland et al.'s book *Identity and Agency in Cultural Worlds*.[19] Figured worlds are "socially produced, culturally constituted activities" in which people develop their sense of self-conception, i.e., identity. Stevens, O'Connor, and Garrison also situated their study in this frame by adopting a definition of identity as "both one's self understandings about and actual ways in which one is positioned—both by others and by institutional representations—within some social world."[52]

Other related works have made efforts to further define and combine theories of identity. For example, Calabrese Barton's[42] investigation of teaching science to homeless children is situated in transitions in the Personality and Social Structure Perspective (PSSP) framework established by Shanahan[14], which focuses on the transitions between interaction, personality, and social structure. The PSSP framework is used to tie together studies relating to identity in school science. Stets and Burke address the distinction between identity and social identity theory, much of which is in relation to terminology, in efforts to establish a more general theory of self.[15] Developed in 1979 by Tajfel and Turner, social identity theory proposes that social identity is an individual's self-conception based on membership in a collective social category or categories.[68] In comparison, Calhoun discusses how the culture of a people shapes identity from the vantage point of social theory.[9] For the sake of simplicity, social identity theory can be thought of as the group nature of identity whereas identity theory is focused on the self-nature.

Furthermore, others such as Smith and Woodworth investigated the development of social entrepreneurs and innovators from a social identity and self-efficacy approach.[51] Identity development in this study is certainly generalizable to studies of identity in engineering and mathematics and science education. The authors propose social entrepreneurship identity can be facilitated by educators through defining the social category group in which the individual will identify, exposure to prototypical members and member characteristics, and active engagement in the social category particularly through group projects. Similarly, Mead formulated that "*society shapes self shapes social behavior*."[13] These social behaviors were later taken up by Stryker and redefined as role choice behavior.[16; 17] While Stryker explores external structures, Burke explored internal mechanisms aligned with more modern cognitive theories of identity development, namely the interactionist perspective or the idea of *multiple selves.*[8] In their evaluation of identity theory, Stryker and Burke take identity to be the "composed meanings that persons attach to the multiple roles they typically play in highly differentiated contemporary societies."[18] It may seem overwhelming to follow all the terminology, especially since these theories are just one word apart from each other, but the main point is that identity and social identity theory overlap and in many cases are complementary.

Expanding in scope and widely cited is the multiple identity framework attributable to Gee.[10] Tate[55], Matusovich et al.[46], Capobianco[22], and others capitalize on the complexities of identity theory by addressing the multiple identities that students formulate as they come to identify with various social, academic, personal, and professional groups. Simply speaking, identity is not as singular as how an individual perceives themselves in isolation from other aspects of their personality. Often individuals project different parts of their identity as dependent on the environment and context. In doing so individuals are continuously doing and undoing their identities to suit their needs in the moment.

In Science and Math

Science, technology, engineering and math (STEM) disciplines have turned to identity theories as a way to identify talented individuals in efforts to fuel recruitment and retention. To this end, many have sought to define what it means to have a science [24; 27; 44] or math identity[25; 26], be a physics person[32], or be a math person[23]. Shanahan provides a synthesis of various other studies of science identity by illustrating the connection between the studies in multiple sociological theoretical frameworks.[14] Her work in this area has given way to the specific investigation of engineering identity. Most of these models qualitatively investigated identity formation and/or erosion through interviews, longitudinal observations and member checking.

More recently researchers have moved into the quantitative sphere, informed by the qualitative work that preceded them. Seemingly the most cited framework on identity in STEM has been Carlone and Johnson, a qualitative piece that defines science identity as the triangulation of performance, recognition and competence in practice.[44] These three components interact with other identities such as racial, ethnic and gender to establish science identity in the individual. Hazari et al. built upon this framework by adding interest to the triangulation of domain-specific identity, in this case physics identity.[32] This work also diagrams social identity and personal identity. The three spheres (social, personal and identification with physics) overlap to form a student's identity (Figure 1). The authors go on to approximate the connection between physics identity and physics career choice in addition to predictors of physics identity, mainly physics interest, science interest, being a physics person, and recognition. There are several studies documenting the formation of science identity and how this development leads to agency and positioning in and out of the science classroom. [45; 48; 50; 53; 54; 76]

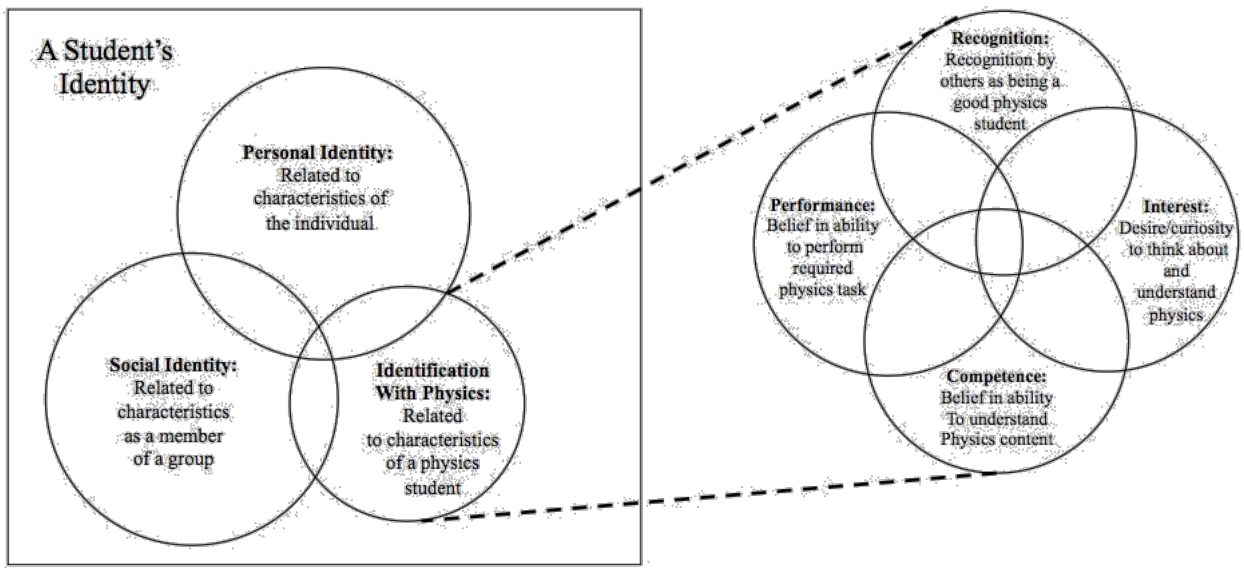

Figure 1 Hazari et al.'s framework for identification with physics[32]

In Engineering

Researchers within and beyond engineering have explored what it means to develop and maintain an engineering identity. The exploration of engineering identity has been an important aspect of engineering and STEM education. Several researchers have undertaken work in the area of engineering identity.[28; 30; 37; 56; 67] However, this work does not build on itself to make a coherent story of engineering identity in the engineering education literature. This assertion is evident and supported by Table 2. Despite this lack of coherence, these studies have been important first steps in exploring specific aspects of identity development in engineering.

Closely related to identity but not explicitly stated, others have provided a review and analysis of existing research on the measurement of the characteristics of engineering students in order to illuminate factors that affect college enrollment and retention.[12] The authors, Li, Swaminathan, and Tang, found that many researchers are specifically looking at the factors that help or hinder the matriculation of underrepresented groups into engineering. Marra, Rodgers, Shen, and Bogue conducted a multi-institution study on self-efficacy and women engineering students.[36] This study further investigates the relationship between ethnicity and feelings of inclusion as related to persistence in engineering. Some, such as Matusovich have sought to address this issue by investigating the motivation behind students choosing engineering as a career.[70] They reviewed many of the choices students make in engineering as a choice in identity due to the external and internal motivations that drive them to persist in the major.

How is Identity Measured in STEM?

As evident from Table 1, identity has been studied both qualitatively and quantitatively in a relatively equal number of studies. These studies range from single items asking whether students feel like an engineer to multifactor scales measuring science identity. Several researchers have studied engineering identity from one perspective or another, including factors related to being an engineer[37]; ways of constructing gender identity in engineering[49]; and outcome expectations, interests, and choice in engineering in relation to self-efficacy[35]. Not unexpectedly, quantitative studies have relied heavily on the use of surveys to relate various constructs and outcomes (Table 3).[34; 39; 77] Estrada et al. also used a survey relating structural equation models to predict scientific integration in undergraduates, graduate students, and those that left college with a baccalaureate but were not pursing graduate school. In this model scientific integration was composed of self-efficacy, identity, and value factors.[27] They found identity was a strong predictor for scientific integration for all groups. Additionally, scientific integration was used as a mediator to predict other educational outcomes namely conducting research, applying to graduate school, and enrolling in graduate school. Godwin et al., used a survey to build a single structural equation model predicting choice of engineering as mediated by engineering identity.[30] This model is more complicated because they constructed engineering identity from physics, math, and science identity factors, which are, constructed of performance/competence, interest, and recognition factors (Figure 1). The results indicate that while performance/competence are important for all domains, without recognition identity formation can be stifled. Other notable results include the large path coefficient indicating the effect of physics identity on engineering identity (0.815) and medium path coefficient of engineering identity on choice of majoring in engineering (0.549).

Table 3 lists the details of qualifying studies employing quantitative methods of STEM identity measurement including any meditating constructs. These studies contain several items per factor (independent variable); for simplification only factor names were included. It is also important to note not all studies specifically used identity as a dependent variable. In fact, the variation in use of engineering identity as independent, dependent, and mediator variables is one contributing factor to confusion about how to measure it. Professional identity and its connection to emergent adulthood[5; 6; 7; 21] are other key aspects that must be incorporated into engineering identity as engineers have different views than scientists, particularly in the area of agency[29]. Meyers et al. also note that engineering "differs from other professions (medicine, law) in the way that it labels its students as *engineers* rather than *engineering students*."[37] Thus, it is critical to address professional dimensions in the full scope of engineering identity. From the studies summarized in Table 3, it is evident that there have been several attempts to define engineering identity; however, there is also a clear need for a more complete measurement tool that combines the science, math, and professional aspects explored in various individual identity studies.

Qualitative studies are also a rich source of data on the formation of engineering identity. Using a multiple identity theoretical framework, Tate and Linn describe the experiences of engineering women students of color.[55] Fleming and Smith in their mixed methods approach found that even in the second year students start to take on an engineering identity, often using the pronoun *we* during the interviews. Through this lens they present three emergent identities: academic, social, and intellectual.[28] The salience of such identities is discussed in reference to the participants' experiences and persistence in engineering programs. Tonso explored the development of engineering identity inclusive of factors relating to campus culture.[56] Her work, situated in a community of practice framework, describes what it means to be an engineer on campus, or *campus engineer identities.* Matusovich et al. situate their study around the question: *What are students' perceptions of themselves as future engineers?*[46] They conclude that students view themselves as being good in math/science, good communicators, good at teamwork, and they enjoy engineering activities, problem solving, and having/applying technical knowledge. However, even students a few years into engineering were unsure of what it means to be an engineer. Using multiple identity theory, Matusovich et al., aimed to understand students' formation of professional identity and identification with engineering.[47] The primary comparison groups in this study were by institution: a military institution, an elite private university with a balanced focus on arts and engineering, and a large public university. Military cadets and public university participants gave more concrete examples of experiences and activities whereas private university students struggled to give such examples. Stevens examined how student identity impacts choice of and persistence in engineering.[52] Although not explicitly labeled as engineering identity, this study illuminates how identity impacts students' choice to stay or leave engineering. More closely related to gender identity, Powell et al. explored gender performance and how women do and undo gender in the process of doing engineering.[49]

Table 3. Quantitative Studies Measuring Identity in STEM. (Number following variables indicates # of items)

Method	**Study**	**Mediator/Controls**	**Dependent Variable**	**Independent Variables**	**Final Model**
Confirmatory Factor Analysis	Kier (2014)[34]	(none)/(none)	STEM Career Interest (11)	11 questions (per STEM domain area) self-efficacy (2), outcome expectations (2), goals (2), interests (2), contextual supports (2), personal disposition (1)	All
Exploratory and Confirmatory Factor Analysis	Capobianco (2012)[22]	(none)/(none)	Engineering Identity (4)	Academic identity (5), School identity (4), Occupational identity (7), Engineering Aspirations (4)	Academic career (6) Engineering career (10)
EFA Simple Descriptives	Fleming (2013)[28]	(none)/(none)	Engineering Identity (4)	Part V Engineering Fields Questionnaire**	All
EFA Logistic Regression	Cribbs (2016)[26]	(none)/gender, mother's education, student's year in college: freshman, junior, senior, graduate	Choice of Engineering Career (1)	Mathematics Identity (2) and Math Recognition-Gender Interaction	All (father's education SAT/ACT score removed from controls)
Multiple Linear Regression	Hazari (2010)[32]	(none)/race ethnicity, standing in school, parental education, community SES, student's birthplace family, support for science	Physics Identity (1)	Performance/Competence (7), Interest (6), Recognition (2)	All

Multiple Linear Regression	Sheppard (2010)[39]	(none) / gender, race ethnicity, mother's education, family income	Intent to major in engineering (1)	Skills (21), Identity (17), Education (31), Workplace (5)	(model dependent)
Simple Descriptives	Meyers (2012)[37]	(none)/(not included)	Do you consider yourself to be an engineer? (1)	Which of the following is necessary to be considered an engineer? (29) All questions were Yes / No	Frequently cited as necessary to be an engineer (6)
Logistic regression				Demographic and background questions (10)	(8)
Logistic regression	Cass (2011)[23]	(none)/ gender, mother's education, SAT-ACT math score	Choice of Engineering Career (1)	Interest (5), Recognition (3), Competence and Performance (4)	Interest (4), Recognition (3), Competence and Performance (4)
Structural Equation Modeling	Chemers (2011)[24]	(model dependent)	Commitment to a science career (3)	Research experience (6), Advanced research experience (14), Instrumental mentoring (6/11), Socioemotional mentoring (7), Community involvement (4/3), Science self-efficacy (10/13), Leadership/teamwork self- efficacy (not included), Identity as a scientist (6)	(model dependent)

Structural Equation Modeling	Cribbs (2015)[25]	Interest and Recognition/(none)	Math Identity	Interest (3), Recognition (2), Competence/Performance (4)	All
	Estrada (2011)[27]	Scientific Integration	Scientific Integration, Conduct Research, Apply to Graduate School, Enroll in Graduate School	Self-efficacy, Identity, Value	All
	Godwin (2013b)[30]	Engineering Identity/(none)	Choice of Engineering (1)	Math Identity (10), Physics Identity (10), Science Identity (16)	All
	Jones (2014)[33]	(model dependent)	Engineering Identification (4) (not the ultimate goal of this project. The researchers were ultimately interested in academic motivation)	eMpower (leader) (5), eMpower (team) (5), usefulness (3), success (4), interest (3), caring (4)	All

** Social Cognitive Career Theory and Self-efficacy framework[4]

What Predicts Identity Versus What Identity Predicts

Table 3 demonstrates that many studies use identity as a mediator or an independent variable to predict engineering or STEM outcomes. These outcomes include engineering career choice[23; 29; 30; 33; 38; 46] or science career commitment[24]. These choices in outcomes are reasonable and help in the understanding and validating of engineering identity particularly as theory evolves, and measures develop.

Does Gender Matter?

Several studies have included research questions and/or findings about gender, which are summarized here. Cass et al.[23] adapted Hazari et al.'s [32] model of physics identity to predict engineering choice using math identity. While math interest and recognition were positive predictors for both genders, the effect of recognition was greater for females. Compared to the baseline of females who are not recognized, the odds ratio of choosing engineering for males who are not recognized was 1:7.58 whereas the odds ratio for females who are recognized was 1:8.28. Using a more direct approach, Meyers et al. asked undergraduate students "Do you consider yourself to be an engineer?"[37] Notably, less than 50% of first-year women identified as engineers, chi-squared tests confirmed a statistically significant difference by gender ($p<0.001$). This was the only subgroup (among first-year, sophomore, junior and senior men and women) of participants that identified less than 60%. Using logistic regression, the authors also found women nearly half as likely to identify as an engineer as men, an odds ratio of 0.485. Recently, Cribbs et al. found both math interest and recognition to be positive predictors of engineering career choice ($p<0.001$). The interaction effect of recognition and gender was stronger for females than for males ($p<0.01$).[26]

Additionally, Brickhouse et al. found that middle school girls' multiple identities had a direct impact on their participation in science.[40] This was particularly evident in reference to their parents' and teachers' view of appropriate gender and academic identities. Godwin et al. found being female is a negative predictor for choice of engineering ($p<0.001$) and a positive predictor for choice of a science career ($p<0.001$).[29] Furthermore, Pierrakos et al. specifically investigated gender differences in freshman engineering students' identification with engineering.[38] They found that males are more likely to have multiple types of exposure to engineering including relatives, STEM courses and activities. Additionally, males identified engineering as a way of doing things hands-on and cited doing hands-on activities and job security as the primary reasons for being an engineer. In contrast, females were more likely to identify with engineering as a way of thinking and cite creativity of the practice as a primary reason for being an engineer.

Tate and Linn viewed gender identity more holistically in how it and race shape identity of engineering women students of color.[55] This integrated approach is aligned with the multiple identities framework; Gee defines identity as "being recognized as a certain type of person".[10] This person's single identity is defined by the interaction and intersection of four different identities: nature identity, institutional identity, discourse identity and affinity identity. Matusovich et al. used this framework in operationalizing engineering identity. In qualitative studies, she and colleagues found that gender, a component of identity, does contribute to shaping career-related competence and value beliefs, and potentially course enrollments.[46] In particular, more female than male participants experienced a lack of connection between their engineering-related values and sense of self (low *attainment values*). Their 2010 study is framed using Eccles' Expectancy Value Model.[3] In sum, a number of studies found differences that suggest future work should continue to consider gender as a factor in the formation of engineering identity. However, as expressed by Beddoes and Borrego in their critique of feminist theory in engineering education, the use of gender in a dichotomous, essentializing way does not fully consider intersectionality of gender identity with engineering or science identity.[78] Truly intersectional work in engineering identity is a distinct direction for future work.

Discussion

Despite a long history of deep theoretical, qualitative and quantitative work on the many facets of engineering identity development, existing measures of engineering identity are still very crude. Many quantitative studies of engineering and science identity use long established theoretical frameworks and rely on more traditional theories such as self- efficacy and academic and social integration.[27; 28; 31; 74] This can be challenging for future work for a number of reasons. Many relevant studies were not necessarily labeled as identity studies, while others asserted the importance of identity but did not use identity theories to inform the research. Engineering identity is still evolving and drawing upon a variety of related identity and other frameworks (e.g., motivation, self-efficacy). The definitions of engineering identity itself vary widely, even in studies that cite the same sources for these definitions (Table 2). Many studies do not cite each other, or focus on one aspect of engineering identity. We did not find any studies that comprehensively combined science, math and professional aspects of engineering identity, nor did we find many exploring the intersection of engineering identities with gender, race, or ethnic identities.

As with other terms that are popularized, the use of identity as a buzzword has made it difficult to find research that actually addresses engineering identity development. In the literature on engineering identity there are many references to self-efficacy and motivation beliefs. There are few published quantitative studies truly focused on engineering identity (Table 3). More confounding, identity is variously treated as an independent variable, dependent variable, or both. Although some studies use it as a mediator variable, much of this work lacks methodological sophistication or longitudinal data to test relationships between identity and persistence in engineering beyond the first year. This may be a consequence of the progression of the literature in different disciplines or a lack of focus on the connections. As a young and relatively undeveloped area of research, engineering identity may be going through a period of convergence in the meaning of terms and use of theories. This can be significantly accelerated if engineering identity studies cite and build upon directly relevant prior work rather than the current situation, which might be characterized as the reinvention of the wheel.

"Identity" has been studied from various vantage points in several disciplines. While it is a strength of engineering education research that it draws upon many theories and disciplines, engineering identity research is currently too disjointed to effectively build on the foundation provided by prior work. By not citing the body of prior studies of identity, we as researchers have missed out on the links not only between studies but also between fields. The major theories – sociocultural, social identity, and multiple identity theory—all go by different names but there is merit in considering how these perspectives overlap and strengthen one another (Table 2). Even those that were not considered as a major category in this review, Eccles' expectancy value, identity stage theory, and organizational theory can still be considered on this continuum.

Moreover, race, gender, sexual orientation, and other social identities have yet to be substantially considered in the study of engineering and science identities. Reflecting on Carlone and Johnson is an example of such a model (Figure 2). Their model clearly references the reciprocal relationship of science identity with one's gender, racial, and ethnic identities. As the authors mention, this is "a connection hinted at, but not made explicit, in previous literature" (p. 1191).[42] Yet only the Venn diagram portion of the figure has been taken up in subsequent studies citing their work. Nearly a decade later this statement still holds true.

A complete appraisal of the quality of the quantitative studies of engineering identity is beyond the scope of this review. It is not clear how useful this would be, since the studies use, define, and measure identity in such different ways. Many studies are new or forthcoming and do not use the same instruments. There is evidence that some measures are coalescing, as Godwin, Hazari, and colleagues continue to publish detailed validation evidence for their evolving measures.

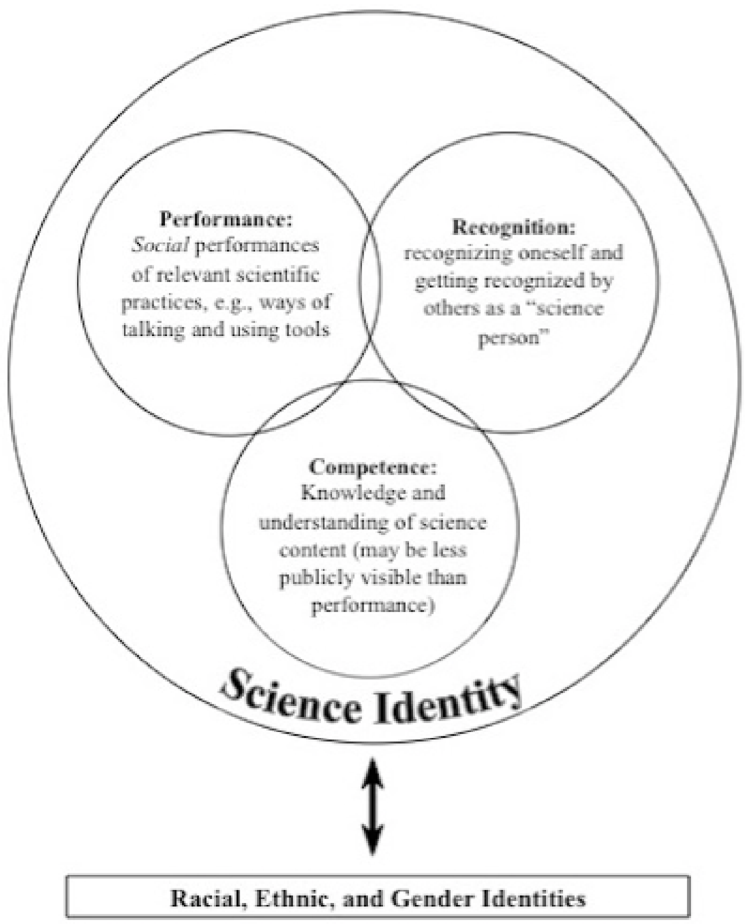

Figure 2 Carlone and Johnson's representation of Science Identity[44]

Implications for Future Research

Identity is complex, multi-faceted, and changes over time. Up to this point engineering education researchers have not clearly expressed the relationship between these related theoretical constructs and engineering identity. Advancing knowledge of engineering identity development and theory can potentially be applied to other disciplines such as math and science. The term “identity” spans studies in psychology, sociology, education, cultural studies, anthropology, and social linguistics. Drawing on this foundation as well as more recent research in physics and math education, engineering education can specifically contribute new knowledge by examining engineering identity over time and across different levels of engineering. Moreover, future work will clarify the relationship between engineering identity and the recruitment and retention of young people to engineering, particularly those from underrepresented groups.

Moving forward, there are several promising directions for intersectional approaches using gender, sexual, and racial/ethnic identity. Moreover, work relating math and science identity to engineering in undergraduates has identified interesting shifts in math and physics identity over time.[30] Prybutok, Patrick, Borrego, Seepersad and Kirisits uncovered similar findings in their survey of undergraduate engineers in mechanical and civil engineering.[79] Meyers et al. report first-year students are 1.5 less likely to identify as engineers than sophomores, juniors and seniors collectively.[37] This insinuates here may be other aspects of engineering identity that are not developed until the sophomore, junior or senior year. For example, the development of professional identity typically coincides with co-op and internships in comparison to undergraduate research experiences that are conducted with faculty. This area of research is particularly important since no studies were identified as investigating engineering identities of advanced undergraduates.

At present, there is little empirical evidence to support the relationship between engineering identity and persistence. Engineering identity needs to be further tested as a potentially important measure to evaluate long-term effects of short-term interventions. As educators and other stakeholders in engineering student success, we can focus our attention on engineering identity to better inform how STEM interventions and outreach activities are assessed by using engineering identity scales and pooling data across sites. Through publication and presentation, a larger and broader population of researchers, educators, policy makers, STEM professionals, parents, and students will be better informed on engineering identity development and its implications for the STEM workforce. This is particularly important in helping to dispel negative stereotypes of engineers that discourage capable individuals from pursuing the field. Through future work, increased recruitment of underrepresented groups can be tailored through mentorship programs to improve students’ identity starting in K12 and extending into undergraduate, graduate school, and professional settings. Tracking identity development into academia and professional settings is critical to retention and warming the chilly climate in engineering that causes many to leave.

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