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A Systematic Literature Review of Engineering Identity Research (2005–2019): Quick Reference Guide*

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For two decades, a growing body of research surrounding engineering identity has emerged as an indicator for interest and persistence in engineering. The purpose of this quick reference guide using a systematic literature process is to identify the scope of work regarding the development of engineering identity as a concept, specifically within undergraduate student populations in higher education (2005–2019). The original literature review focused search criteria on studies that examine underrepresented populations and their ability to navigate multiple identities within engineering enculturated environments. This work was conducted by two independent researchers and coded based on a systematic review process. Search terms for the review included: "identity" AND "engineering", with refined search terms "women", "women of color", "underrepresented" and NOT "STEM" as explained in the paper. The review included 649 titles in the initial search and resulted in 43 final studies categorized into three tables. This quick reference of engineering identity literature can be utilized to reference past research, specifically in the field of engineering in higher education. The literature review was conducted on articles written prior to 2020 due to the timeline required to describe populations from a retrospective study. Researchers concluded that engineering identity research was 1) difficult to discern due to lack of uniformity across terms and factors that are easily identified and 2) contained gaps in literature, especially for studies that claimed to understand women and underrepresented populations. A summary of research is provided to provide a quick reference and comparisons of research populations, themes, and gaps.

Keywords: quick reference; engineering identity; systematic literature review; women in engineering; underrepresented populations; quick reference guide

1. Introduction

The lack of women pursuing engineering degrees and careers in male-dominated fields has been of interest to researchers. Though progress has been made overall, women still remain underrepresented in STEM-related fields [1]. In engineering, women represent less than 24.6% of the overall undergraduate population in universities across the US [2]. Further, many female students continue to be underrepresented in certain disciplines within engineering that are considered "non-traditional" [3]. For the past decade, women graduating with degrees in non-traditional engineering majors, especially mechanical, electrical, and computer science, have stagnated at 12–13% [2]. To examine the number of underrepresented students entering and persisting in engineering, researchers have documented trends. However, gaps in research show a lack of understanding for the process associated with attracting underrepresented students into non-traditional disciplines and how climate or other factors affect overall success rates. Therefore, research that serves to define individual attributes for persistence and to understand environmental factors that affect overall retention of engineering students is of vital importance.

To examine student success factors, research on identity and STEM identity has emerged in multiple disciplines. In psychology and education, identity theory has evolved to reveal three accepted identity style types: diffuse-avoidant, normative, and informational [4, 5]. These identity styles have been used by educational researchers to predict student academic success rates [6], especially while transitioning to university settings [7]. Though these identity styles are widely accepted, engineering identity has grown roots mainly from STEM identity models. STEM identity is understood to contain both internal and external components. This theory includes an individual's ability to identify with STEM and the ability of the larger STEM domain to recognize the individual as a member of their community [8, 9].

One of the issues with STEM identity models is that researchers are undecided upon defined characteristics that constitute identity and ways to translate these characteristics into valid identity measurement instruments [10]. As a consequence, many studies have linked engineering identity to the development of academic identity, especially an affinity towards core subjects, such as math identity [11, 12] and physics identity [13]. By defining

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identity solely on the basis of academic competence/ performance, interest, and recognition, STEM identity models have often excluded the overarching experience of underrepresented populations, including women and women of color [14].

Researchers have only begun to understand the complexity that underlies STEM identity for marginalized populations. This complexity includes intersectionality between multiple identities, such as gender, ethnicity, ability, and socio-economic status [14]. Gaps that exist for underrepresented populations include a comprehensive understanding of connections between internal identity, social identity and the external culture (engineering and other), and models for the underlying complexity within each context [15]. Therefore, for engineering identity to emerge as a holistic theory, defining factors that underlie core identity, coupled with techniques that grow academic and professional identity within underrepresented populations in engineering, are crucial research areas.

The purpose of the literature review and quick reference is to differentiate engineering identity from other disciplinary identities and to acknowledge more prevalent research emerging that clarifies engineering identity as a singular concept. Examining research that defines engineering identity will assist to expose prevalent themes and provide an idea for future directions in engineering educational research. For clarity, it is important to mention that engineering identity theory is often overlapped, coupled, and confused with other constructs including self-efficacy, growth-mindset, and grit. While this terminology is accepted throughout engineering educational communities, this literature review will seek evidence for, and use terminology that pertains to, academic persistence and retention. As an added condition, literature focused on underrepresented populations has been deliberately identified. For the purpose of this paper, the term underrepresented is used throughout this publication to indicate students who are not represented in engineering at the same rate as local, statewide, or national populations. Reference to underrepresented students in this review specifically indicates women and women of color (e.g., African American, Hispanic, Latina, Native American), unless otherwise specified.

2. Research Questions

The systematic literature review was driven by specific research questions and required research prior to 2020. Though questions served to navigate the engineering education literature, it is acknowledged that the process for the review was not based upon grounded theory [16]. Due to criteria utilized in this study, references cited do not encompass current research in this area. For example, engineering identity focus, without including STEM identity, deliberately excluded several studies with underrepresented research populations that may have provided a broad definition for engineering identity development or other insights. Methods that outline criteria for inclusion are detailed in methods, section 3.0. This systematic literature review was guided by the following research questions (RQs):

RQ 1: What studies emerged that conceptualize engineering identity as a singular concept in higher education?
RQ 2: What populations have previously been studied in the engineering identity literature during the time period (2005–2019)?
RQ 3: What categorizations of research methods were clear in engineering identity literature?
RQ 4: What were the main identity themes in each publication?

3. Methods

The following sections describe methodology used to synthesize the systematic literature review and iterate the process to obtain scholarly works and examine research.

3.1 Framework

Framework of this systematic literature review was primarily informed by Borrego, Foster, and Froyd [17]. Relevant to engineering education, authors argue that seminal publications, important works that provide new insights and research directions, could be better informed by systematic reviews that utilize interdisciplinary sources. Systematic reviews differ from other literature reviews by offering a process that can be replicated and is highly documented. In this literature review, a scoping review [18] was first implemented to assess the breadth of multidisciplinary research performed over four decades. Due to the number of sources initially found on ERIC via ProQuest (24,913), a systematic review process was applied to narrow sources for relevance [19]. Within this iterative process, the search-screen-appraise-synthesis method was implemented to provide a comprehensive search and identify literature that specifically focused on four research questions of interest [17]. Further, systematic reviews that are "state-of-the-art" contain four types of complementary methodologies: search (retrieval), selection (apply criteria), coding (quality evaluation), and synthesis (analyze results) to further refine results [20].

A team of two independent researchers applied

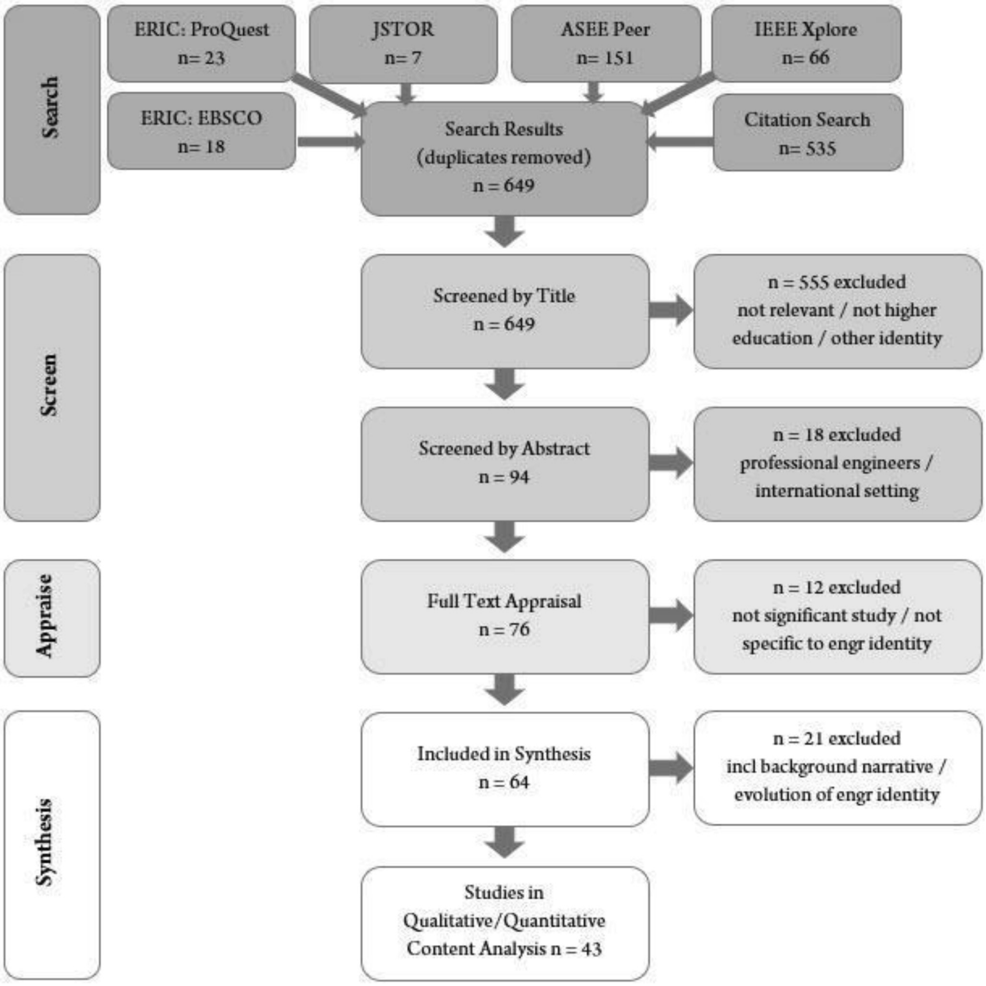

Fig. 1. Figure details a flowchart that outlines steps taken during the systematic review process. This process was conducted by one researcher only to eliminate articles according to specific criteria.

qualitative content analysis to categorize methods and identify themes. Finally, citation searching or citation indexing [21] was employed to further identify research frequently referenced by authors performing larger, longitudinal studies within engineering education. As described in subsequent sections, multiple criteria were applied at each step to determine the quality and relevance of individual scholarly works. To answer RQ1, Fig. 1 represents the overall framework and process for the systematic literature review. The following sections describe that process in detail.

3.2 Search

3.2.1 Databases, Refine Terms

Scoping was used as a primary technique to probe databases, narrow specific search terms, and survey multidisciplinary literature to encompass engineering identity as a topic. Initially, search results on ERIC via ProQuest revealed over 24,900 (24,913) sources relevant to identity, as a singular term, and showed to be too comprehensive. After scoping, search terms and databases were refined to include only those most relevant to engineering and engineering education. At this stage, it was observed that researchers from multiple disciplines used convoluted terminology (different language) to describe "engineering identity" as well as relate engineering identity to specific theories or concepts within those disciplines. Given that engineering identity is a burgeoning concept, further work was done to eliminate complexity and look for salient themes that appeared across the engineering literature when addressing identity. For this review, the final search terms were: "identity" AND "engineering". More refined search terms included "women", "women of color", "underrepresented" and NOT "STEM". Databases used in the initial search were: ERIC via ProQuest, ERIC | EBSCO, JSTOR, ASEE peer, and IEEE Xplore.

It should be noted that after citation searching/ indexing was performed, references were gathered in additional databases as they did not appear as complete works in the databases listed above. Other databases/search engines used were: ResearchGate, Academia, Google Scholar, and Wiley online library

3.2.2 Criteria and Inclusion

To narrow the scope of the study, search criteria were used to further focus topics and provide viable references. As a common research practice, sources were restricted to those that were full text, peer reviewed, and written in English [22]. Therefore, the majority of sources were found in journal publications and/or conference presentations, with a significant number of studies presented as conference papers five years prior to 2020. While testing search criteria, the year of publication was initially restricted from 2010 to February 2020. However, the final list of literature reviewed contains up to 20 references written prior to 2010. These sources were included as they provided relevant information and a historical context for the evolution of engineering identity and measurement instruments. Two book titles were also included as references due to their numerous mentions by authors in current engineering identity literature. It should be noted that though books and book chapters are included in this literature review, full texts were not retrieved or reviewed in the study. These references will be discussed in detail and included in a future publication.

3.2.3 Exceptions

After the initial search, it was recognized that the search criteria were too narrow. Further data mining found well-published authors in this area or studies mentioned by multiple engineering educators. Citation searching/indexing was used to find significant studies or commonly cited references that could also be included for the purpose of this literature review. This process stage used modified criteria from scoping but yielded several cross-referenced sources. Exceptions to the search criteria were made to reveal sources that did not contain "engineering identity" in the title and were either (1) mentioned by multiple authors; (2) significant studies; (3) notable book references from well-known authors in fields other than engineering; (4) contained more complete definitions of identity and development of identity theory; or (5) included a close variation to "engineering identity" as a search term (e.g., "engineer identity" and "engineering identities"). Other descriptors found that were included, but not limited to, were: "affect", "agency", "belonging", "communities of practice", "gendered identities", "multiple identities", "representation", "self-efficacy", "self-presentation", "self-concept", and "social norms". After searching databases and expanding criteria for inclusion with citation searching/indexing, 649 references were found. These references were further narrowed by performing the next steps.

3.3 Screen

For a reference to be included, the study population had to specify undergraduate students in higher education, attending US institutions. By applying these criteria, approximately 32 studies were eliminated as they focused on K-12 populations or professional engineers. Preliminary screening indicated the most relevant articles included titles containing "engineering" or "engineering" WITH "identity" as a specific study focus. In addition, the reference had to fit within one of the parameters specified by the research questions. To reiterate, research questions may be paraphrased as: (a) was the study specific to engineering identity?; (b) was the data disaggregated and did it contain noted differences for women and underrepresented populations?; (c) what were the study method categorizations?; and (d) what were the main engineering identity themes?

During this stage, article titles and abstracts were reviewed for relevant study subjects and academic environments. Of the 649 references, 555 were excluded due to irrelevant study focus, or not relevant in higher educational contexts. It was noted that many of the references eliminated in this phase were qualitative studies conducted by researchers in other disciplines that gave a historical basis or context for defining engineering identity. Though these may have been viable sources of information, they were eliminated during the screening stage to remain focused on the research questions at hand.

Of the 94 abstracts that were reviewed, 18 were eliminated due to study subjects consisting of either professional engineers or were conducted in an international setting (6 total). At this stage, conference papers that were works in progress or did not present a significant research study contribution were also eliminated, including those that described program interventions with small populations of students involved as "engineering identity building activities" (12 total). Though eliminated references may have provided beneficial information, they were not included due to the primary focus of this particular literature review.

3.3.1 Coding and Filtering

To ease the process of reviewing titles and abstracts, an excel spreadsheet was created to provide quick access to the following information: publication year; author(s) name and contact information; title of reference; website or citation link, database where source was found, and date found; abstract;

conclusions and results; noteworthy mentions with page numbers; category type 1 (e.g., journal article, primary source/website, book/publication, dissertation, conference paper); category type 2 (e.g., research study, definition, report, literature review, identity scale instrument); themes for three subject areas (e.g., identity types, multiple identities, STEM identity, academic identity); population studied (e.g., number of study participants, gender disaggregated, ethnicity disaggregated)/additional themes; notes and additional information.

At this stage, 76 full articles were retrieved and cataloged into the spreadsheet to provide easy access and an ability to appraise relevant sources. Multiple screening attempts were conducted to ensure that sources included in the full-text appraisal phase were the most significant and relevant. Again, several sources from the citation searching/indexing phase were ambiguous and were retained to be analyzed in the full-text review phase to ensure a comprehensive list of publications were obtained. It is important to mention that during the title and abstract review phase, a few articles related to the development of academic identity or identity types were eliminated.

3.4 Appraise

Full texts were retrieved and compiled from a variety of database sources. The majority of references from conference proceedings were retrieved from ASEE Peer (25) and IEEE Xplore (10). Other journal articles were retrieved from Academia/ResearchGate (12), ERIC: EBSCO (5), JSTOR/JEE (7), SAGE (5), and Google Search/Misc. (12). At this stage, 10 references were eliminated due to not meeting criteria of being specific to engineering identity, convolution of identity with other concept (i.e., confusing identity with self-efficacy or related concept), or other factors including: small population size, authors were unaware of previous research, and authors did not build upon previous results.

3.5 Synthesis

3.5.1 Qualitative/Quantitative Content Analysis

To answer RQs, specifically RQ1, a total of 64 studies were included in the synthesis stage, and a total of 43 studies were used in the qualitative analysis. Twenty (21) references were found to be useful to explain background narrative for the development of engineering identity theory and the evolution of measurement instruments; however, this will be part of a comprehensive analysis, which will be published in the future. Many of these references were most likely gleaned during the citation searching / indexing phase. As a primary measure, references were cataloged according to the research method used (qualitative, quantitative, mixed) and the data instrument used. The number of subjects in the study was also tracked to indicate the breadth of the study and determine significance. The authors will mention that data instruments and their significance were analyzed; however, data instruments will be discussed in a future publication.

3.5.2 Coding

To address RQ3 during synthesis, 43 studies were categorized and coded according to their research methods independently by two reviewers. Each text was reviewed, and research techniques were organized into three distinct categories: qualitative, quantitative, and mixed methods. This stage revealed that the majority of studies included in this literature review contained quantitative methods (27 studies). Further, several quantitative studies included a large number of subjects, with study populations ranging from n = 35 to n = 10,492. It was also observed that many of these large-scale studies occurred across multiple institutions and contained longitudinal information, though not specifically tracked at this stage. Also, the majority of these studies (19/27) have been conducted since 2015 and include much of the work on developing measurement instruments specific to engineering education.

Qualitative studies (11) were conducted mostly from 2005–2011, with two exceptions. These studies seemed to have a much smaller number of subjects, and one study provided a case-study narrative for a single student. Though subject numbers were small and usually were conducted at a single location, these qualitative studies were important in the development of current engineering identity theory.

Finally, five (5) studies used a mixed methods approach (qualitative and quantitative). These studies ranged from 2008–2019 and contained both small and large numbers of subjects. Table 1 describes research methods used by each of the studies in the synthesis stage.

To answer RQ2 and fully understand study populations and how data was disaggregated, a spreadsheet was created to track the author/year, number of subjects, and whether or not data was disaggregated to study populations of interest (F-Gen, socio-economic status (SES), gender, race/ethnicity, ability, military, LGBTQ+). In addition, this allowed a quick assessment of gaps in literature and future research directions. In engineering identity research, there is relevance and importance for studies to disaggregate data. However, throughout the literature, researchers observed that although many studies included an awareness of the need for this type of information, authors failed to include disaggregated data in their results. Table 2 describes

Table 1. Research methods are summarized in columns with primary author and publications referenced in chronological order, regardless of research method used. The table details the year study was conducted and population size

Qualitative	Quantitative	Mixed
Tate, 2005 [15] n = 5	Rubineau, 2007 [25] n = 75	Chachra, 2008 [26] n = 160
Capobianco, 2006 [23] n = 24	Dukhan, 2008 [27] n = 35	Fleming, 2013 [36] n = 202
Tonso, 2006 [24] n = 33	Cass, 2011 [32] n = 10,492	Revelo, 2015 [43] n = 22
Eliot, 2008 [28] n = 36	Meyers, 2012 [35] n = 701	Kendall, 2019 [60] n = 892
Beam, 2009 [29] n = 36	Godwin, 2013 [37] n = 6,772	Rohde, 2019 [62] n = 579
Foor, 2009 [30] n = 118	Godwin, 2013 [38] n = 6,772	
Pierrakos, 2009 [31] n = 8	Jones, 2013 [39] n = 363	
Eliot, 2011 [33] n = 36	Knight, 2013 [40] n = 510	
Matusovich, 2011 [34] n = 20	Cech, 2015 [41] n = 312	
Godwin, 2017 [50] n = 1	Godwin, 2015 [42] n = 6,772	
Torralba, 2019 [64] n = 16	Godwin, 2016 [44] n = 3,337	
	Pierrakos, 2016 [45] n = 260	
	Prybutok, 2016 [46] n = 563	
	Stoup, 2016 [47] n = 82	
	Tatar, 2016 [48] n = 915	
	Curtis, 2017 [49] n = 562	
	Henderson, 2017 [51] n = 397	
	Patrick, 2017 [52] n = 1,288	
	Borrego, 2018 [53] n = 1,528	
	Kendall, 2018 [54] n = 765	
	Patrick, 2018 [55] n = 474	
	Sax, 2018 [56] n = 1,355	
	Verdin, March 2018 [57] n = 2,916	
	Verdin, 2018 [58] n = 2,916	
	Choe, 2019 [59] n = 1,536	
	Kendall, 2019 [61] n = 184	
	Taheri, 2019 [63] n = 1,640	

the populations studied and how / if populations of interest were disaggregated and presented in the final results.

Finally, to track the quality of research findings in engineering educational contexts, studies were examined and coded according to different identity types and themes. Again, a spreadsheet was created that tracked the author/year, number of subjects,

Table 2. Answers RQ1-3 by listing 43 studies in chronological order with population size and research method used. The table further disaggregates data into categories of populations studied or mentioned within the publication.

Primary Author, Year	Subjects n = X	Method	F-Gen	SES	Gender	Race/ Ethnicity	Ability	Military	LGBTQ
Tate, 2005 [15]	5	Qual			X	X			
Capobianco, 2006 [23]	24	Qual			X				
Tonso, 2006 [24]	33	Qual			X				
Rubineau, 2007 [25]	75	Quant			X				
Chachra, 2008 [26]	160	Mixed			X				
Dukhan, 2008 [27]	35	Quant							
Eliot, 2008 [28]	36	Qual			X				
Beam, 2009 [29]	36	Qual			X	X			
Foor, 2009 [30]	118	Qual			X	X			
Pierrakos, 2009 [31]	8	Qual			X				
Cass, 2011 [32]	10,492	Quant			X	X			
Eliot, 2011 [33]	36	Qual			X				
Matusovich, 2011 [34]	20	Qual						X	
Meyers, 2012 [35]	701	Quant			X				
Fleming, 2013 [36]	202	Mixed			X	X			
Godwin, 2013 [37]	6,772	Quant		X	X				
Godwin, 2013 [38]	6,772	Quant							
Jones, 2013 [39]	363	Quant			X				
Knight, 2013 [40]	510	Quant	X	X	X	X			
Cech, 2015 [41]	312	Quant			X	X			
Godwin, 2015 [42]	6,772	Quant			X				
Revelo, 2015 [43]	22	Mixed			X	X			
Godwin, 2016 [44]	3,337	Quant							
Pierrakos, 2016 [45]	260	Quant							
Prybutok, 2016 [46]	563	Quant							
Stoup, 2016 [47]	82	Quant			X				
Tatar, 2016 [48]	915	Quant			X				
Curtis, 2017 [49]	562	Quant							
Godwin, 2017 [50]	1	Qual			X	X			
Henderson, 2017 [51]	397	Quant			X				
Patrick, 2017 [52]	1,288	Quant							
Borrego, 2018 [53]	1,528	Quant							
Kendall, 2018 [54]	765	Quant				X			
Patrick, 2018 [55]	474	Quant			X				
Sax, 2018 [56]	1,355	Quant			X	X			
Verdin, March 2018 [57]	2,916	Quant			X				
Verdin, 2018 [58]	2,688	Quant	X						
Choe, 2019 [59]	1,536	Quant			X	X			
Kendall, 2019 [60]	892	Mixed			X	X			
Kendall, 2019 [61]	184	Quant							
Rohde, 2019 [62]	579	Mixed							
Taheri, 2019 [63]	1,640	Quant			X				
Torralba, 2019 [64]	16	Qual			X				

and a categorization related to certain identity types (self-perceived identity, academic identity, professional identity, peer/social identity, engineering cultural identity/belonging, and multiple identity). Definitions for each categorization researchers used are as follows:

- self-perceived identity – researchers determined results contained the classical Gee, 2001 [8] definition for identity as both internal and external recognition components were present;
- academic identity – researchers defined this as an individuals' identity with grades and subject

matter, such as math and physics, as discussed in study methodology and results;

- professional identity – results discussed identity development for a particular major, career, or other extracurricular activities;
- social-peer identity – other students recognized the individual as an engineer or member of engineering community;
- -engineering cultural identity – results contained influence of engineering institutional environments and student's sense of belonging;
- multiple identity – results contained recognition of broader socio/cultural influences that were present and the impact on individuals.

To answer RQ4, studies were also examined and categorized for major themes and findings. Listing major themes clarified how each study defined identity and the qualities deemed important for engineering identity development. Categorizations were difficult to determine as studies referred to engineering identity as an all-encompassing term. For the purpose of this review, researchers surmised inferences to professional or academic identity, for example, and categorized articles based on definitions listed in the previous paragraph. Table 3 includes identity types and themes present in the literature examined.

4. Limitations

This review is limited for several reasons. First, bias could have been introduced through the concentration of literature from journal articles and conference presentations. Though these sources were peer-reviewed, the reviews themselves may not have been rigorous. As a novel concept, reviewers in the engineering community may have had a limited scope of knowledge regarding engineering identity and identity theory, in general. It is also noted that this literature review provides limited reference to books, book chapters, and other sources (e.g., theses or dissertations were not considered). Therefore, the literature review may only provide a superficial understanding of engineering identity and its theoretical basis. Including a wider range of published sources may have provided a deeper understanding for the evolution of engineering identity as a concept, rather than information gleaned solely from journal articles and conference proceedings.

Second, when scanning initial sources and citation searching/indexing, it was observed that authors were not especially versed in the body of research performed by identity theorists in psychology, education, or health/medicine, for example. Also, researchers were not especially aware of well-known, longitudinal and multi-institutional studies from the 1990s that have been conducted to understand persistence and retention issues in underrepresented populations. In addition, disciplines tended to use idiosyncratic language, particular to that discipline, to describe identity characteristics that are similar in multiple fields. Due to the disconnect between research on identity, STEM identity, and engineering identity; engineering identity literature may offer parallel concepts without drawing connections. Therefore, research on engineering identity remains segregated and limited. For this literature review, information has been restricted to knowledge gleaned by the engineering educational community, and it is recognized that this may not contain the broadest understanding of identity constructs or concepts.

As an added note, the technique of screening by title, prior to screening by abstract, may have provided limitations for the number and quality of references included in this literature review [65]. Screening for the inclusion of terms, such as "engineering" and "identity", or "engineering identity", may have provided a false representation of studies, especially those specifically dedicated to engineering underrepresented populations. Generally, engineering researchers are concerned with supporting and retaining underrepresented populations. Therefore, studies that focus on underrepresented populations are usually titled as such to draw special attention to research involving said populations. To clarify, studies may have included valuable information on engineering identity development for underrepresented populations but were missed due to absence of the words "engineering" or "identity" found in their title alone.

Finally, studies conducted on international populations, or written in different languages, were not considered as differences in culture and demographics exist between countries (e.g., European, Asian, Scandinavian, or North American populations, including Canada). It is acknowledged that many of the studies that examine gender differences in engineering contexts are still influenced by cultural nuances that may or may not be present in US universities. Further, geographic cultural differences found within study populations in the US were not considered as part of the research questions at hand, for example differences in Western-American, Southern-American, and Eastern cultures. For this literature review, external culture found in US universities was generically framed as "engineering culture" and considered to be understood as uniform across studies and the research subjects.

Table 3. Studies are listed in chronological order with population size and categorized by identity type mentioned within the research as well as organized into one of six main themes (engineering identity, academic identity, cultural identity, professional identity, gendered identity) and lists each article's major findings

Primary Author, Year	Subjects	Self-Perception	Academic	Profes-sional	Social/ Peer	Engineering Cultural "Fit" or "Belonging"	Multiple Identity	Themes/Findings
Tate, 2005 [15]	5	X	X		X			Engineering identity (EI): academic, social, intellectual
Capobianco, 2006 [23]	24		X	X		X		Professional identity (PI): academic, institutional, gendered, role-models
Tonso, 2006 [24]	33		X		X	X		Engineering identity (EI): nerds, academic-achievers, greeks
Rubineau, 2007 [25]	75	X		X	X			Professional identity (PI): positive peer effects for men, not women
Chachra, 2008 [26]	160	X		X				Engineering identity (EI): gender differences in engineering design activities / connect identity and commitment
Dukhan, 2008 [27]	35			X				Engineering identity (EI): identity with service learning
Eliot, 2008 [28]	36	X		X			X	Professional identity (PI): purposeful construction of professional identity / internal frame of references / external frame of reference / multiple identities (academic, personal interests, family)
Beam, 2009 [29]	36	X		X	X			Professional identity (PI): identity with recruitment and retention
Foor, 2009 [30]	118		X				X	Gendered identity (GI): EI perception of field, feminizing disciplines "business" vs. "technical"
Pierrakos, 2009 [31]	8			X		X		Professional identity (PI): identity with interest and preparation / recruitment and retention
Cass, 2011 [32]	10,492	X	X					Academic identity (AI): math constructs predict engineering career choice males/females
Eliot, 2011 [33]	36	X		X				Professional identity (PI): external and internal frames of reference
Matusovich, 2011 [34]	20			X			X	Engineering identity (EI): men and women, no data disaggregated
Meyers, 2012 [35]	701	X		X				Engineering identity (EI): self-identify due to belonging and organizational recognition. Factors to be an engineer: making competent design decisions, working with others, accepting responsibility.
Fleming, 2013 [36]	202					X	X	Engineering identity (EI): identity shaped by minority serving institutions (MSI's)
Godwin, 2013 [37]	6,772	X	X					Engineering identity (EI): identity coupled with interest, significance for math, physics, science identities
Godwin, 2013 [38]	6,772	X	X					Engineering identity (EI): significance for math, physics, science identities / personal and global agency
Jones, 2013 [39]	363		X		X			Engineering identity (EI): identity with stereotype threat / gender identity
Knight, 2013 [40]	510	X	X	X				Engineering identity (EI): access, performance, retention / identity with programs

Table 3 (*cont.*)

Primary Author, Year	Subjects	Self-Perception	Academic	Profes-sional	Social/Peer	Engineering Cul-tural "Fit" or "Belonging"	Multiple Identity	Themes/Findings
Cech, 2015 [41]	312	X		X				Professional identity (PI) / gendered identity (GI): gendered professional identities
Godwin, 2015 [42]	6,772	X	X					Engineering identity (EI): identity variables are interest, recognition, performance/competence (math) / agency / physics identity
Revelo, 2015 [43]	22		X	X	X	X	X	Engineering identity (EI): identity with cultural belonging and "familia" / academic, social, professional identity through SHPE
Godwin, 2016 [44]	3,337	X	X	X	X			Engineering identity (EI): student identity = personal identity (related to individual characteristics), social identity (member of a group), engineering identity (interest, performance/competence, recognition); developed from Hazari et al. (2010), physics identity K-12 model
Pierrakos, 2016 [45]	260	X			X	X		Engineering identity (EI): composite unified self-concept, distinctiveness, participation, self-enhancement, visibility of affiliation / citizenship is best
Prybutok, 2016 [46]	563	X	X		X			Engineering identity (EI): engineering identity with design efficacy, creativity, global agency as factors
Stoup, 2016 [47]	82	X	X					Engineering identity (EI): self-concept differentiation (SCD) identity with personality (agreeableness, conscientiousness, extroversion, neuroticism, openness to experience) and authenticity
Tatar, 2016 [48]	915	X		X	X			Engineering identity (EI): self-determination theory (SDT), Chickering's seven vectors (competence, interpersonal relationships, manage emotions, autonomy toward interdependence, purpose, identity, develop integrity)
Curtis, 2017 [49]	562	X		X	X	X		Engineering identity (EI): measurement instrument development = 38 items / 11 factors
Godwin, 2017 [50]	1	X			X		X	Engineering identity (EI): subject-related identity / agency with critical engineering identity / social construction of identity / interest, recognition / communities of practice
Henderson, 2017 [51]	397	X						Engineering identity (EI): identity with fixed or growth mindset
Patrick, 2017 [52]	1,288			X				Professional identity (PI): identity measurement instrument align w/ ABET a-k. Constructs: framing and solving problems, design, project management, analysis, collaboration, tinkering
Borrego, 2018 [53]	1,528	X		X				Engineering identity (EI): 2 item scale measures professional practice, engineering performance/competence, engineering recognition, engineering interest

Table 3 (*cont.*)

Primary Author, Year	**Subjects**	**Self-Perception**	**Academic**	**Profes-sional**	**Social/Peer**	**Engineering Cul-tural "Fit" or "Belonging"**	**Multiple Identity**	**Themes/Findings**
Kendall, 2018 [54]	765			X	X			Engineering identity (EI): professional engineering identity found with HSI Hispanic students / social identity found in PWI Hispanic students
Patrick, 2018 [55]	474	X		X	X			Engineering identity (EI): IPE survey constructed from APPLES, SaGE, Hazari et al. (2010) and Meyers (2012)
Sax, 2018 [56]	1,355					X		Cultural identity (CI): belonging and student climate, underrepresented women and men / yes control group
Verdin, March 2018 [57]	2,916			X				Engineering identity (EI): engineering identity with grit in F-Gen students / no effect from performance/competence to identity
Verdin, 2018 [58]	2,688	X	X			X		Academic identity (AI): discipline identity with grit, personality, physics identity, math identity, performance/competence (engineering, physics, math)
Choe, 2019 [59]	1,536		X	X				Engineering identity (EI): framing and problem solving, design, project management, analysis, collaboration, tinkering
Kendall, 2019 [60]	892		X	X	X			Engineering identity (EI): performance/competence, interest, recognition, framing and solving problems, design, project management, analysis, collaboration, tinkering
Kendall, 2019 [61]	184		X	X	X			Engineering identity (EI): performance/competence, interest, recognition, framing and solving problems, design, project management, analysis, collaboration, tinkering
Rohde, 2019 [62]	579	X	X	X		X		Engineering identity (EI): performance/competence, interest, recognition, belonging, academic interest in EE and computing
Taheri, 2019 [63]	1,640	X	X	X	X	X		Engineering identity (EI): performance/competence, recognition, interest, belonging
Torralba, 2019 [64]	16			X				Engineering identity (EI): form engineering identity in makerspace

5. Results

This section reviews major findings and provides information on the inclusion of literature to answer specific research questions. Note: There are significant studies that have led to the development of engineering identity; however, research depicting identity in other fields was not widely included. Significant works commonly mentioned in the engineering education literature [11, 13, 66, 67] are not included in the results as they did not meet the narrow criteria set for this literature review, nor did they meet criteria set for publication type.

5.1 Literature Reviews, Groundwork for Engineering Identity

There are three notable literature reviews, included as references used for historical purposes, out of the twenty found useful to explain background narrative for the development of engineering identity theory and the evolution of measurement instruments. The first literature review was presented as a conference paper and provided a broad overview of the development of identity theory in social science (psychology, sociology, anthropology), education, and STEM (math and physics) [68]. Two other literature reviews provided an overview of contributing fields and development of identity in engineering education, which were Morelock's, 2017 systematic review of identity in engineering education (definition, factors, interventions, measurement) [65] and the Rodriguez et al., 2018 systematic review of engineering identity in higher education literature [69]. These works are seminal and present a broad understanding for research and groundwork laid to conceptualize engineering identity.

Due to the narrow scope and constraints of this literature review, the authors defer to citations located in each previous literature review to provide a more comprehensive understanding of the body of work surrounding identity and STEM identity. Further, literature that pertains to the development of math identity and physics identity is relevant, though not heavily explored in this review. Each academic core subject identity theory plays a significant role in the development of engineering identity as it is currently understood. This concept will be further explored in future publications.

5.2 Studies that Conceptualize Engineering Identity as a Singular Concept

Of the 43 total articles that met multiple criteria for full analysis (higher education, engineering undergraduate student population, etc.) for this literature review, 30 (69.8%) made reference to "engineering identity" or "identity" within their title or sought to define engineering identity as a singular concept. Though categorization during the literature review was subjective, eight (18.6%) provided reference to engineering identity as "professional identity" and one (2.3%) as "academic identity" directly in their title. It was noted that the remaining five studies (11.6%) referred to engineering identity in conjunction with another concept or area of significance.

5.3 Review of Methods for Engineering Identity Studies

As previously discussed in section 3.5.2, forty-three (43/64) research studies were categorized according to their research methods including; qualitative, quantitative, and mixed methods. Of the 43, nearly two-thirds (27/43 = 62.8%) of the studies used quantitative methods. Several quantitative studies contained a large number of subjects (e.g.: n = 6,772 or n = 10,492) and many of these large-scale studies contained longitudinal data across multiple institutions. The majority of quantitative research studies (19/27 = 70.4%) were conducted since 2015. Qualitative studies (11/43 = 25.6%) were conducted from 2005 – 2011, with two exceptions, and consisted of a smaller number of subjects. Five (5) studies (5/43 = 11.6%) used a mixed methods approach. Articles were placed into this category based on agreement by the reviewers, although they failed to mention this method specifically. These studies ranged from 2008–2019 and contained both small and large numbers of subjects. As previously referenced, Table 1 categorizes research methods used by each of the studies in the synthesis stage (section 3.5). [See Table 1]

5.4 Engineering Identity Development in Women and Underrepresented Populations

Primary review of literature indicates that 16/43 (37.2%) articles mentioned gender, "minority", or provides reference to an underrepresented population in their titles. However, full text review identified a significant number of researchers were concerned with the development of engineering identity in underrepresented populations and provided disaggregated data for special populations. Of the 43/64 research studies examined, 17/43 (39.5%) disaggregated data based on gender alone (*note: not necessarily the same 16 articles listed above that mentioned underrepresented populations); eleven (11/43 = 25.6%) studies disaggregated and reported data based on gender and race/ethnicity; one (1/43 = 2.3%) study disaggregated and reported data based on gender, race/ethnicity, and other factors (F-Gen and SES); other studies disaggregated data based on F-Gen status (2/43 = 4.7%), veteran/military status (1/43 = 2.3%), race/ethnicity only (1/43 = 2.3%); and ten (10/43 = 23.3%) studies did not disaggregate data to distinguish differences between any population of interest. However, two (2/10 = 20.0%) studies that did not disaggregate data, collected data on gender and race/ethnicity and one (1/10 = 10%) collected data on gender that could have been disaggregated to explore population differences in engineering identity [See Table 2].

5.5 Engineering Identity Literature Correlated to Student Success and Retention

Though many studies mentioned the need to tie engineering identity into student success and retention. Only two studies (2/43 = 4.7%) tied engineering identity to recruitment and retention [29, 31]. In fact, both of these studies defined engineering identity as a "professional identity" and contained the same research teams, presenting two different papers at two different engineering education conferences. The first paper centered on freshmen engineering student populations and the implications for recruitment and retention [29], while the other study examined engineering persisters vs. engineering switchers and focused on a broader age-group for engineering undergraduate students. Again, full text review revealed that although many of the studies understood the importance of engineering identity on persistence and retention issues, very few studies made a direct correlation between their findings and actual observed recruitment and/or retention data.

6. Recommendations

6.1 Uniformity Across Terms and Factors

As previously mentioned, the initial difficulty to assemble relevant research came from the use of numerous terms and descriptive language for engineering identity across fields. The majority of variation came from the field of engineering research itself. An initial search of "identity" was not sufficient to focus on engineering identity. A search for "engineering identity" revealed that although researchers were intent on describing engineering identity, they used other terms, or variations of terms, to describe their work (i.e.: "engineer identity" and "engineering identities").

Citation searching/indexing revealed other descriptors were included and convoluted with engineering identity such as, "affect", "agency", "belonging", "communities of practice", "gendered identities", "multiple identities", "representation", "self-efficacy", "self-concept", "social norms", etc. Some of these references provided valuable information, however, were not easily accessible during initial search efforts. In addition, there is not a clear agreement between researchers regarding engineering identity factors. By borrowing factors from other disciplines (science, math and physics), researchers were able to create a starting point. This starting point has led to multiple theories, with various tangential directions, within engineering that have led to confusion and lack of adoption of existing knowledge. Therefore, there is a need to create uniformity with terminology and some consensus of factors that constitute engineering identity.

6.2 Constraints & Gaps in Literature

This literature review was performed under significant constraints: gender and ethnicity in US higher educational institutions. Specifically, literature was sought that described engineering identity formation from the perspective of women and women of color. Though only a few engineering identity studies exist in this area, historically, the engineering education community has recognized the disparity of black and Hispanic/Latinx populations' participation in engineering.

More work can be done to study underrepresented students and their identity development. Moreover, information on women's participation in specific engineering majors (computer science, electrical engineering, mechanical engineering) was also sought to further identify strategies to build identity in non-traditional, male-dominated disciplines. There were even fewer studies found that tied in majors with identity formation in these populations. Using constraints narrowed the breadth of the literature review and allowed reviewers to identify individual studies dedicated to understanding the experience specifically for women and women of color.

The reviewers also recognize that discussing engineering identity in a vacuum, without providing a context for engineering culture and the overall environment in higher education, is deficient. Several studies mentioned "gendered experiences" however, literature included in the review that mentions development of engineering identity in conjunction with the impact of a gendered engineering environment remains sparse.

7. Conclusion

In summary, this systematic review was useful to explore engineering identity literature published before 2020 and based on terminology commonly used within the engineering research community. This categorization of engineering identity literature may be utilized to further understand past and current research. From this review, it is apparent that engineering identity is a burgeoning concept that can serve to better understand the student experience and beyond. Engineering identity theory contains essential elements for institutions to understand ways to improve student retention and graduation rates. It is also essential for institutions to understand and recognize differences between underrepresented populations' experience and traditional students. More research should be conducted in the future to understand the experience of and identity formation within underrepresented populations.

As a continuation of this work, future publications will explore the origins of engineering identity theory through the evolution of math and physics identity theories. Gaps in literature will be discussed and future directions for engineering identity research.

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