Community cultural wealth in science, technology, engineering, and mathematics education: A systematic review

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Abstract
Background: One emerging approach to diversity and inclusion in engineering is to take an assets-based view of what students from nondominant communities bring to their education and work experiences.

Purpose/Hypothesis: The purpose of this review is to understand how community cultural wealth (CCW), an assets-based framework, has been applied in science, technology, engineering, and mathematics (STEM) education research. We address research questions focused on (a) the characteristics of studies using CCW in STEM education, (b) examples of the six types of capital (aspirational, linguistic, familial, navigational, social, and resistant) in STEM educational settings, and (c) gaps and opportunities in how CCW is being applied in STEM education.

Design/Method: We identified 33 dissertations, theses, journal articles, and conference papers using systematic review procedures. To qualify, each study must present empirical data and include at least one type of CCW capital in its results or discussion. We coded study characteristics, such as methods, participant populations, and research setting. We qualitatively analyzed each of the six types of CCW capital.

Results: Studies tended to focus on higher education settings, engineering, and qualitative methods, particularly student interviews. We identified several specific engineering-relevant examples of assets for each type of capital. Future work should collect data from faculty, staff, and family members identified in several studies as important to CCW in addition to foregrounding student voices.

Conclusions: In synthesizing existing studies, this review provides insight into how an assets-based framework is being interpreted and provides a foundation for more assets-based perspectives in future engineering education work.

Keywords
critical theory, equity, first generation, race/ethnicity, systematic review
1 | INTRODUCTION

Despite decades worth of attention and effort, students from a number of groups remain both underrepresented and marginalized in United States science, technology, engineering, and mathematics (STEM) education, including students from Black, Latinx, Native American, and first-generation backgrounds, as well as students with disabilities (Byars-Winston, Estrada, Howard, Davis, & Zalapa, 2010; National Science Foundation, 2019). Clearly, fundamentally different approaches to how we view diversity and inclusion are needed to ensure that STEM disciplines and careers are more representative of our broader society.

One such approach to shifting perspectives on diversity and inclusion in STEM is to take an assets-based view of what students from nondominant communities bring to their education and work experiences (Martin et al., 2019; Yosso, 2005). We use the term “nondominant” to encompass all students who are not part of the historical majority in educational institutions rather than the terms “underrepresented minorities (URM)” or “marginalized” (Gutiérrez & Rogoff, 2003). While the other terms are frequently used in the literature, we chose the term nondominant for several reasons. First, the changing make-up of the U.S. population renders the term “URM” less impactful as many racial groups are no longer considered minorities in the general population. We want to remain consistent with the studies in our systematic review and highlight groups who remain nondominant within spaces associated with STEM, and the term nondominant is more inclusive to all underrepresented populations within STEM (i.e., gender). Second, while our intention is to acknowledge the oppressive systems and power structures currently in place, the purpose of this research is a focus on student assets. The term “nondominant” emphasizes power relations between the students and institutions, while keeping the focus on the students. The terms “minoritized,” “underserved,” and “marginalized” place focus on the role of the system rather than the students. We do not want to diminish the role institutional structures and systems play in potentially marginalizing nonmajority groups in STEM; rather, we aim to highlight how students are capable and accomplished by using their strengths within these constraints. Since our work seeks to highlight student assets and actions despite facing these environments, the term nondominant is most appropriate for use in our systematic review.

An assets-based view is in contrast to a deficit-based perspective, which emphasizes the challenges and disadvantages that students face, for example, by being underprepared for rigorous math and science coursework due to school inequities or coming from a family that cannot financially or emotionally support majoring in STEM (Gandara & Contreras, 2009; Valencia, 2010). As this review demonstrates, STEM students can develop important personal resilience and strategies in the face of these challenges, and the commonly cited challenges are not necessarily as widespread as deficit-based discourse would have us believe. Deficit-based perspectives are typically implicit, a default stance in response to the initial establishment of higher education in many countries to serve a primarily White, male, upperclass population of traditional-aged students (Ladson-Billings, 2004; Liu, 2011). Many within the system have not fully considered the ways in which higher education privileges the students for which it was established while marginalizing others (Bensimon, 2005; Harper, 2010).

While there is much critique against taking a deficit-based approach to viewing students from backgrounds underrepresented in STEM (e.g., Harper, 2010), there is significantly less literature detailing what an assets-based approach might look like, particularly in STEM educational settings (Martin et al., 2019). One theoretical framework that emphasizes assets is community cultural wealth (CCW; Yosso, 2005). CCW identifies at least six types of wealth that students, particularly those from Communities of Color,1 possess and develop during their education (Table 1). CCW is one of several theories building on the foundation of Critical Race Theory (CRT) that critiques how society and education restrict power from and therefore oppress marginalized groups. It uses Bourdieu’s descriptions of cultural capital (Bourdieu, 1977) as a foundation to provide a starting point for identifying assets of Communities of Color.

Yosso’s (2005) landmark work describing CCW has been cited nearly 5,000 times since its publication in 2005 (Google Scholar, n.d.). Some of these citations represent applications of CCW to studying STEM students or STEM education settings. This prior literature provides a unique opportunity for understanding assets previously identified for STEM students from nondominant communities (including but not limited to Communities of Color) so that researchers and educators can eventually take more assets-based approaches to diversifying STEM. We use a systematic literature review approach to identify and synthesize the findings. The research questions we addressed are:

1. What are the characteristics of studies that use Yosso’s (2005) CCW framework in studies of STEM disciplines?
2. Specifically, what are examples of the six types of capital identified in STEM educational settings?
3. What are gaps and opportunities in how CCW is being applied in STEM education research?
Systematic review is a research approach designed to identify and synthesize all of the relevant prior literature on a given topic (Borrego, Foster, & Froyd, 2014). Systematic reviews are appropriate when a literature base exists but stakeholders are unaware of the overall conclusions that can be drawn from it (Gough, Oliver, & Thomas, 2012; Petticrew & Roberts, 2006). The benefits of a systematic review include identifying important gaps in the literature, future directions for research, and specific recommendations for practice (Borrego et al., 2014). This particular topic of assets that STEM students from nondominant communities bring to and develop during their education is appropriate for a systematic review based on the increasing use of CCW in studies of STEM educational settings; the interdisciplinary nature of STEM education research that spans K–12 through higher education; and increasing interest and focus in the broader community on diversity, equity and inclusion in STEM.

In this review, we applied a broad definition of STEM educational settings, but we found primarily studies of students pursuing bachelor’s degrees, including many students starting their education at 2-year colleges. We identified a few studies of K–12 students and programs, as well as one study of a practicing K–12 teacher. Half of the qualifying studies focused solely on engineering. All used Yosso’s (2005) CCW framework to identify examples of at least one of the six types of capital in analyzing their empirical data. The methods and findings are described in detail, following a description of CCW and related theories.

### Table 1 Types of capital identified in community cultural wealth (CCW) theory (Yosso, 2005, pp. 77–80)

| Type of capital   | Definition                                                                                                                                 |
|------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| Aspirational     | Ability to maintain hopes and dreams for the future even in the face of real and perceived barriers                                         |
| Linguistic       | Intellectual and social skills attained through communication experiences in more than one language and/or style                          |
| Familial         | Cultural knowledges nurtured among *familia* (kin) that carry a sense of community, history, memory, and cultural intuition             |
| Social           | Networks of people and community resources                                                                                               |
| Navigational     | Skills of maneuvering through social institutions                                                                                         |
| Resistant        | Knowledges and skills fostered through oppositional behavior that challenges inequality                                                   |

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## 2 BACKGROUND LITERATURE

Within critical theory, education is situated as the gatekeeper of cultural capital and, therefore, power because classrooms perpetuate what counts as valuable knowledge, behaviors, and skills in society. Bourdieu and Passeron (1979) identified this cultural capital as the knowledge, behaviors, and skills acquired over time through socialization and education. Bourdieu (1986) further described these forms of capital as embodied, objective and institutionalized. For example, cultural capital can be embodied through norms and skills, such as table manners and language, which are then displayed as individuals interact with others. Cultural capital can also be objectified through material objects, such as dress, furniture, and food, which signal to others the amount of capital possessed. Finally, this capital can exist within institutions, such as job titles and academic degrees, which can be measured, certified and ranked throughout the world. These types of cultural capital are important throughout our society, yet education can limit access to them by perpetuating a traditional view of what counts as capital.

Other critical scholars have recognized the importance of identifying the cultural capital students from nondominant communities possess and bring with them to and through educational settings. Moll, Amanti, Neff, and Gonzalez (1992) identified specific funds of knowledge students from nondominant communities brought to school from their homes and communities that could be used in informing their learning. These researchers found that classroom practices sometimes underestimate and constrain what children are able to display intellectually because of restricted cultural norms. For example, in high school engineering contexts, Latinx students incorporated their everyday familial, community and recreational practices within the cultural practices of engineering (Wilson-Lopez, Mejía, Hasbún, & Kasun, 2016). These authors found that students drew from engineering-related funds of knowledge when working on engineering projects or problems in their everyday lives. They argued that making an “explicit connection between [the engineering] discipline and [students’] everyday lives can create a Third Space of...
learning and knowing” (p. 302). Soja (1996) introduced Third Space as another perspective of interpreting surroundings with the consideration of social aspects of a space in addition to the physical and descriptive aspects. Wilson-Lopez et al. (2016) describe this Third Space in a STEM-specific context as a place where students can experience and display their social capital. In a conceptual Third Space, students can combine both perceived spaces (i.e., a university) and conceived spaces (i.e., a competitive and rigorous academic environment) with their lived experiences in an open space with unforeseen opportunity and empowerment (Soja, 1996). This combination is particularly important for students who have been historically marginalized. Thus, Third Space (Soja, 1996) is both formal and informal, where the official and unofficial spaces of the learning environment intersect, creating a potential for authentic interaction and a shift in the social organization of learning and what counts as knowledge (Gutiérrez, 2008). Both funds of knowledge (Moll et al., 1992) and Third Space (Soja, 1996) represent valuable assets-based approaches to diversifying STEM education. However, most studies focus primarily in K–12 and thick description of how the environment around the student (i.e., home) contributes to the assets of the students themselves. CCW studies, by comparison, tend to be less concerned about home environments and are, therefore, a potentially better source for foregrounding student assets. Additionally, there are more higher education studies using CCW that would inform engineering education specifically.

Thus, Yosso’s (2005) CCW framework is a potentially more actionable framework that is often applied with a focus on the assets of the student. Using the foundations of CRT (Stefancic & Delgado, 2001), Yosso (2005) recognized the liberatory potential of schooling (Freire, 1970, 1973; hooks, 1994) while acknowledging the tension of schools as institutions that often “oppress and marginalize” (p. 74). Specifically, Yosso (2005) acknowledged that not only is the racialized assumption that students from nondominant groups lack cultural capital deficit-based thinking but also a form of “contemporary racism” (p. 75). Rather than identifying what students lack upon entering and engaging in formal schooling, Yosso (2005) calls for a shift of societal norms to value the cultural wealth of nondominant groups. CCW focuses on the cultural knowledge, abilities, skills, strategies and networks nondominant communities’ possess with the goal of transforming education and empowering People of Color to utilize the assets abundant in their communities. Yosso (2005) identified six forms of capital that compose the theory of CCW (Table 1). These forms of capital “are not mutually exclusive or static, but rather dynamic processes that build on one another as part of community cultural wealth” (Yosso, 2005, p. 77). They were conceptualized for the purpose of conducting research, teaching, and developing educational environments that serve a larger purpose of struggling towards social and racial justice. Thus, we believe the six types of capital provide a potential path toward assets-based thinking about students from nondominant backgrounds that are traditionally marginalized in STEM. In this systematic review of the literature, we sought to comprehensively identify studies that apply CCW to STEM educational settings and identify assets that STEM students bring to and develop during their education.

3 | METHODS

We followed the systematic review procedures for engineering education and other social science fields, as detailed in Borrego et al. (2014) and Petticrew and Roberts (2006). Our research questions served as the basis for determining the inclusion criteria. During analysis, we completed both a quantitative and qualitative synthesis of all qualifying studies, regardless of the methods employed by the study authors.

3.1 | Positionality

All three authors have engaged in teaching, advising or outreach with STEM students. These experiences serve as the foundation for our research exploring asset-based approaches. We identify as dominant (i.e., White) but have experienced some marginalization as women in STEM. Denton has an undergraduate degree and work experience in engineering, and is working toward a PhD in STEM education. Borrego has three degrees in engineering and identifies as an engineering education researcher and first-generation college student. Boklage has an undergraduate degree in biology and a PhD in curriculum and instruction and identifies as a STEM education researcher.
3.2 | Inclusion criteria

Prior to beginning the search process, we determined the inclusion criteria for qualifying studies. Denton and Borrego discussed potential inclusion criteria and established specific guidelines. To be considered in the systematic review, the studies must meet the following criteria:

IC1: Contain empirical results from an empirical study.
IC2: Discuss at least one of the six types of CCW capital (aspirational, linguistic, familial, social, navigational, or resistant) as an outcome in the results or discussion.
IC3: Position at least one STEM discipline or STEM education as central to the study.
IC4: Be published since 2005 and cite Yosso’s (2005) paper on CCW.

IC1 resulted in our excluding purely conceptual or theoretical work lacking new empirical results. Thus, reports, essays, and many books were excluded from this review. We bounded our search to journal articles, conference papers, theses and dissertations. IC2 resulted in excluding studies that discussed CCW in the literature review or theoretical framework only, without applying capital to interpret data. The specific, broadly inclusive definition of STEM applied in IC3 is detailed in the search strategy below. We built our search strategy from IC4 by primarily searching for studies that cited Yosso (2005).

3.3 | Search strategy

We followed Borrego et al.’s (2014) recommendations for search strategies, including consulting with a librarian and searching multiple databases to capture all relevant studies. Denton met with an engineering librarian during the search for database recommendations and search strategy suggestions. We primarily used Web of Science and Google Scholar. Both databases allow users to search within articles citing a specific publication, in this case Yosso (2005). This approach aligned our search strategy with IC4. We additionally searched in Education Resources Information Center (EBSCO), Compendex (Engineering Village), and ProQuest Dissertations & Theses Global. Due to the interdisciplinary nature of STEM education, we searched in both education and STEM databases to capture all relevant studies. To ensure inclusion of all relevant dissertations, we searched ProQuest Dissertations & Theses Global. At the advice of the librarian, we stopped searching additional databases once we reached study saturation, that is, search results were predominantly duplicating previous searches. We captured the majority of studies in the initial Google Scholar search, although several were added through searching other databases. Denton completed the database search, conferring with Borrego throughout the process.

Preliminary screening searches indicated that focusing on all STEM disciplines would result in a diverse but manageable set of qualifying studies. Key physical and biological STEM disciplines are included by searching each of the terms listed below:

engineer*, “engineering education”, “STEM education”, bioengineering, chemistry, physics, “computer science”, geoscience, math, mathematics, “materials science”, astronomy, geology, “environmental science”, statistics, bioscience, “life sciences”, “biological science”, “biological sciences”

This text string captures all disciplines that we considered as “STEM” in this systematic review. Commas separate the search terms, quotations were used to search multi-word phrases, and a wildcard character (*) was used to capture variations of engineer, engineering, etc. The within-citation text results in Google Scholar and Web of Science did not allow for searching a text string combining all of the terms at once. The screening process is further detailed in Figure 1.

3.4 | Selection process

Denton completed the selection process with frequent input from and discussion with Borrego throughout the process. We initially screened out studies that were not related to STEM disciplines (IC3) through title and abstract review. We considered studies as not related to STEM if the student population or study setting did not connect to any STEM discipline. After reviewing for a STEM focus, we identified studies that did not substantively discuss CCW (IC1) despite citing Yosso (2005).
We excluded an additional 194 studies from our dataset. Most of these excluded studies used Yosso (2005) as a general reference for CRT. One hundred seven studies remained following the screening for STEM focus and discussion of CCW. We removed seven studies for lacking empirical data (IC1). After examining the full text of the studies, we excluded an additional 14 studies for not being connected to STEM (IC3). Most of these studies included STEM participants among other non-STEM participants, with no STEM-specific literature review, results, or discussion. One study was categorized as a poster (i.e., no full text was available) and removed from the dataset. We further removed studies that did not discuss at least one type of capital as an outcome (IC2). Studies excluded due to IC2 fell into the following categories: CCW only mentioned in the literature review (eight studies), CCW only discussed in future work or implications (3), CCW not central to the study (3), CCW only mentioned in the discussion (10), CCW only included in positionality (1), and CCW only used as theoretical framework (25). Two conference papers were excluded since they were covered entirely by subsequent journal articles. In total, 33 studies met all our inclusion criteria and were retained for further analysis.

3.5 | Analysis

Regardless of the methods applied by the authors of the primary studies, we completed quantitative and qualitative analysis and coding for all qualifying studies. Detailed analytic methods are described in the following sections.

3.6 | Quantitative synthesis

Denton completed the quantitative synthesis and coding. Prior to analysis, she discussed items of interest with Borrego to develop the quantitative coding strategy. We coded each study based on the following items: author, type of study (journal, conference, or thesis/dissertation), name of journal or conference (if applicable), year published, method, method details, number of participants, participant characteristics (such as race, gender, grade level), research questions, theoretical framework, study population, STEM discipline, centrality of CCW, and type(s) of capital discussed as outcomes. Theses are completed as part of a master’s program, while dissertations are required for doctoral degree completion. Denton read all qualifying studies in detail and simultaneously coded the studies, recording these data in an Excel workbook. Throughout this process, Denton and Borrego met regularly to discuss quantitative findings and refine the coding strategy. These results are presented below in tables and where relevant as totals and percentages.

3.7 | Qualitative synthesis

We initially divided the six types of capital during qualitative synthesis, with each author qualitatively analyzing two types of capital across all qualifying studies. We considered how each type of capital was conceptualized across the
studies, looking for similarities and differences among the studies as well as specific examples of each type of capital in STEM education settings. During the ongoing analysis, we held regular meetings to check interpretations, overlaps, and judgment to ensure accurate representations of each primary study author’s original work while limiting the influence of our own interpretations and opinions. We defined each type of capital, provided examples from the qualifying studies, and discussed each type of capital in relation to the others due to the overlapping nature of CCW. Since most studies described multiple types of capital, all three authors carefully read and discussed the 33 qualifying studies. We combined and discussed findings across each type of capital. These findings are presented in text sections below.

We also considered multiple ways of evaluating the quality of the studies. Since most of the studies employed primarily qualitative methods, we did not want to assign numerical quality scores using a rubric. Rather, considering the alignment of stated theoretical perspectives with the analysis and discussion within each study would be more appropriate (e.g., Lincoln & Guba, 1985). However, several studies used multiple frameworks including CCW and as a result engaged with CCW to varying degrees. While scoring studies on the basis of how central CCW was to their analysis would be potentially informative, it conflates our systematic review goals with more general criteria for assessing study quality. Below, we report on factors that influenced the overall quality of the set of 33 studies.

3.8 Limitations

We acknowledge that our search procedures and criteria may not have captured all relevant studies qualifying for the review. Based on our search, CCW is more commonly used with research conducted in higher education settings. Thus, our systematic review may not necessarily be representative of all of the work being done around student assets and assets-based research. For example, other assets-based frameworks such as funds of knowledge (Moll et al., 1992) and Third Space (Soja, 1996) may be more popular for studies conducted in K–12 classroom or outside-of-school settings. Our keywords would have captured K–12 mathematics studies, but we may have missed K–12 science studies that were not associated with a specific science discipline. While we have possibly excluded relevant books or book chapters that would add to our findings, we note that most engineering education-related systematic reviews exclude books for practical reasons (Borrego, Foster, & Froyd, 2015), and we followed this same guideline. Specifically, books and edited volumes are not indexed consistently in databases, abstracts may not be available for initial screening, and it is difficult to create a coding system to effectively accommodate brief articles as well as full-length books. Given the preliminary nature of many of our qualifying studies, we believe that there are few if any high quality STEM education assets-based books already in print.

4 FINDINGS

4.1 General characteristics of the qualifying studies

Thirty-three studies qualified for inclusion in our systematic review. Characteristics of the qualifying studies are listed in Table 2, with information about study type, participant population, research setting, methods, research approach, and STEM discipline. Of the qualifying studies, 25 used a qualitative research design, two studies were quantitative, and six studies used a mixed methods research design. The qualitative studies largely relied on interviews or focus groups as their primary source of data. The quantitative studies used survey questionnaires to collect their data, and the mixed methods designs varied. Quantitative methods frequently correlated CCW with other constructs, such as engineering identity or deaf mentoring practices, rather than only measuring CCW. In terms of format, the majority \((n = 20)\) of qualifying studies are dissertations/theses, 10 are journal articles, and three are conference papers. We did not identify any studies published prior to 2012. Each qualifying study discussed at least one type of CCW capital (Table 3), including aspirational capital (28 studies), familial capital (24 studies), linguistic capital (15 studies), navigational capital (26 studies), resistant capital (24 studies), and social capital (25 studies). Most studies discussed multiple types of capital, with 12 studies including all six types. Only four studies examined one type of capital. The remaining studies included three to five types of capital.

While our inclusion criteria focused on English language rather than geographic location, all but one qualifying study (from South Africa) was conducted in the United States. The conference and journal paper authors tended to be discipline-based education researchers (DBER) with some STEM background, while many of the dissertation and thesis
| Author (year) | Study type | Participant population | Research setting | Methods | Research approach | Science, technology, engineering, and mathematics (STEM) discipline |
|--------------|------------|------------------------|------------------|---------|------------------|---------------------------------------------------------------|
| Aguilar-Valdez et al. (2013) | Journal | Students and teacher in a dual-language math–science–Spanish class | Elementary school (fourth, fifth, and sixth grade) | Qualitative | Observations and interviews | Science and math |
| Braun, Gormally, and Clark (2017) | Journal | Deaf students who had previously had a research experience and deaf faculty | 4-Year institution | Mixed methods | Survey and interviews | STEM (not further specified) |
| Carbajal (2015) | Thesis | Latina undergraduate students | 4-Year institution (HSI) | Qualitative | Interviews and focus groups | STEM (biology, biochemistry, engineering, mathematics) |
| Carrigan et al. (2015) | Conference | Pell-eligible undergraduate students | 4-Year institution | Qualitative | Interviews | Engineering |
| Chavez (2018) | Dissertation | Latinx alumni (graduated with an undergraduate STEM degree) | 4-Year institution | Qualitative | Interviews | STEM (biology, chemistry, information technology, engineering, and mathematics) |
| Coronella (2018) | Dissertation | First-generation Latinx undergraduate students and first-generation female advisors | 4-Year institution | Qualitative | Interviews, open-ended responses, asset maps, and focus groups | Engineering |
| Cortes (2017) | Dissertation | First-generation Latinx undergraduate students | 4-Year institution | Qualitative | Interviews, focus groups, and interviews | Math |
| Dika, Pando, Tempest, Foxx, and Allen (2015) | Journal | Black, Latinx, and Asian undergraduate students and/or first-generation undergraduate students | 4-Year institution | Quantitative | Survey | Engineering |
| Dika, Pando, Tempest, and Allen (2017) | Journal | Black and Latinx undergraduate students | 4-Year institution | Mixed methods | Survey and focus groups | Engineering |
| Forbes (2016) | Dissertation | Black doctoral students who received an undergraduate degree from an HBCU | 4-Year institution (HBCU) | Qualitative | Interviews | STEM (biology, chemistry, physics, computer science, engineering, mathematics) |
| Foxx (2014) | Dissertation | Black and Latinx undergraduate students | 4-Year institution | Qualitative | Interviews | Engineering |
| Kester (2017) | Dissertation | First-year students in the College of Natural Sciences | 4-Year institution | Quantitative | Survey | Science (biology, chemistry, physics, etc.) and math |

(Continues)
| Author                  | Study type | Participant population                                                                 | Research setting            | Methods   | Research approach                                           | Science, technology, engineering, and mathematics (STEM discipline) |
|-------------------------|------------|----------------------------------------------------------------------------------------|----------------------------|-----------|------------------------------------------------------------|---------------------------------------------------------------------|
| Liccardo (2018)         | Journal    | Black, South African female graduate students                                           | 4-Year institution         | Qualitative | Interviews                                                 | STEM (not further specified)                                         |
| Longoria (2013)         | Thesis     | Latina undergraduate students and STEM professionals                                    | 4-Year institution and STEM workforce | Qualitative | Interviews                                                 | STEM (biology, computer science, engineering, mathematics)          |
| Martin and Newton (2016)| Conference | Engineering professionals who received an undergraduate degree                         | 4-Year institution         | Qualitative | Interviews                                                 | Engineering                                                         |
| McKnight (2016)         | Dissertation | Black female graduates of a STEM-themed magnet high school                           | High school                | Qualitative | Interviews and artifacts                                   | STEM (science and math)                                             |
| McPherson (2012)        | Dissertation | Black female undergraduate students                                                      | 4-Year institution         | Qualitative | Interviews and reflection                                 | STEM (pre-business, biology, biochemistry, health sciences, engineering, mathematics) |
| Mercédeze (2015)        | Dissertation | Latina undergraduate students                                                          | 4-Year institution         | Mixed methods | Survey, interviews, and focus groups                       | STEM (geoscience, biology, marine biology, nutritional science, human development/family sciences, engineering, mathematics) |
| Mobley and Brawner (2018)| Journal    | First-generation undergraduate students who transferred from a 2-year institution      | 4-Year institution         | Qualitative | Interviews                                                 | Engineering                                                         |
| Napp-Avelli (2014)      | Dissertation | Latinx immigrant caregivers                                                            | Pre-K and kindergarten     | Qualitative | Interviews and observations                                | Math                                                               |
| Peralta, Caspary, and Boothe (2013) | Journal | Latinx undergraduate students and alumni                                              | 4-Year institution         | Mixed methods | Survey and focus groups                                   | STEM (not further specified)                                         |
| Preston (2017)          | Dissertation | Black female doctoral students who received an undergraduate degree from an HBCU     | 4-Year institution (HBCU)  | Qualitative | Interviews                                                 | STEM (biology, physics, chemistry, biochemistry, cancer and cell biology, materials science, environmental science, engineering) |
| Revelo (2015)           | Dissertation | Latinx undergraduate students involved in Society of Hispanic Professional Engineers (SHPE) | 4-Year institution (HSIs included, multiple institutions) | Mixed methods | Interviews, observations, and survey                       | Engineering                                                         |
| Revelo and Baber (2018) | Journal    | Latinx undergraduate students involved in Society of Hispanic Professional Engineers (SHPE) | 4-Year institution         | Qualitative | Interviews                                                 | Engineering                                                         |
| Author (year)          | Study type | Participant population                        | Research setting                                      | Methods        | Research approach                                           | Science, technology, engineering, and mathematics (STEM) discipline |
|------------------------|------------|-----------------------------------------------|-------------------------------------------------------|----------------|------------------------------------------------------------|---------------------------------------------------------------------|
| Rosbottom (2016)       | Dissertation | Latina undergraduate students                | 4-Year institution                                    | Qualitative    | Interviews                                                  | Engineering                                                          |
| Rubinson (2016)        | Dissertation | Alumni of the high school after-school program | High school after-school program                      | Mixed methods   | Focus groups and survey                                     | STEM (focus on marine science)                                       |
| Samuelson and Litzler (2016) | Journal | Black and Latinx undergraduate students       | 4-Year institution (MSIs included, multiple institutions) | Qualitative    | Interviews                                                  | Engineering                                                          |
| Singer, Schlemer, Liptow, and Chen (2018) | Conference | Undergraduate students in the program for engineering excellence for partner schools (PEEPS) program | 4-Year institution                                    | Qualitative    | Interviews                                                  | Engineering                                                          |
| Synstelien (2013)      | Dissertation | Female undergraduate students who participated in an introduction to engineering program in high school | 4-Year institution                                    | Qualitative    | Fiction writing as research (FWR): Interviews, journal responses, and Facebook observations | Engineering                                                          |
| Tolbert and Cardella (2016) | Journal | Black middle school students                  | Middle school                                         | Qualitative    | Interviews                                                  | Engineering                                                          |
| Tolbert (2017)         | Dissertation | Black male undergraduate students and Black middle school students and parents | 4-Year institution and middle school after-school program | Qualitative    | Interviews and focus groups                                 | Engineering                                                          |
| Williams (2014)        | Dissertation | Black female mathematics teacher              | Middle school, high school, 4-year institution        | Qualitative    | Auto-ethnography: Storytelling, conversations, documents, journal entries, and dialogue | Math                                                                |
| Zamudio (2015)         | Thesis      | Latina alumni (graduated with an undergraduate STEM degree) | Transfer from 2-year institution to 4-year institution (HSIs included, multiple institutions) | Qualitative    | Interviews                                                  | STEM (biochemistry/cell biology, microbiology, health science, geology, engineering, math) |
TABLE 3  Types of capital in qualifying studies used in this systematic review

| Authors (year) | Science, technology, engineering, and mathematics (STEM) disciplines | Aspirational capital \( (n = 28) \) | Linguistic capital \( (n = 15) \) | Familial capital \( (n = 24) \) | Social capital \( (n = 25) \) | Navigational capital \( (n = 26) \) | Resistant capital \( (n = 24) \) |
|---------------|-------------------------------------------------|-------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Aguilar-Valdez et al. (2013) | Science and math | X | X | X | X | X | X |
| Braun et al. (2017) | STEM | X | X | X | X | X | |
| Carbajal (2015) | STEM | X | | | | X | |
| Carrigan et al. (2015) | Engineering | X | | | | | |
| Chavez (2018) | STEM | X | X | X | X | X | X |
| Coronella (2018) | Engineering | X | | | | | X |
| Cortez (2017) | Math | X | | | | | X |
| Dika et al. (2015) | Engineering | X | | | | | X |
| Dika et al. (2017) | Engineering | X | X | X | | | |
| Forbes (2016) | STEM | X | X | X | | | X |
| Foxx (2014) | Engineering | X | X | X | | | X |
| Kester (2017) | Science and math | | | | | | X |
| Liccardo (2018) | STEM | | | | | X | X |
| Longoria (2013) | STEM | | X | X | | | X |
| Martin and Newton (2016) | Engineering | X | X | X | X | | |
| McKnight (2016) | STEM | X | X | X | | | X |
| McPherson (2012) | STEM | X | X | | | | X |
| Mercédez (2015) | STEM | X | X | X | X | | |
| Mobley and Brawner (2018) | Engineering | X | X | X | | | |
| Napp-Avellí (2014) | Math | X | X | X | X | X | X |
| Peralta et al. (2013) | STEM | X | X | | | | |
| Preston (2017) | STEM | X | X | X | X | | |
| Revevo (2015) | Engineering | X | X | X | X | | |
| Revevo and Baber (2018) | Engineering | | | | | | X |
| Rosbottom (2016) | Engineering | X | X | X | X | | X |
| Rubinson (2016) | STEM | X | X | X | X | | |
| Samuelson and Litzler (2016) | Engineering | X | X | | | | X |
| Singer et al. (2018) | Engineering | | | X | X | X | |
| Synstelien (2013) | Engineering | X | X | X | X | | X |
| Tolbert and Cardella (2016) | Engineering | | | | | | X |
| Tolbert (2017) | Engineering | X | X | X | X | X | |
| Williams (2014) | Math | X | X | X | X | X | |
| Zamudio (2015) | STEM | X | X | X | X | X | |

authors were education researchers not associated with STEM disciplines (e.g., higher education). Nearly half the qualifying studies focused on engineering (15 studies), 13 on STEM, three on mathematics, and two on science and mathematics. Eight of the 13 STEM studies included engineering, and the other five were unclear about their sampled disciplines. More detail on disciplines is provided in Table 2. Almost all studies situated their work in relation to educational institutions, including elementary school (2 studies), middle school (3 studies), high school (3 studies),
2-year institutions (2 studies), 4-year institutions (27 studies), and the STEM workforce (1 study). Several studies focused on multiple institutional settings, for example, 2-year to 4-year transfer, with higher education serving as the most frequent setting. Consistent with Yosso’s (2005) intention for CCW, the majority of studies focused on Latinx (16 studies) or Black (12 studies) student populations. For clarity, we use consistent terminology when referring to racial and ethnic groups, including Black to include participants described by primary study authors as African American and Latinx for Hispanic, Latino/a, Chicano/a, and other terms. Additional populations of interest in the qualifying studies included first-generation college students (four studies), transfer students (two studies), deaf students (one study), and after-school program participants (two studies). A few studies were located at specific institution types, such as Historically Black Colleges and Universities (HBCUs, two studies) and Hispanic-Serving Institutions (HSIs, three studies).

In terms of quality, we identified a number of factors that would influence a reader’s interpretation of the relative usefulness of various studies. More than half of our qualifying studies are dissertations or theses, which many other systematic reviews exclude due to assumptions of lower quality or length considerations. Due to the longer length, some dissertations attempted to combine multiple frameworks and as a result did not use CCW as centrally as most of the conference and journal papers did. Conference papers and journal articles were more likely to be focused on a single framework, often CCW, but may not have been based on as extensive a data set as dissertations. As expected, we found journal articles generally better developed and therefore more useful than conference papers. Some studies relied on the overlap between different types of capital to avoid labeling specific examples as a particular type of capital, and they were not as explicit about overlaps as we would have liked. This finding is discussed further under the Section 4.8 below. Finally, our broad inclusion criterion IC1 allowed us to include studies analyzing empirical data using less traditional methods, including autoethnography and narrative analysis to create composite personas. These details are included in Table 2 to provide additional context for readers as they consider the qualitative findings reported below. In Section 5, we address how some studies may not have applied CCW in the ways intended by Yosso (2005).

### 4.2 Aspirational capital

The first type of capital we examined in detail was aspirational capital, which Yosso (2005) defined as “the ability to maintain hopes and dreams for the future, even in the face of real and perceived barriers” (p. 77). Twenty-eight studies identified at least one example of aspirational capital in their data. For example, in Dika et al. (2017), aspirational capital emerged as the most important form of capital used for the persistence of nondominant students in engineering. Many studies described this persistence as contingent upon a personal ability to remain focused on goals despite real or imagined barriers to students’ aspirations. This persistence was described as “resilience in the form of a disposition toward success” (Samuelson & Litzler, 2016, p. 97) and a “motivation to push though while maintaining a positive attitude” (Zamudio, 2015, p. 71). Dika et al. (2017) argued for the importance of students’ recognition of their aspirational capital, while Samuelson and Litzler (2016) suggested that students did not necessarily need to acknowledge or recognize the barriers to their aspirations, because students’ “hopes and dreams for the future … function as capital. Their aspirations motivated them to persist in engineering” (p. 108). Chavez (2018) described similar forms of evidence for aspirational capital as “when future hopes were maintained despite the presence of obstacles or discouraging remarks Latinx experienced from peers or faculty” (p. 156). One study attributed aspirational capital to the degree attainment of Black women in a range of STEM disciplines (McPherson, 2012).

Other studies suggest that aspirational capital can extend to other stakeholders who contribute to student success including faculty, advisors, mentors (Braun et al., 2017; Preston, 2017; Revelo, 2015), campus affinity organizations (Revelo, 2015), individuals in the engineering profession (Carbajal, 2015; Revelo, 2015), and family members (Napp-Avelli, 2014). For example, Carbajal (2015) described the “use of aspirational capital working alongside familial capital” (p. 58) as crucial for Latina baccalaureate attainment. This relationship between the various forms of capital manifested in different results. In a study of first-generation 2-year college engineering transfer students, Mobley and Brawner (2018) found students expressed their aspirational capital through a fear of disappointing family members that resulted in motivation to persist after experiencing setbacks. Chavez (2018) found students reached out to siblings for support to navigate the educational system and to parents for encouragement to continue to aspire to college and complete a degree. Authors often described the expression of aspirational in conjunction with other forms of capital.
4.3 Linguistic capital

Fifteen studies, the fewest of any of the six types of capital, identified at least one form of linguistic capital as an empirical outcome in their work. Identification of linguistic capital frequently focused on language, specifically the bilingualism of participants. Six studies included Spanish speakers as participants (Chavez, 2018; Napp-Avelli, 2014; Peralta et al., 2013; Revelo, 2015; Rubinson, 2016; Zamudio, 2015), while another study examined communication within the deaf community as linguistic capital (Braun et al., 2017). Spanish and American Sign Language (ASL) were the only languages included in discussion of participant bilingualism. Engineering and STEM students viewed their bilingualism as helpful during internships and jobs that involved global projects and communicating with native Spanish speakers (Chavez, 2018; Revelo, 2015; Zamudio, 2015). Bilingual participants developed social relationships with other Spanish-speakers during college and at work (Zamudio, 2015). Similarly, learning scientific content knowledge was compared to learning a new language in several studies and identified as a form of linguistic capital (Aguilar-Valdez et al., 2013; Peralta et al., 2013; Zamudio, 2015). While one study argued that bilingual students have an advantage in learning science due to their existing language skills (Zamudio, 2015), another study claimed that bilingual students are disadvantaged in learning science due to language fatigue (Peralta et al., 2013). One study discussed ASL bilingualism in the context of mentoring relationships, which was conceived broadly without specific examples (Braun et al., 2017).

Some studies applied linguistic capital more broadly than spoken language, including different methods of communicating as a form of linguistic capital. One study emphasized the different ways math teachers can use their linguistic capital to communicate and work with their students (Williams, 2014). Several studies acknowledged how institutions (Synstelien, 2013) and professional fields (Rubinson, 2016; Tolbert, 2017) often have their own language, vocabulary, and norms of communication. Parents (Synstelien, 2013; Tolbert, 2017) and after-school programs (Rubinson, 2016) can help students gain linguistic capital by strengthening their mathematical literacy and helping them develop professional skills. Two studies introduced the idea of code-switching as a form of linguistic capital (Martin & Newton, 2016; McPherson, 2012). In both studies, participants traversed different environments (e.g., home and school) and changed their language and dialect based on the environment. One participant explained that her success in the classroom was due to her ability to “talk white” (Martin & Newton, 2016, p. 4). None of the studies examined storytelling as a method of communication as described by Yosso (2005).

4.4 Familial capital

Twenty-four studies described examples of familial capital in their data. Most of these studies operationalized familial capital as instances in which interview participants mentioned their families. Most often, this interpretation meant parents, but studies also included siblings and extended family including grandparents, aunts, uncles and cousins. These studies described how family was supportive in broad ways, such as encouraging students to persist, showing pride in their accomplishments, supporting STEM as a desirable career choice, telling stories of resilience, and setting expectations for doing well in school and being respectful of teachers and professors (Chavez, 2018; Coronella, 2018; Dika et al., 2017; Forbes, 2016; Longoria, 2013; McKnight, 2016; Mercédez, 2015; Mobley & Brawner, 2018; Napp-Avelli, 2014; Peralta et al., 2013; Rosbottom, 2016; Samuelson & Litzler, 2016; Synstelien, 2013; Tolbert, 2017; Williams, 2014; Zamudio, 2015). Three studies mentioned how family supported developing a strong academic work ethic by checking in often with students about whether they had completed homework assignments or college applications (Longoria, 2013; Mercédez, 2015; Peralta et al., 2013). Six studies included at least one participant whose parents shared firsthand knowledge of STEM careers (Dika et al., 2017; Foxx, 2014; McKnight, 2016; Samuelson & Litzler, 2016; Synstelien, 2013; Tolbert, 2017). Others described how families imparted more practical knowledge described as “street smarts” (Martin & Newton, 2016, p. 5) or networked with extended family and others to get advice specific to STEM careers (Chavez, 2018; Rosbottom, 2016; Tolbert, 2017). A few studies mentioned how parents supported STEM interests while their children were growing up, for example tinkering, carpentry, computers (Tolbert, 2017), toys and kits (Rosbottom, 2016) or Lego blocks (Samuelson & Litzler, 2016). Some studies mentioned families’ financial support of higher education (Forbes, 2016; Rosbottom, 2016), including students making decisions about where to attend based on limiting strain on family finances (Chavez, 2018; Mobley & Brawner, 2018; Zamudio, 2015), pursuing a STEM degree so that they could eventually support a family (Coronella, 2018), living with extended family members while attending college (Zamudio, 2015), and living with a grandmother who could watch young
children while their parents pursued STEM careers (Napp-Avellli, 2014). Six studies mentioned STEM students as role models for younger siblings or cousins, both wanting to be or being told by parents to serve as role models (Chavez, 2018; Foxx, 2014; Rosbottom, 2016) and having been inspired by an older family member (Mobley & Brawner, 2018; Williams, 2014; Zamudio, 2015).

Another aspect of familial capital mentioned by Yosso (2005) includes community. Few studies explored familial capital arising from non-family relationships, but these are worth mentioning. To augment or substitute for family support of STEM aspirations, studies described how engineering students found an extended family in student organizations that included community service, mentoring and tutoring activities (Foxx, 2014; Revelo, 2015; Samuelson & Litzler, 2016). Two studies focused on HBCUs and found that students, faculty and staff at the institutions served as extended family to support students’ STEM achievement (Forbes, 2016; Preston, 2017). Similarly, a study of an out-of-school program for high school students found that the relationships developed and modeled by program mentors supported participants much like a family would (Rubinson, 2016). Finally, a survey development study focused on deaf students operationalized familial capital as interacting with the deaf community (Braun et al., 2017). Participants described these organizations as a “second family” (Rubinson, 2016) and the afterschool program as a “home away from home” (p. 71). Familial capital beyond relatives connected social capital closely with the familial capital that can develop in STEM programs and on college campuses to develop supportive, family-like relationships. Of the six studies cited in this paragraph, all but one (Samuelson & Litzler, 2016) identified the same relationships as sources of social capital.

4.5 Social capital

Twenty-five studies identified at least one example of social capital using their data. Many of these studies had multiple descriptions for social capital beyond Yosso’s (2005) original definition as “the networks of people and community resources ... that can provide both instrumental and emotional support to navigate through society's institutions” (p. 79). Twelve studies described peers as an important source of social capital for both emotional support (Revelo, 2015; Singer et al., 2018) and social support (Aguilar-Valdez et al., 2013; Chavez, 2018; Coronella, 2018; Dika et al., 2015; Dika et al., 2017; Forbes, 2016; Foxx, 2014; McPherson, 2012; Revelo, 2015; Singer et al., 2018; Zamudio, 2015). Cohort programs (Singer et al., 2018) and affinity groups such as Society of Hispanic Professional Engineers (Dika et al., 2017; Revelo, 2015) and National Society of Black Engineers (Dika et al., 2017) served as sources of social capital and supported students in their transition to university life. These networks provided students opportunities to connect with others “who have similar experiences or cultural backgrounds [and] can help students not only navigate this environment but also serve as emotional support” (Singer et al., 2018, p. 6). Networks can also serve as a “buffer” (p. 71) for situations in which many 2-year to 4-year transfer students encounter negative experiences (Zamudio, 2015). Latinx students found social capital in the classroom community and academic group work (Cortes, 2017).

Individuals were also a source of social capital. For example, when reflecting on her STEM magnet high school experience, a Black female participant described “positive peer pressure” as a source of social capital along with “a healthy level of pressure when it came to academics” (McKnight, 2016, p. 78). In K–12 settings, STEM teachers were important sources of social capital (McKnight, 2016; Rosbottom, 2016). In higher education settings, interactions with faculty mentors served as important sources of social capital (Braun et al., 2017; Chavez, 2018; Dika et al., 2015; Dika et al., 2017; Forbes, 2016; Foxx, 2014; McKnight, 2016; Synstelien, 2013; Zamudio, 2015). Foxx (2014) found that students recognized the importance of interacting with faculty members and took advantage of office hours to use the interaction “to establish professionalism and investment in their academic success” (p. 142). Four studies specifically mentioned the importance of institutional empowerment agents (Chavez, 2018; Coronella, 2018; Foxx, 2014; Zamudio, 2015). Examples of these individuals include advisors, engineering and non-engineering professionals, mentors, coaches (Foxx, 2014), faculty, and alumni leaders (Zamudio, 2015). These agents shared and transferred important knowledge and are sources of positive experience and social capital for individuals from nondominant student populations. Black women stated that exposure to social capital resulted in their persistence in STEM majors (McPherson, 2012). Individuals outside of the institution can serve as sources of social capital as well. In Tolbert (2017), parents emphasized the importance of exposure to Black engineers in their community, which provides access to social capital and helps Black youth see engineering as a career pathway, develop an engineering interest, and navigate the world around them. In this sense, the community was also a source of social capital.
4.6 Navigational capital

Twenty-six studies included navigational capital as an empirical outcome. Navigational capital was frequently conceptualized around Yosso's (2005) definition as capital used to maneuver through institutions designed for dominant populations. Accordingly, many studies focused on how participants used navigational capital to maneuver through STEM majors within an institution or gained STEM-specific navigational capital prior to college (Carrigan et al., 2015; Chavez, 2018; Coronella, 2018; Cortes, 2017; Dika et al., 2015; Forbes, 2016; Foxx, 2014; McKnight, 2016; McPherson, 2012; Mercédez, 2015; Revelo, 2015; Rosbottom, 2016; Rubinson, 2016; Synstelien, 2013; Tolbert, 2017; Williams, 2014) or the profession (Braun et al., 2017; Preston, 2017; Revelo, 2015). Several other studies described strategies participants used to navigate educational institutions in general. Higher education institutions were overrepresented in navigational capital, with most studies focused on preparing students for higher education or how navigational capital was enacted once at the institutions. Two studies reviewed the navigational capital involved during transfer from 2-year to 4-year institutions (Mobley & Brawner, 2018; Zamudio, 2015), and one study looked at the transition from college to graduate school (Preston, 2017).

Many of these studies described how participants used resources to assist their navigation through institutions. People were often framed as resources within the studies. Most frequently, peers provided a form of navigational capital to participants (Carbajal, 2015; Coronella, 2018; Cortes, 2017; Forbes, 2016; Foxx, 2014; McKnight, 2016; McPherson, 2012; Mercédez, 2015; Preston, 2017; Revelo, 2015; Rosbottom, 2016; Rubinson, 2016; Samuelson & Litzler, 2016; Zamudio, 2015), often as an emotional support through friendships or academic support through study groups and homework partners. Studies often referred to student organizations (Carbajal, 2015; Chavez, 2018; Foxx, 2014; Mercédez, 2015; Revelo, 2015; Singer et al., 2018) and, more specifically, professional affinity student organizations (Chavez, 2018; Coronella, 2018; Foxx, 2014; Mercédez, 2015; Napp-Avelli, 2014; Revelo, 2015; Singer et al., 2018), as providing students with emotional support and academic resources. For example, SHPE provided a space where participants could interact with others of their culture. Additionally, STEM professionals attended SHPE meetings to share their experiences (Revelo, 2015). Individuals employed by higher education institutions were referred to as navigational capital, such as faculty members (Carbajal, 2015; Chavez, 2018; Cortes, 2017; Foxx, 2014; Preston, 2017; Samuelson & Litzler, 2016; Synstelien, 2013; Zamudio, 2015), university and department staff (Carbajal, 2015; Samuelson & Litzler, 2016; Zamudio, 2015), and advisors (Carbajal, 2015; Chavez, 2018; Coronella, 2018; Preston, 2017; Samuelson & Litzler, 2016). Faculty often helped connect participants to co-op/internship and research opportunities, encouraged their academic success, and wrote letters of recommendation. Similarly, mental health counselors provided navigational capital through emotional support and arranging for testing accommodations (Chavez, 2018). Mentors was a term used broadly within several studies at higher education institutions, referring to engineering student resident assistants, deaf mentors, and graduate students (Braun et al., 2017; Coronella, 2018; Rosbottom, 2016). Different programs, such as scholarship cohort groups, engineering-specific resident halls, and honors programs, provided support with a community of peers and available resources (Preston, 2017; Rosbottom, 2016; Singer et al., 2018). Individuals working in K–12, such as teachers (Aguilar-Valdez et al., 2013; McKnight, 2016; Mercédez, 2015) and counselors (McKnight, 2016), provided navigational capital to participants. Outside of institutional settings, family served as a form of navigational capital (Chavez, 2018; Forbes, 2016; Mercédez, 2015; Napp-Avelli, 2014; Synstelien, 2013; Tolbert, 2017), whether through emotional support, creating opportunities, or advice based on their experiences.

Participants also sought out or used resources themselves in addition to relying on others. Some studies mentioned the web-based resources used by participants as they sought information (Mobley & Brawner, 2018) and their use of office hours as an academic resource (McPherson, 2012; Samuelson & Litzler, 2016). Another study highlighted personal characteristics of the participants as navigational capital, specifically qualities and competencies related to thinking outside of the box and continually asking questions (Samuelson & Litzler, 2016). Three studies described the time management skills developed and used by participants (Carbajal, 2015; Martin & Newton, 2016; Preston, 2017). There was overlap between what resources participants sought and what resources were provided by individuals categorized as navigational capital in the paragraph above. For example, tutoring services, study groups, emotional support, and faculty support were both sought by participants and proactively provided by faculty and peers. Additionally, participants expressed a desire to provide navigational capital to others after their own successful navigation, such as participating in engineering outreach events (Rosbottom, 2016) or helping others in student organizations (Revelo, 2015).
4.7 | Resistant capital

Twenty-four studies identified at least one example of resistant capital. Many of these studies expanded on Yosso’s (2005) definition of resistant capital using Solorzano and Bernal’s (2001) definitions of three types of resistance: self-defeating, conformist and transformative. Revelo and Baber (2018), the only study to focus exclusively on resistant capital, summarized these definitions and provided STEM examples:

Self-defeating resistance refers to an individual or group that has critical awareness of systemic forces shaping inequalities but low motivation for social justice. This is a student who is aware and critiques structural norms in STEM education that negatively shape experiences for People of Color, but decides to switch out of a STEM major, contributing to low persistence rates in STEM for Students of Color. Conformist resistance is when individuals or groups fail to challenge structural inequalities but focus on improving opportunities for traditionally marginalized populations by changing individual or group dispositions to better match norms within the structure. For example, graduating Students of Color in STEM may develop a program for incoming students that provides insights on social norms of the department or college but fails to challenge its grounding in individualistic, value-neutral ideology. A transformative form of resistance refers to both a critique of the system and high motivation for systemic changes to the structure. In a STEM department or college, Students of Color actively resist norms by embracing collectivist perspectives and engaging in amplified acts against norms that negatively shape their experiences. (p. 254)

In the qualifying studies we reviewed, conformist resistance was identified most frequently. Several authors explained that persisting in a STEM major and overcoming stereotypes that they may not belong or be able to succeed in STEM is itself an example of resistant capital (Carbajal, 2015; Chavez, 2018; Cortes, 2017; Foxx, 2014; Martin & Newton, 2016; Revelo, 2015; Rosbottom, 2016; Samuelson & Litzler, 2016; Synstelien, 2013; Zamudio, 2015). In some cases, undergraduate students additionally felt a responsibility to succeed so they could serve as role models and mentors to others (Revelo & Baber, 2018; Synstelien, 2013).

Participants in three of the studies described how discussions between parents and their children developed resistant capital (McKnight, 2016; Napp-Avelli, 2014; Tolbert, 2017). Napp-Avelli (2014) included specific examples of incidents that mothers used to prepare their daughters to respond to marginalizing comments from others. Latinas in particular needed resistant capital to overcome traditional gender role expectations of their parents and future spouses that did not leave room for them to pursue STEM success and have children (Longoria, 2013; Synstelien, 2013). HBCU faculty members mentored undergraduates about what to expect pursuing research experiences and graduate study at a Primarily White Institution (Preston, 2017). High school Students of Color in an out-of-school group mentoring program had

reflective conversations ... with mentors guiding the participants to learn their strengths and areas for improvement, and developing positive self-images. Through conversations about their strengths, areas for growth, and self-image, participants grew to identify and combat stereotype threat. (Rubinson, 2016, p. 272)

Attending a math and science magnet school had similar impacts on building students’ resistant capital (McKnight, 2016).

Another important strategy for developing resistant capital was connecting with others, including classmates and instructors (Carbajal, 2015) or peers through student organizations (Chavez, 2018; Foxx, 2014; Revelo, 2015; Revelo & Baber, 2018; Singer et al., 2018). Affinity groups such as SHPE helped Latinx students develop an on-campus familia (Chavez, 2018;Revelo, 2015; Revelo & Baber, 2018). Through student organizations and other volunteer opportunities, participants engaged in outreach activities to encourage interest in STEM among K–12 Students of Color (Revelo, 2015; Revelo & Baber, 2018).

Some studies mentioned participants being motivated by social justice (Revelo & Baber, 2018; Samuelson & Litzler, 2016; Singer et al., 2018) and how it may help students to develop transformative resistance in the future (Revelo & Baber, 2018). Social justice concerns included broad societal problems such as homelessness and sustainability as well as issues of underrepresentation in STEM disciplines.

A few specific acts of resistance identified in the studies are worth mentioning. In Cortes (2017), one participant spoke out in class when the instructor made marginalizing comments, while other participants “resisted rules and structures that were counterproductive to their studying, such as sneaking food into libraries so they could study for
longer amounts of time” (p. 90). A Student of Color who did not identify as Native American took down posters advertising Columbus Day events on campus because she found them offensive to indigenous students (Synstelien, 2013).

4.8 Gaps and opportunities in how CCW is being applied in STEM education

In general, study authors tended to focus on shallow interpretations of capital, rather than highlighting more nuanced examples. For example, authors frequently associated linguistic capital with spoken language (i.e., Spanish), but they rarely discussed written language. Only two studies focused on different methods of communicating (through teaching and sign language) as forms of linguistic capital. No studies included examples of storytelling or artistic mediums, despite Yosso’s (2005) definition including both as key components of linguistic capital. Similarly, familial capital examples tended to focus on immediate family members (i.e., parents and siblings), which is a limited interpretation of Yosso’s (2005) definition of familial capital, which includes the idea of familia and surrounding community as forms of familial capital. Familial capital “can be fostered within and between families, as well as through sports, school, religious gatherings and other social community settings” (Yosso, 2005, p. 79). Aspirational capital tended to be associated with goals, without any additional interpretations from authors. Navigational capital overwhelmingly focused on how people provided resources to participants, with a very limited focus on how participants navigated through environments on their own. Only a few examples were provided, such as seeking out online resources and managing time effectively. While Yosso (2005) acknowledges the connection between social and navigational capital, “navigational capital thus acknowledges individual agency within institutional constraints, but it also connects to social networks that facilitate community navigation through places and spaces” (p. 80), our qualifying studies focused on the role of institutional agents, largely ignoring the individual actions of the participants and their own resilience. Further, while a few social capital studies described empowerment agents, they lacked a clear definition and scope. An extension of their discussion of empowerment agents could help identify specific social capital to support student success. Within resistant capital, it may be difficult to expect students, particularly in such politically conservative fields as STEM disciplines, to seek to dismantle unjust educational systems as they are learning to navigate them. This is less a gap in how other researchers have applied CCW than a limitation to the approach of interviewing students to be considered in future research designs.

4.9 Overlap between types of capital

Numerous studies described an overlap between one type of capital and another. These findings align with Yosso’s (2005) framework, described as the “various forms of capital are not mutually exclusive or static, but rather are dynamic processes that build on one another” (p. 77). In the qualifying studies we reviewed, aspirational, navigational, and social capital were most frequently described as overlapping with one another and other types of capital.

Twelve qualifying studies (Carbajal, 2015; Chavez, 2018; Dika et al., 2017; Foxx, 2014; Longoria, 2013; McKnight, 2016; Mercédez, 2015; Mobley & Brawner, 2018; Peralta et al., 2013; Rubinson, 2016; Synstelien, 2013; Tolbert, 2017) specifically described the overlap of aspirational and familial capital. In Chavez (2018), both familial capital and aspirational capital were essential elements described by Latinx college students in their decision to pursue higher education. For example, students sought support from siblings to navigate the educational system and from parents for encouragement not only to aspire to college but also to complete a degree. Napp-Avelli (2014) describes the aspirational capital of Latinx immigrant caregivers who conceived their involvement in their children’s lives as much larger than providing material needs. These parents prioritized participating in school activities and events as well as engaging with academics at home. The close relationship between familial and aspirational capital was a common theme throughout studies that identified aspirational capital as a result of parental emphasis on education (e.g., Longoria, 2013). One study (Rubinson, 2016) described aspirational capital developed through both social and familial capital.

Multiple studies (Chavez, 2018; Foxx, 2014; Napp-Avelli, 2014; Revelo, 2015; Rubinson, 2016; Samuelson & Litzler, 2016; Synstelien, 2013) identified an overlap between aspirational capital and navigational capital. Samuelson and Litzler (2016) describe this relationship as a contrast of disposition and skills. “While aspirational capital indicates resilience in the form of a disposition towards success, navigational capital signifies resilience in the form of a set of skills enabling Students of Color to maneuver through educational institutions” (p. 97). In this study of Students of Color
who persisted through engineering, “student comments reflected a combination of aspirational capital and navigational capital and demonstrated how dispositional and skills-based types of capital work together in support of student persistence” (p. 102). Two studies (Carbajal, 2015; Revelo, 2015) identified the importance of role models within STEM fields as sources of both aspirational and navigational capital.

Navigational capital frequently overlapped with several other types of capital. Most frequently, navigational capital overlapped with social capital (Braun et al., 2017; Carbajal, 2015; Coronella, 2018; Forbes, 2016; Foxx, 2014; Mobley & Brawner, 2018; Revelo, 2015; Rosbottom, 2016; Samuelson & Litzler, 2016; Synstelien, 2013; Tolbert, 2017; Tolbert & Cardella, 2016). This largely occurred when discussing individuals as a form of navigational capital, as social resources (faculty, peers, etc.) were conceptualized as navigational capital. Familial and navigational capital overlapped in one study (Rubinson, 2016), with the community of an after-school program providing participants with navigational capital. Resistant and navigational capital overlapped in two studies (Chavez, 2018; Foxx, 2014), with students successfully navigating the existing barriers or lack of support as a form of resistance. Linguistic capital overlapped with navigational in one study (Synstelien, 2013).

Eight studies identified and articulated an overlap of social capital with familial (Coronella, 2018; Forbes, 2016; Foxx, 2014; McKnight, 2016; Mercédez, 2015; Preston, 2017; Rubinson, 2016; Tolbert, 2017). Some studies were straightforward in describing this overlap, for example, in a study exploring STEM Latina identity support, Mercédez (2015) described this relationship as “family as social capital” (p. 193). McKnight (2016) described familial capital as a larger source of capital which “encompass[ed] social capital” (p. 115). Coronella (2018) identified an alignment of social and familial capital in providing support for students on their journeys to and through college. Other studies were not as explicit but referenced the previously discussed connection of social capital with the familial capital that can develop in STEM programs and on college campuses to develop supportive, family-like relationships.

Few studies described the overlap between the other types of capital; resistant and linguistic capital in particular overlapped the least with other types in the studies we reviewed.

5 | DISCUSSION

Our systematic literature review on application of Yosso’s (2005) CCW framework in STEM education identified 33 qualifying studies. Each study cites Yosso (2005), discusses at least one type of capital as an outcome, positions STEM as central to the study, and presents original empirical findings. The qualifying studies described each type of CCW capital, including aspirational (28 studies), linguistic (15 studies), familial (24 studies), social (25 studies), navigational (26 studies), and resistant (24 studies). We examined trends across characteristics of the qualifying studies, including methods, study type, participant population, research setting, research approach, and STEM discipline (Table 2). Our earliest qualifying study was published in 2012, 7 years after Yosso (2005) was published, which emphasizes that using assets-based frameworks in STEM education is currently emerging and has potential to shape the field. We investigated how the different types of capital were conceptualized across qualifying studies, noting similarities and differences within each type of capital and trends related to the overlap of different types of capital.

Several trends emerged from characteristics of the 33 qualifying studies. The majority of studies used a qualitative research design with interviews or focus groups serving as the primary data collection method. While a few studies administered surveys as part of a quantitative (two studies) or mixed methods design (six studies), the survey designs lacked a robust measurement of CCW, often containing no more than one survey item for each type of capital. This lack of focus on quantitative measures of capital is at least in part because the surveys were often designed to determine whether CCW correlated with another construct, such as engineering identity or deaf mentoring practices, rather than having a main goal of measuring CCW. Many would argue that student voices must remain central to CCW in ways that cannot be honored using quantitative or survey research methods. Further, the overlaps and synergies between types of capital, along with the possibility for new types to emerge, may make CCW items unsuitable for factor analyses that would accompany scale development. Nonetheless, it would be important for assets-based perspectives to be integrated into quantitative studies that often drive policy decisions. The many examples of capital identified in the studies reviewed here could be used to develop new items and measures that are more assets-based. For example, instead of only asking whether students have a parent who is an engineer, it may be more appropriate to ask whether students are in contact with an extended family member who is a practicing engineer or a more advanced engineering student.

We acknowledge that interviews and focus groups provide unique insight into participants’ CCW through open-ended responses. Most of the qualitative studies attempted to identify all six types of CCW capital based on participant
responses, with varying degrees of success. Very few (n = 4) studies focused on one specific type of capital, and as a result some of these were particularly informative concerning what capital can mean in STEM education settings. These initial, exploratory studies (particularly those considering all types of capital) illustrate the relative newness of applying CCW as a framework within STEM education and provide a foundation for more focused future work. Our findings illustrate the need to consider whether and how CCW can be studied quantitatively to complement the existing qualitative work using CCW.

Further, the qualifying studies tended to focus solely on students, without collecting data from faculty, administrators, or family members. Taken together however, these student-focused studies provide ample evidence of the role of family members, faculty and academic staff as central to multiple types of capital, particularly familial, navigational, social, and resistant. A common theme situated people as resources, through the knowledge they shared and actions they took to help students navigate educational systems. The studies concluded that others can contribute significantly to STEM students’ development and identification of capital to help them succeed in STEM education environments. Not having included these individuals as study participants’ limits our ability to write specific implications for practice targeted to institutions or educators. While focusing on students gives voice to their experiences and perspectives in ways that are true to CCW, it also risks placing the burden of succeeding on the students themselves, an implicit deficit-based perspective (Deil-Amen, 2011). Future research should, in addition to students, collect data from people who were identified as forms of capital in the qualifying studies, such as family members, faculty, advisors, administrators, and program managers. To promote change, assets-based research should include these individuals as they may be in a unique position to identify assets, change institutional structures and encourage student success.

We previously acknowledged the large number of dissertations and theses in our qualifying studies. First, by definition dissertation and thesis research is by new researchers and not peer reviewed. This situation may contribute to the lack of nuance we observed in applying CCW to interpreting research results. Second, while almost all of the journal and conference papers were written by authors identifying as DBER, dissertation and thesis authors displayed a greater mix between DBER and other education disciplines. This affiliation means that while Yosso’s (2005) CCW framework is being applied in STEM education research, researchers who identify with a STEM discipline (e.g., engineering education researchers) are not necessarily the ones using this framework. We think this finding is important to note because engineering education will not change if equity-focused researchers from outside the field are the only ones using assets-based frameworks. To create lasting change in how we conduct research and practice within engineering education, DBER—including engineering educators—must begin to apply the frameworks to the field as well.

Other emphases are apparent from the characteristics of the qualifying studies. Most studies used “STEM” as a term to describe their sampling of various science, math, and engineering majors although a few studies included business, health sciences, and human development/family sciences as STEM (Table 2). However, few studies focused on math (three studies) or science (zero studies) individually, while almost half (15) of the 33 qualifying studies focused on engineering. Additionally, the research setting of the qualifying studies was overwhelmingly at 4-year institutions (27 studies), with most of the remaining studies situated at K–12 schools or 2-year institutions. Six of the 4-year institution studies were at least partially situated outside of Predominantly White Institutions, including three studies at HSIIs (Carbayal, 2015; Revelo, 2015; Zamudio, 2015), two studies at HBCUs (Forbes, 2016; Preston, 2017), and one multi-institution study at Minority-Serving Institutions (Samuelson & Litzler, 2016). Only two studies were conducted outside of educational institutions. Informal settings, such as after-school programs, home environments, or the local community, were of limited focus.

Many of the studies honored Yosso’s (2005) original intention of building on the work of CRT by focusing on Latinx and Black students as study participants. Other studies expanded the idea of CCW to apply to other nondominant populations within STEM, such as transfer students, first-generation college students, and deaf students. We applaud this adaptation to other nondominant groups as we believe it is important to recognize how certain pathways and student characteristics can make traversing educational institutions difficult, given current institutional structures that do not serve all students equally. However, we also caution any extensions from the original target population, as sufficiently extending the theory contains its own challenges and difficulties if not completed thoughtfully and with detailed attention to the original work.

One explanation for the lack of deep introspection into Yosso’s (2005) original definition of the six types of capital may be the interview protocol design used in these qualitative studies. Questions often encompassed the obvious definitions of capital, which may limit the range of participant responses that the authors received. The limited interpretations also align with the preliminary nature of applying assets-based frameworks, and CCW in particular, to STEM education research. We would expect more basic examples of capital to be emphasized in early work as researchers...
are just beginning to learn and apply CCW. The frequency with which each type of capital appeared in the qualifying studies differed, with linguistic the least frequently mentioned and aspirational and social included in nearly every study. We believe the difference in frequency is related to these shallow interpretations of capital. For instance, aspirational capital was commonly associated with goals and social capital with people, which explains their high frequency.

The overlap among different types of capital aligns with Yosso’s (2005) original statement that the idea of capital is not a static concept; each type of capital feeds into the others. Several studies, particularly dissertations and theses, attempted to categorize each example provided by participants as a specific type of capital. Such methods limit the richness of the data, by excluding participant stories from more than one type of capital. For example, a faculty member helping a student was viewed as social capital, navigational capital, or both depending on the specific author’s interpretation. Aspirational, navigational, and social had the greatest overlap. Reasons for the overlap may be due to people (social capital) often serving as resources to help students with the action of navigating (navigational capital) through institutions needed to achieve their goals (aspirational). Resistant and linguistic capital had the least amount of overlap with other types of capital in our qualifying studies, perhaps because most studies did not explore either of these two types beyond the most common interpretations. This finding is not to say that overlaps do not exist; rather, the authors of the qualifying studies did not identify potential overlaps. For example, code-switching between ways of speaking at school and home was described as linguistic capital in two studies but not identified in either study as conformist resistant capital.

Several STEM- and engineering-specific findings emerged from our qualitative analysis of capital. STEM degree attainment was framed in multiple studies as being more challenging than earning a bachelor’s degree in a non-STEM field, due to specific degree requirements and existing stereotypes about who belongs in STEM. Extended family networks were needed to find people with STEM-specific knowledge, even when closer family members with college degrees in other disciplines were available. Differences between engineering and STEM studies were related to the unique nature of engineering as a profession. The aspirational capital of wanting to earn a degree was emphasized more in engineering studies, perhaps because students could more easily picture themselves working as engineers. In familial capital, encouragement to study was emphasized in STEM studies, while engineering studies were the only ones mentioning parents with STEM degrees or who supported tinkering or playing with Legos. Learning of science content was compared to learning a new language due to the number of new terms and definitions involved, mostly in STEM studies. In contrast, professional norms were an aspect of linguistic capital more prominent in engineering studies. Several studies mentioned the economic freedom associated with having earned an engineering degree. Students described their desire to support their family financially, including parents and siblings, as part of their motivation for choosing an engineering major. Engineering students viewed their role as particularly important, desiring to broaden participation in engineering and serve as role models in their communities. They described the personal importance of giving back through volunteering with outreach activities. While engineering students desired to be role models themselves, STEM and engineering students benefitted from having role models. Practicing engineers (but not alumni in other STEM disciplines) were a source of both aspirational and social capital. These connections were especially important for helping engineering students navigate internship and co-op interviews and assignments. Affinity groups such as SHPE and NSBE were important settings that allowed engineering students to combine their social identity with their developing academic and professional interests and for emotional support. In general, it was important for students to find a community or *familia* within STEM, but engineering studies were the only ones that mentioned student organizations as a source of community. Finally, social justice motivations and the few examples of transformative resistant capital were discussed only in engineering studies.

6 | IMPLICATIONS

6.1 | Implications for research

We choose to highlight Yosso’s (2005) CCW framework and its use in STEM education research to understand the current state of how assets-based research is being conducted in the field. While CCW is just one example of several existing assets-based frameworks within education, our systematic review yields important implications in how assets-based frameworks are currently applied by STEM education researchers. The way CCW has been used in prior studies
of STEM education (as reviewed here) has focused on external and extracurricular supports rather than the teaching and curriculum development that many faculty members consider to be among their core job functions. The qualifying studies identified examples of particularly supportive faculty members who mentored students and considered students' professional development and study skills. Few studies considered how STEM curricula, including examples and project settings, might better recognize and build students' capital. Funds of knowledge (Moll et al., 1992) and Third Space (Soja, 1996), as alternative assets-based frameworks, may be more useful in focusing on curriculum and culturally responsive (Ladson-Billings, 2004) or inclusive teaching practices (Tanner, 2013). Funds of knowledge (Moll et al., 1992) studies tend to collect data in and about students' home lives consistent with a K–12 focus, but Smith and Lucena (2016) have shown how experiences such as helping family members and working in agricultural, construction, and manufacturing settings are useful assets in the engineering workforce. Thus, funds of knowledge (Moll et al., 1992) may be an important framework for guiding assets-based curriculum change in higher education.

Using assets-based theoretical frameworks such as these is an important step, but the practice does not guarantee that the research will be truly assets-based. We found several instances in which CCW was used in deficit-based statements. For example, Rubinson (2016) framed a student's decision to matriculate at a 2-year institution (rather than a 4-year institution) as lacking aspirational capital and not having goals for the future. This deficit-based interpretation fails to account for the access that 2-year institutions provide to higher education and the capital students develop attending 2-year colleges, balancing other responsibilities while working toward an associate's or bachelor's degree, and in transferring to 4-year institutions if they so choose. In contrast, an assets-based view of this same student would highlight their navigational capital in choosing a pathway that allows them to avoid accumulating debt while potentially supporting family. As researchers, we must examine how we are adopting frameworks and whether we are adhering to the original intentions of the authors such as Yosso (2005), Moll et al. (1992), and Soja (1996). This critique of prior work aligns with our earlier comments on how authors, particularly in dissertations, emphasized categorization and distinctions between types of CCW capital, rather than discussing the nuances in overlap and how one type of capital reinforces another. Further, it is important to honor these theories by emphasizing student voices without implicitly placing the onus for change on students (Deil-Amen, 2011).

This review also identified gaps in research methods. Interview protocols should be designed to elicit deeper participant responses than, for example, simply asking about immediate family and labeling those responses as familial capital. More work should involve faculty, advisors, or family members as research participants rather than relying solely on students for data. Many of the primary studies we reviewed show that institutional agents such as faculty and staff can have a substantial role in encouraging student success and recognizing student capital. We need a greater understanding how faculty and staff currently value student capital and how they help build and encourage it. Broader research approaches such as ethnography and case study which utilize other data sources in addition to interviews may be even better suited to understanding the context of systems in which various types of CCW are being recognized or ignored. Students should not shoulder the burden of success in a system that does not serve them equitably. It should be up to institutions and their faculty and staff to transform the system to support the success of all students (Bensimon, 2005). Further, it is difficult for college students to critique the systems in which they are currently embroiled, and faculty and staff may provide additional perspectives on resistant capital in particular. Finally, quantitative researchers should carefully consider whether and how CCW can be studied quantitatively. Assets-based instrument development can draw from existing literature on the use of CCW in STEM education, such as the many examples identified in this review.

6.2 Implications for practice

The studies we reviewed identified a number of specific ways in which faculty members and advisors supported students' capital. They connected students to co-op/internship and research opportunities, encouraged them to apply, reminded them of deadlines, wrote recommendation letters, advised students on how to act in various professional situations, and made referrals to other offices and services on campus. For faculty, office hours were an important time to learn about students' goals and advise them on ways to work toward those goals. Explaining the importance of office hours and encouraging students to visit may be important first steps to activating student capital. Many students described developing supportive, family-like relationships with faculty and advisors. HBCU faculty was described in two studies as being particularly skilled at developing these relationships with students. Faculty and staff should be
optimistic and enthusiastic about students’ chances of succeeding through hard work and persistence. They can also be pragmatic in preparing nondominant students for challenges they may face when moving to a new environment such as a job or graduate school.

One of our goals in conducting this review was to raise awareness of assets that nondominant groups bring to engineering education. We view awareness as an initial step to changing institutions to better serve students from nondominant groups. When institutional agents such as faculty, advisors and administrators are more aware of assets, they can help students recognize, develop and celebrate those assets. Students, faculty, advisors and administrators may then work together to convince employers and others of students’ unique assets. Further, greater knowledge of assets-based frameworks and how they apply to engineering students will help these institutional agents understand how various policies and competitive selection procedures marginalize particular groups of students. Awareness is a necessary but insufficient step to transforming our educational institutions to be more equitable and inclusive.

7 | CONCLUSION

This systematic literature review identified 33 qualifying studies which apply Yosso’s (2005) CCW framework in STEM education. This work provides insight into how an assets-based framework is being interpreted and highlights gaps and opportunities for research and practice. It is important to understand how our own interpretations and biases may be influencing our work with students, particularly since deficit-based perspectives are usually the default. Especially in engineering education, we need to understand how we are describing nondominant student populations, such as females, Students of Color, students with disabilities, transfer students, first-generation and low socioeconomic status students, and others. Prior work has framed these student populations as facing particular obstacles including lack of support or preparation for engineering. Particularly as the demographic diversity of society continues to expand, we must be open to supporting the success of all students by expanding our view of the assets students bring to their education. This work synthesizes existing studies and provides a foundation for more assets-based perspectives in future work.

ACKNOWLEDGMENTS

The authors wish to thank librarian Laraine Dallas for assistance with search procedures and JEE editors and reviewers for particularly constructive feedback.

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ENDNOTE

1 We capitalize Communities of Color and Students of Color as an extension of consistently capitalizing racial/ethnic categories including Black and Latinx throughout the article as is done in some of the assets-based literature we cite, including Yosso (2005).

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How to cite this article: Denton M, Borrego M, Boklage A. Community cultural wealth in science, technology, engineering, and mathematics education: A systematic review. J Eng Educ. 2020;109:556–580. https://doi.org/10.1002/jee.20322