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## LITERATURE REVIEW

# Funds of Knowledge in STEM Education: A Scoping Review

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**Background:** Assets-based research is becoming more widespread and may be particularly important as we continue to work towards equity within engineering education. It is important to understand how assets-based theoretical frameworks have been taken up in STEM education research in recent years.

**Purpose:** We examine how funds of knowledge (Moll et al., 1992), an assets-based framework, is applied in STEM education and can be used to advance engineering education research. Funds of knowledge was created to help K–12 teachers adapt their classroom teaching and curriculum to better serve their students.

**Scope/Method:** Scoping review procedures resulted in 42 qualifying studies. We analyzed characteristics of the qualifying studies and qualitatively coded the use of the funds of knowledge framework. Codes included the following categories: identification, curriculum, teaching, and learning.

**Conclusions:** Funds of knowledge is prevalent in the STEM education literature. Studies tended to be qualitative, with observations and interviews as the most common research methods. Research often took place both in the classroom and at after-school programs. Most studies centered on K–12 students and teachers, often focusing on how to improve teaching, curriculum and lesson plans, or the connection between the community and schools. Funds of knowledge may assist curriculum change in K–16 if used more widely in engineering education, which could have important implications for equity in engineering. Gaps and opportunities in the application of funds of knowledge in STEM education include assessing the efficacy of funds of knowledge interventions on students by connecting to student learning outcomes or theories of identity, self-efficacy, and belonging.

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**Keywords:** funds of knowledge; scoping review; equity; critical theory; research to practice

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## Introduction

Despite continued efforts and incremental progress, we have not yet reached equitable levels of representation within STEM fields. This disparity becomes particularly troubling within engineering, which remains largely White and male. Students of Latinx, Black, Native American, and first-generation backgrounds, as well as students with disabilities, continue to be underrepresented in STEM fields (Byars-Winston et al., 2010; National Science Foundation, 2019). Women also lack representation in engineering and computer science. Inequities within STEM additionally persist in less visible ways, such as the continued marginalization of nondominant students, with implicit messages about who belongs and can succeed in STEM. Throughout this paper, we use the term nondominant to refer to marginalized and underrepresented minority (URM) groups to remain inclusive of all groups and place the focus on the students, rather than the systems actively oppressing students. However, it is important to consider how we are designing educational practices and classrooms and serving students within those spaces.

The use of assets-based theoretical frameworks may be one way to address issues of racial and gender equity within STEM (Martin et al., 2019). By design, educational institutions were not created to serve nondominant students (Ladson-Billings, 2004; Liu, 2011) and therefore tend to view their different life experiences as deficits. An assets-based approach would seek to change the curriculum and teaching practices to reflect students' backgrounds and strengths, ultimately resulting in greater motivation, learning, and retention. In contrast, a deficit-based approach would expect students to adapt to educational practices, placing responsibility on the students. Practitioners should consider how their learning environments serve students, particularly those who have been historically marginalized or ignored. In response to deficit-based research, which depicted students as lacking, assets-based frameworks were created to highlight strengths of nondominant individuals and communities and to help structure and design educational practices for such students. As assets-based research is becoming

more widespread, it is important to understand how assets-based theoretical frameworks are taken up in STEM education and how its use in engineering education research can be expanded. This is particularly important from an equity perspective, as we work to improve our practices to serve nondominant students.

There are several assets-based theoretical frameworks, including funds of knowledge (Moll et al., 1992), community cultural wealth (Yosso, 2005), and third space (Moje et al., 2004). In this paper, we focus on the funds of knowledge framework due to its emphasis on integration of student life experiences into educational systems. Funds of knowledge may be more action-oriented than other assets-based frameworks such as community cultural wealth, which highlights nondominant individuals' capital. A core group of researchers have devoted decades to development and application of the funds of knowledge framework, from their original work (Moll et al., 1992) and book (González et al., 2005) to many other papers and extensions. The original article (Moll et al., 1992) and book (González et al., 2005) have been cited over 7,500 and 5,100 times, respectively, emphasizing their prevalence in educational research. We aim to further understand how funds of knowledge works within STEM education, both in terms of types of research conducted and how educational spaces are changed to better serve students. A previous systematic review examined funds of knowledge in STEM education, focusing solely in secondary and post-secondary settings (Verdín et al., 2016).

We conducted a scoping review of funds of knowledge within STEM education. Scoping reviews provide an overview of the state of research in a specific field and help answer broad questions in a subject area (Arksey & O'Malley, 2005), which aligns with our intentions for conducting this review. While definitions of scoping reviews vary, they often involve "a process of summarizing a range of evidence in order to convey the breadth and depth of a field" (Levac et al., 2010, p. 1). We examined studies that used funds of knowledge to guide their work in a significant way, specifically applying funds of knowledge in their findings. We found that the framework has been extensively taken up in a variety of ways, with many different examples, settings, and participant populations.

### Research Questions

1. What are the characteristics of studies that use Moll's (1992) funds of knowledge framework in studies of STEM disciplines?
2. Specifically, what are examples of the types of funds of knowledge identified in STEM educational settings?
3. What are gaps and opportunities in how funds of knowledge is being applied in STEM education research?

### Background Literature

Building on work from Vélez-Ibáñez (1988), anthropology and education researchers began a collaboration to implement the anthropological idea of *funds of knowledge* into education systems (Hogg, 2011). In their original work, Moll et al. (1992) defined funds of knowledge as "these historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual function and well-being" (p. 133). They provided specific examples of funds of knowledge within six categories: agriculture and mining (soil and irrigation systems, timbering), economics (market values, building codes), household management (budgets, cooking), material and scientific knowledge (carpentry, automobile repair), medicine (herbal knowledge, first aid procedures), and religion (moral knowledge and ethics). The concept of funds of knowledge captures the multitude of activities present in daily household functions and the knowledge involved with carrying out those tasks. However, households are not isolated from larger communities, where exchange of knowledge occurs. Individuals may also inhabit different roles in various relationships, highlighting the multi-faceted nature of knowledge held by individuals. Grounded in working-class Mexican households, the goal of Moll et al. (1992) was changing the relationship between home and school, specifically how classrooms were structured. Moll et al. (1992) actively worked to challenge deficit viewpoints by changing teacher-student relationships. Another focus involved minimizing the amount of passive learning activities present in schools, through the recognition of the many opportunities for active learning occurring within the home.

Teacher-researcher partnerships are intrinsic to Moll et al.'s (1992) funds of knowledge educational framework. Anthropologists and education researchers worked with teachers in a workshop format, instructing teachers how to conduct qualitative anthropological research, drawing heavily on ethnography. They taught the teachers observational and interviewing techniques, with additional training in writing field notes, managing collected data, and analyzing data. Following training, teachers conducted several home visits with selected students, supported by the researchers. Teachers employed protocols to interact with students and their families, engaging in conversations about their home life and interests. Following their home visits, teachers created new curriculum and lesson plans based on funds of knowledge they identified. The intention of home visits was for teachers to gain a greater understanding of the many aspects of student life and types of knowledge held by students, which they could integrate into their classrooms. Moll et al. (1992) provides an in-depth example of a home visit and how a teacher designed a curriculum unit around Mexican candy. Lessons included creating definitions of *candy*, categorizing types of candy, surveying student favorite candies, and choosing a student-generated topic to study in depth. Students chose to examine ingredients involved in candy production,

using scientific methods such as hypothesis testing during their investigations. Differences between Mexican and U.S. candy were explored, with students discovering fewer ingredients in Mexican candy due to lack of artificial sweeteners. A parent demonstrated how to make Mexican candy, sharing her knowledge of food consumption and production with students. At the end of the unit, students identified future research topics, demonstrating interest in global patterns of food consumption and production.

Moll et al. (1992) further clarified the relationship between funds of knowledge and culture, stating, "Although the term *funds of knowledge* is not meant to replace the anthropological concept of culture, it is more precise for our purposes because of its emphasis on strategic knowledge and related activities essential in households' functioning, development, and well-being" (p. 139). Funds of knowledge gained popularity after the 1992 publication and has remained a fixture of assets-based research over the past 30 years. Moll and colleagues continued their work with funds of knowledge over several decades, including a book in 2005 (González et al., 2005). Several collaborators have extended funds of knowledge in their own ways, including the funds of identity theory (Esteban-Guitart & Moll, 2014) and development of a discipline-specific research agenda in funds of knowledge, such as mathematics (Civil, 2007). Other prominent assets-based frameworks in education have adapted funds of knowledge in various ways. For example, third space (Moje et al., 2004) refers to the creation of an environment or space designed to help students thrive, where student experiences and school learning coexist. Moje et al. (2004) explains, "the construction of the *third space* that merges the *first spaces* of people's home, community and peer networks with the *second space* of the Discourses they encounter in more formalized institutions, such as work, school, or church" (p. 41), and situates funds of knowledge as an essential part of the first space. Moje et al. (2004) draws upon three different perspectives of third space (Bhabha, 1994; Gutiérrez et al., 1999; Soja, 1996) and situates the theory in STEM education contexts. Other researchers similarly focus on funds of knowledge and discourse present in third space within science (Calabrese Barton & Tan, 2009). Given that in recent decades, the funds of knowledge framework has been extended and conceptualized in many different ways, we are interested in how funds of knowledge has been applied in STEM education research specifically. We focus on theory application in various research contexts as a necessary first step preceding exploration of the different theoretical interpretations and extensions.

## Methods

We conducted a scoping review of the funds of knowledge literature within STEM education. Scoping reviews are appropriate when the number of potential qualifying studies is high and the inclusion criteria evolves during the search process (Arksey & O'Malley, 2005; Levac et al., 2010; Munn et al., 2018). Scoping reviews tend to be completed in an iterative process, involving frequent adjustments during the literature search and selection. Despite the growing popularity of scoping reviews, methodologies used remain largely inconsistent (Tricco et al., 2016). Most scoping reviews are situated within the medical or health fields (74.1%, Pham et al., 2014) and include aspects less common in engineering education work, such as clinical trials and grey literature. We used Arksey & O'Malley's (2005) framework as a guide, following the five stages of conducting a scoping review: (1) identifying the research question, (2) identifying relevant studies, (3) study selection, (4) charting the data, and (5) collating, summarizing, and reporting the results. Our study aligns with their fourth reason to conduct a scoping review, "to identify research gaps in the existing literature" (Arksey & O'Malley, 2005, p. 21). However, because there are no existing guidelines for engineering education scoping reviews, and very few have been conducted at this point, we also followed recommendations for engineering education systematic reviews, as detailed in Borrego et al. (2014). Scoping reviews differ from systematic reviews in that systematic reviews aim to answer more specific questions and complete a quality assessment of the qualifying studies.

## Positionality Statement

We approach assets-based research with an intention to honor communities that are often underserved or ignored within STEM educational settings. Further, we seek to understand how topics of equity are conceptualized and researched within the field, particularly in engineering education. We believe that engineering education can benefit from broader study of STEM education. While efforts in recent decades have focused on equity issues of access, we believe that much work remains to be done to serve students of all backgrounds. Our goal as researchers is to push forward progressive thinking and ideas, working to dismantle policies, culture, and structures that disproportionately have a negative impact on non-dominant students. We do not place blame on individuals, or even institutions, for ongoing equity issues present in STEM fields, as we recognize the complexity of these issues and the historical nature of systemic oppression and injustice. We firmly believe that engineering and other STEM fields should be accessible and inclusive for all youth, as STEM degrees confer personal economic benefits and societal impact. Our experiences as women in engineering in different settings, including industry and graduate school, contribute to our understanding of issues facing nondominant communities within STEM fields. However, we identify as dominant in other ways (i.e., race), which also positions us in a privileged position within STEM.

### **Inclusion Criteria**

We established initial inclusion criteria based on our research questions and adjusted the criteria during the search and selection processes as our understanding of the literature and its scope evolved (Arksey & O'Malley, 2005). The finalized inclusion criteria are as follows:

- IC1: Must be an empirical study and/or contain empirical outcomes within the paper
- IC2: Use funds of knowledge to guide the study in a significant way
- IC3: Focus on one or more STEM disciplines and/or STEM education
- IC4: Cite Moll et al. (1992) and/or González et al. (2005) or subsequent book editions
- IC5: Be published within 2010 to 2019
- IC6: Be published in a peer-reviewed journal or conference paper
- IC7: Contain a unique dataset when compared with other qualifying studies

Scoping reviews often contain many different types of literature, such as theoretical work, review papers, and grey literature (Arksey & O'Malley, 2005). After reviewing literature collected in our initial search, we realized our research questions centered around peer-reviewed, empirical work (consistent with many prior engineering education systematic reviews), resulting in IC1 and IC6. While non-empirical sources are not included as qualifying studies, we used them to supplement our understanding of the ways STEM education has taken up the funds of knowledge framework. We excluded book chapters, dissertations, theses, posters, reports, professional development handouts, and any other non-peer reviewed sources based on IC6. We excluded theoretical articles and review papers based on IC1. We excluded studies that did not focus on science, technology, engineering, mathematics, or STEM as content areas of study based on IC3.

To reflect the current field of research, we considered the past decade of publications (IC5) for two reasons: 1) Engineering education has grown significantly as a field in the past ten years, and 2) there has been a recent push to include more elements of engineering in K–12 subjects (e.g., the Next Generation Science Standards). We excluded studies published prior to 2010 and after 2019. We finalized qualifying studies in early 2020. Based on IC4, we excluded studies if they did not cite foundational work on funds of knowledge within education, Moll et al. (1992) or González et al. (2005). We included studies which cited subsequent book editions of González et al. (2005). Based on IC2, we excluded studies that briefly mention funds of knowledge and do not incorporate it as key part of study framing, research design, or findings. The determination of what counts as to *guide the study in a significant way* evolved during our search and selection process. Based on IC7, we included one study from a unique dataset and excluded the remainder from our qualifying studies (Borrego et al., 2014). We added this inclusion criterion after discovering several authors wrote multiple papers originating from a single dataset, to align with our goal of understanding the funds of knowledge literature in STEM education broadly.

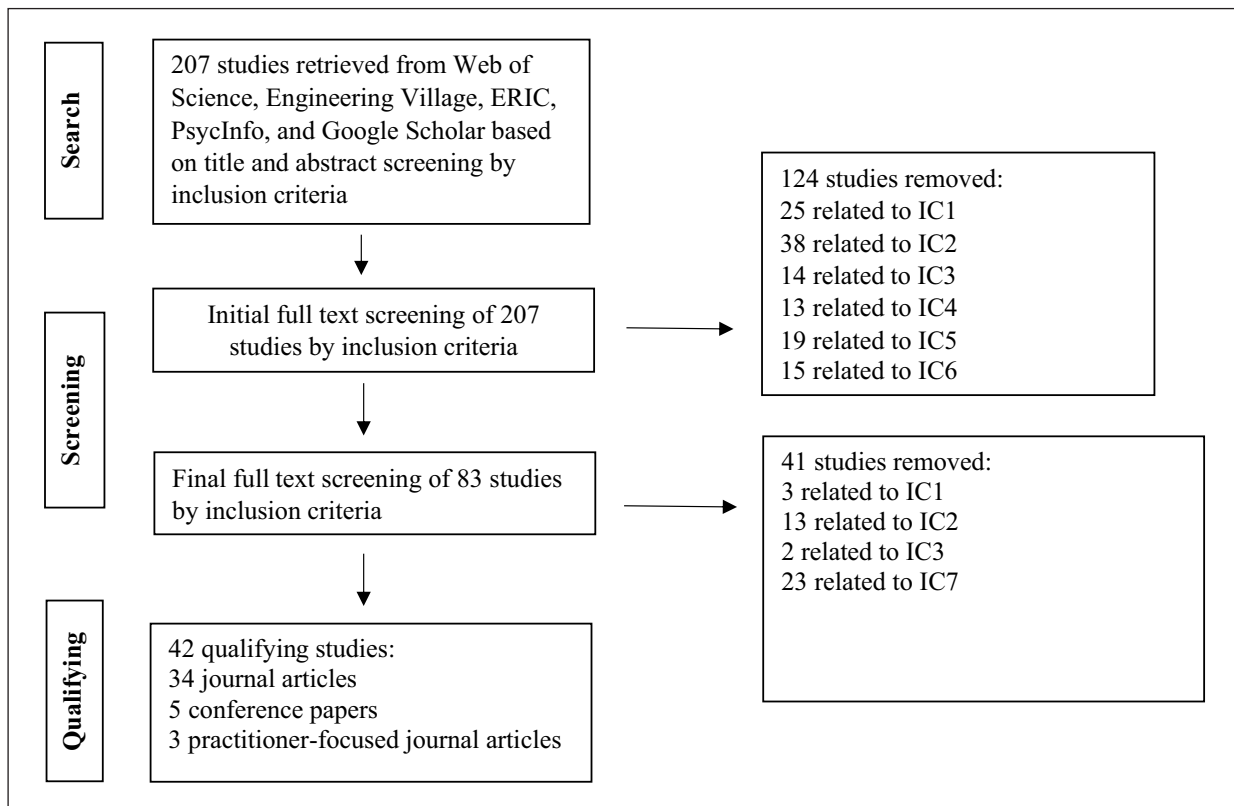
### **Search Strategy**

During our search, we primarily used the following online databases: Web of Science, Engineering Village, Education Resources Information Center (ERIC), and PsycInfo. We chose both content-specific and social science databases to maximize the retrieval of potential qualifying studies. We used Google Scholar to supplement our primary database search. We used the within-text citation function for Moll et al. (1992) and González et al. (2005) in Google Scholar, reviewing the first 100 entries retrieved for each source when using the designated search terms. We reviewed all entries found when searching the four primary databases for inclusion. Within each database, we used the text string, *funds of knowledge* AND [STEM discipline], to search for qualifying studies. [STEM discipline] was replaced with engineering, science, technology, mathematics, and STEM, for a total of five designated search text strings per database.

### **Selection Process**

Due to the iterative nature of scoping reviews and evolving inclusion criteria, it is difficult to create a graphic that accurately displays the nature of the search and selection process. **Figure 1** contains a condensed and greatly simplified display of our search and selection process to determine qualifying studies. We provide additional details of the evolving inclusion criteria and simplifications displayed in **Figure 1** in the paragraphs below.

During our database search, we collected 207 articles for consideration in our scoping review. Several preliminary searches informed the final methodical search through the four primary databases and supplemental database to ensure saturated collection of relevant studies. Within the databases, we screened article titles and abstracts based on relation to funds of knowledge (IC2) and focus on STEM (IC3). We downloaded all studies potentially relevant to STEM or funds of knowledge. For example, the searches for technology often resulted in digital technology studies situated around student language and literacy. We only downloaded studies related to technology education, rather than the use of educational technology. After gaining an understanding of literature scope, we established IC6 and subsequently only downloaded relevant journal articles and conference papers. During the search iterations, we realized our overarching focus on application of funds of knowledge in empirical work and established IC1.



**Figure 1:** Simplified search and selection process for qualifying studies.

As with our search process, we completed several rounds of full-text screening with the downloaded studies. **Figure 1** displays this process as occurring in two steps, labeled initial and final full-text screening. In actuality, multiple rounds of full-text screening occurred, in an iterative and non-linear process. In **Figure 1**, earlier iterations of screening are included in the *initial text screening*, while later iterations are included in *final text screening*. During earlier iterations of full-text screening, we removed 38 studies that did not significantly focus on funds of knowledge (IC2) and 14 studies that were not related to STEM (IC3). Studies removed due to IC2 typically mentioned funds of knowledge briefly once or twice in the paper, lacking deep connection to overall study purpose. We removed 25 non-empirical studies (IC1) after the establishment of IC1 during our search iterations. Similarly, 15 studies were not categorized as peer-reviewed journal articles or conference papers (IC6) and were therefore excluded. We established IC5 and removed 19 studies. We confirmed citation of the major works of funds of knowledge in education contexts, Moll et al. (1992) and González et al. (2005), removing 13 studies (IC4).

During later iterations of full-text screening, we focused on strengthening definitions of what counts as empirical (IC1) and significant (IC2) and added IC7 to address overlap between studies. We required studies to have a methods section to be considered empirical, excluding studies consisting of vignettes or an essay-like narrative. We removed three studies due to IC1. We refined the idea of funds of knowledge guiding the study in a significant way, excluding studies that briefly mentioned funds of knowledge in their results or included funds of knowledge as a very limited part of a larger framework. We removed thirteen studies due to IC2. In case of overlapping papers, we chose one representative paper to include as a qualifying study. If funds of knowledge was clearly more central to one study in a set of papers, we included that study in our scoping review and excluded the others. However, when it was not obvious which study had a greater focus on funds of knowledge, we followed a procedure to determine study inclusion. First, we selected journal articles over conference papers. Additionally, we selected the more research-focused of the papers in situations where authors published research-focused and practitioner-focused versions of their work, and we selected the most recent paper when multiple, research-focused journals were published by the same authors from the same dataset. We removed 23 studies due to IC7. Overall, the screening process yielded a collection of 42 studies for our scoping review.

### Analysis

We completed quantitative and qualitative analysis to synthesize all qualifying studies, described in the following sections. Quantitative analysis centered on study characteristics, such as research methods and educational setting. Qualitative analysis involved the coding and analysis of study usage of funds of knowledge, such identification or curriculum.

### Quantitative Synthesis

We completed quantitative synthesis of qualifying studies to further understand characteristics of research studies using funds of knowledge in STEM education contexts. Study characteristics of interest included general study details and varying aspects of research methods. Using Microsoft Excel, the first author coded each qualifying study according to the following categories: publication type, year of publication, general methods, types of data collection, STEM discipline, research setting, and participant population. In cases where terms differed between studies, we chose one representative term to encompass all similar descriptions. For example, we use the term *Latinx* to refer to all individuals of Latin American descent in our coding, rather than the term *Hispanic* as used in some studies. As another example, different types of observations occurred in our qualifying studies and we used the overarching term *observations* within methods, rather than detailed descriptions of each observation type. Table A1 (Appendix) contains coded results for each qualifying study in this review, and in the findings section, we report descriptive quantitative measures for each of these coded results.

### Qualitative Synthesis

The two authors iterated through several rounds of coding during qualitative synthesis. The first author conducted the full coding process, periodically checking and finalizing codes with the second author. Following an initial full-text reading of the qualifying studies, we refined our focus on applications of funds of knowledge within STEM education. Codes were determined by considering how studies used funds of knowledge in their results section. After finalizing codes, each qualifying study fell into one or more of the following coded categories: *identification*, *curriculum*, *teaching*, and *learning*. Code definitions are included in **Table 1**. To simplify presentation of results, we assigned most studies to one category. If there was an equal focus on two different aspects, we assigned studies to two categories.

### Limitations

While Arksey and O'Malley (2005) recommend searching through reference lists, key journals, and existing networks in addition to databases, we used only databases for our literature search. Additionally, scoping reviews frequently include grey literature, theoretical work, and review papers, which we excluded from our study (as do other engineering education researchers (Borrego et al., 2015)). Both decisions have likely limited the studies in our review and influenced our interpretations of the funds of knowledge landscape in STEM education. Our decision not to search more specific terms for various STEM disciplines (i.e., biology) may have resulted in not identifying more funds of knowledge studies at the high school or undergraduate level. Our decision to exclude studies that connected to funds of knowledge in less significant ways may have limited our ability to discuss how funds of knowledge is related to other theories. Similarly, the exclusion of studies that did not cite Moll et al. (1992) or González et al. (2005) potentially limited our understanding of how other authors have expanded the idea of funds of knowledge since the original publications. To avoid over-representing authors, we removed papers that originated from the same dataset, which potentially biased the distribution of themes presented below, as well as limited any conclusions in how funds of knowledge can be applied differently to the same dataset. Twenty-three studies were excluded for drawing from non-unique data sources, which suggests that the qualitative, ethnographic, and design-based research characteristics of funds of knowledge studies may be incompatible with systematic review recommendations from engineering education to include only one study per dataset. Despite these limitations, however, the findings from the scoping review presented here still yield important insights regarding how funds of knowledge has been used in STEM education research and what particular advantages it can offer to ongoing engineering education research.

## Findings

### *General characteristics of the qualifying studies*

Forty-two studies qualified for inclusion in our scoping review. Table A1 (Appendix) displays additional information regarding characteristics of each qualifying study, such as author and year, study type, participant population, research setting,

**Table 1:** Definitions of qualitative codes.

Code	Definition
Identification	Focus on determining participants' funds of knowledge for individuals, a particular group, or in a specific setting or activity
Curriculum	Focus on design and/or implementation of longer curricular units (i.e., multiple connected lessons) that attend to students' funds of knowledge
Teaching	Focus on how teachers attend to students' funds of knowledge during instruction and lesson planning or understand the concept of funds of knowledge
Learning	Focus on student cognitive processes in relation to funds of knowledge

methods, types of data collection, and STEM discipline. Almost all qualifying studies were categorized as journal articles (37 studies), with three of those published in journals geared towards practitioners. The remaining five studies were published as conference papers or proceedings. Notably, there was a large variety in publication venues, with the 42 qualifying studies published in 38 different journals or conferences. All studies were published in either STEM-specific education (25 studies) or general education venues (17 studies). Examples of STEM-specific publications included *Cultural Studies of Science Education*, *Journal of Engineering Education*, and *Mathematics Teacher Educator*. The general education publications tended to have a specific focus external to STEM, such as *Journal of Research in Early Childhood Education*, *Journal of Teacher Education*, and *Equity & Excellence in Education*.

Almost all qualifying studies used qualitative methods (40 studies), with the exception of one quantitative study and one mixed methods study. Most studies drew upon multiple types of data collection during their analysis, including interviews (30 studies), observations (30 studies), artifacts (23 studies), and focus groups (8 studies). Data triangulation often resulted in the use of two (14 studies), three (13 studies), or four or more (5 studies) types of data collection in the studies. Ten studies applied only one type of data collection, distributed almost equally between the use of observations, interviews, and artifacts. Surveys, both Likert-scale and open-ended reflections, were used in four studies. Types of artifacts analyzed varied between studies, with examples including student work, written reflections, drawings, and photographs. Studies focused on the disciplines of science (16 studies) and mathematics (11 studies) most frequently. Additional studies were conducted in engineering (5 studies), technology (2 studies), and multidisciplinary contexts (STEAM, STEM, or science and math; 8 studies).

Qualifying studies took place in a variety of research settings, predominately after-school programs (10 studies) and four-year institutions (8 studies). Several studies were situated at pre-K–12 education institutions, such as nursery school (1 study), elementary school (4 studies), middle school (6 studies), and high school (2 studies). Studies also often occurred within other out-of-school contexts, such as local communities or participant homes (5 studies), professional development programs (4 studies), summer programs (2 studies), science museums (1 study), and field trips (1 study). Overall, almost half of the qualifying studies took place in out-of-school settings. While the majority of studies (33 studies) occurred within the United States (U.S.), we noted exceptions in the Research Setting column in Table A1. Locations of international research settings included Australia, New Zealand (2 studies each), England, Sweden, Finland, the Philippines, and India (1 study each).

Study participants often consisted of pre-service (9 studies) or in-service teachers (12 studies). In-service teacher participants were situated as teaching in the classroom or as part of a cohort in professional development programs. Eight studies included families as their study participants, often including both parents and children. Students of all levels and ages were included as participants, such as early childhood (1 study), elementary school (10 studies), middle school (6 studies), high school (5 studies), undergraduate (2 studies), and graduate students (1 study). Six studies included both teachers and students as their participants, while other studies focused solely on either teachers or students. Several qualifying studies focused on nondominant participant backgrounds (e.g., race, ethnicity), such as Latinx (9 studies), Black (4 studies), and Indigenous (including Ojibwe and Dakota; 3 studies) students, teachers, and families. Three studies focused on refugees from Somalia and Burma, and there was one ethnographic study of a Vietnamese immigrant teacher. Additional ethnic communities represented in the studies include Torres Strait Islanders (1 study), the Hmong (1 study), and participants from Trinidad & Tobago (1 study).

### ***Application of funds of knowledge***

We categorized qualifying studies according to how they applied funds of knowledge in their results section, either as identification, curriculum, teaching, or learning (**Table 2**). We tried to assign studies to just one category, although there are overlaps between the four categories. One study was assigned to two categories, since their results evenly focused on two different aspects (Borgerding, 2017).

#### **Identification**

Eleven studies centered on identification of participant funds of knowledge in relation to STEM. Identification was often focused within specific groups, such as communities with a common cultural identity or family units. Studies also identified students' funds of knowledge present during specific activities, such as after-school programming and free play. While most studies identified funds of knowledge inductively, a few studies identified funds using pre-existing categorizations. The main themes were communities, categorization, and engagement.

Six studies identified funds of knowledge of local communities, focusing on STEM ideas and practices related to their cultural practices (Albrecht & Upadhyay, 2018; Alvaré, 2017; Ewing, 2014; Handa & Tippins, 2013; Harper, 2016; Svarovsky et al., 2017). Studies often involved researchers physically entering community spaces, which is crucial to the ethnographic methods used in Moll et al. (1992). Emphasis was on the community as a whole and family practices, rather than a specific lens on students. One study identified Karen refugee families' funds of knowledge, such as gardening and its relation to sustainability science (Harper, 2016). Culturally, their community garden connected the refugee families, who used gardening practices from their homeland in Burma, and involved the scientific practices of horticulture and land cultivation. Similarly, another study examined the scientific ideas and practices connected to Somali refugee mothers' home practices, such as

**Table 2:** Funds of knowledge applications of qualifying studies.

Authors (Year)	STEM discipline	Identification (n = 11)	Curriculum (n = 9)	Teaching (n = 15)	Learning (n = 8)
Aguirre et al. (2012)	Mathematics			X	
Albrecht and Upadhyay (2018)	Science	X			
Alvaré (2017)	Science (env science)	X			
Andréé and Lager-Nyqvist (2012)	Science		X		
Borgerding (2017)	Science (evolution)			X	X
Borgerding et al. (2017)	Science (physics)				X
Bose (2017)	Mathematics				X
Brown et al. (2018)	Science		X		
Ciechanowski et al. (2015)	STEM			X	
Cribbs and Linder (2013)	Mathematics			X	
Diaz and Bussert-Webb (2017)	Science and math			X	
Durá et al. (2015)	Science (food)		X		
Edwards et al. (2015)	Science (env science)		X		
Ewing (2014)	Mathematics (sorting and partitioning)	X			
Fox-Turnbull (2015)	Technology				X
Gallivan (2017)	Mathematics			X	
Gonsalves (2014)	Science		X		
Graue et al. (2015)	Mathematics			X	
Handa and Tippins (2013)	Science	X			
Harper (2016)	Science	X			
Irish and Kang (2018)	Science			X	
Kafai et al. (2014)	Computing & engineering		X		
Kajamaa et al. (2018)	STEAM				X
Kern et al. (2012)	Science (physical science)			X	
Kier and Khalil (2018)	Engineering			X	
McLaughlin and Calabrese Barton (2013)	Science			X	
Mejia et al. (2019)	STEM			X	
Miller and Roehrig (2016)	STEM		X		
Mills et al. (2019)	Science		X		
Milne and Edwards (2013)	Technology				X
Razfar (2012)	Mathematics				X
Ryu et al. (2018)	STEM			X	
Ryu et al. (2019)	STEM	X			
Smith and Lucena (2016)	Engineering	X			
Stoehr and Civil (2019)	Mathematics			X	
Svarovsky et al. (2017)	Engineering	X			
Tan and Calabrese Barton (2010)	Science			X	
Tan et al. (2018)	STEM (making)		X		
Walkington (2017)	Mathematics				X
Williams et al. (2016)	Mathematics	X			
Wilson-Lopez et al. (2016)	Engineering	X			
Worthington and van Oers (2016)	Mathematics	X			



home remedies (e.g., anise seed drinks), using honey as a natural preservative, and home ailment treatments, such as tea (Albrecht & Upadhyay, 2018). Somali mothers who participated in the study viewed science as more useful when it connected to their home practices.

Two studies identified community funds of knowledge related to village fishing practices (Ewing, 2014; Handa & Tippins, 2013). In Ewing (2014), Torres Strait Islanders shared community practices of dividing fish among family members, which involved the mathematical practices of sorting and partitioning. Handa and Tippins (2013) explored the practices of a Filipino agriculture and fishing village, specifically rice cultivation using methods of *sab-og* (modern) or *dapog* (traditional), and *palupad*, a structure used to catch local shrimp and fish. Tensions existed between the new and old ways of rice cultivation, such as the continued use of fertilizers and pesticides despite the harmful effects on local fish populations.

Two studies applied previously identified community funds of knowledge to different settings, with mixed results (Alvaré, 2017; Svarovsky et al., 2017). Svarovsky et al. (2017) co-created science museum activities based on funds of knowledge present in making practices of local families from racialized nondominant groups. Their categories of making included arts/crafts, cooking/food production, repairs/renovations, activities/toys, and clothing/accessories. Alvaré (2017) reported on program directors' attempts to incorporate misidentified funds of knowledge in a professional development program with science teachers from the U.S. and Trinidad and Tobago. Assumptions about perceived Trinidadian culture caused discomfort and some offense to participants, including lengthy explanations of computer basics, direct personal questions during work, and inaccurately identifying certain foods as Trini.

Three additional studies focused on identification of funds of knowledge of their participants, with less emphasis on cultural and community funds than previously discussed studies (Smith & Lucena, 2016; Williams et al., 2016; Wilson-Lopez et al., 2016). Two of these studies categorized student and family funds of knowledge based on existing frameworks (Williams et al., 2016; Wilson-Lopez et al., 2016). Wilson-Lopez et al. (2016) examined the funds of knowledge present when Latinx high school students worked on an engineering design project during an after-school program. The categorizations used were as follows: workplace, health of self and family, transnationalism, and household management (*family*); volunteerism and community organizations (*community*); and sports and popular culture and digital technologies (*recreational*). Williams et al. (2016) identified the mathematical funds of knowledge possessed by parents of Latinx K–12 students. The categories used were family history, labor history, family networks, resources in the home, knowledge transmission, and values and goals. For example, knowledge transmission involved parents talking about mathematics with their children during daily household activities, such as cooking or shopping. Smith and Lucena (2016) identified funds of knowledge of low-income, first-generation engineering undergraduate students, often highlighting prior jobs, hobbies, and family background. For example, one participant's experience gardening led to an interest in environmental systems, such as irrigation, and for another, cooking and sharing food from her home country established a trusting relationship with operators during an engineering internship.

Two studies identified funds of knowledge present while students engaged in classroom activities (Ryu et al., 2019) and during free play (Worthington & van Oers, 2016). In an after-school science program focused on topics of weather and climate change, Burmese refugee youth shared practices from their home country, such as the use of *thanakha*, a paste made from ground bark, for sun protection (Ryu et al., 2019). Mathematical practices involving three- and four-year-olds' knowledge from their home lives and interests were evident during their play interactions, often counting or referencing units of time or money (Worthington & van Oers, 2016). For example, one child, who often shopped with her mother, created an imaginary ice cream stand, where she charged her friends money for ice cream orders and provided time estimates for order preparation. Wilson-Lopez et al. (2016) additionally connected identified funds of knowledge to how students engaged with the engineering design process when working on their projects. For example, one group had students who played soccer recreationally on different surfaces (i.e., grass, turf, and parking lots) and noticed that different surfaces called for different cleat designs, connecting their ideas to physics and traction during the problem identification stage of the design process.

While not coded as identification studies, additional studies in the subsequent sections contain examples of funds of knowledge. Several studies coded as teaching provide examples of how teachers identified and incorporated student funds of knowledge into classroom teaching.

### Curriculum

Nine studies examined funds of knowledge within the context of curriculum, which was frequently designed for students based on their interests and home life. One study described curriculum that introduced the concept of funds of knowledge to in-service teachers. Most funds of knowledge-based curricula were implemented, while one study focused on a curriculum ideation session. The main themes were curriculum topics, format, development, and student engagement with the curriculum.

Five studies described curriculum topics related to students' funds of knowledge (Brown et al., 2018; Durá et al., 2015; Edwards et al., 2015; Kafai et al., 2014; Miller & Roehrig, 2016). In three studies, curriculum topics were designed around the local culture and communities to which the students belonged (Durá et al., 2015; Kafai et al., 2014; Miller & Roehrig, 2016). For example, Durá et al. (2015) used a curriculum based in food pedagogy to connect cooking practices Latinx students see

in their home life to scientific processes and artifacts. Students learned about the role of corn in battery function, tools commonly used to process corn in the home, such as *metate* and *comal*, and shared homemade corn-based recipes from their families. Kafai et al. (2014) designed an e-textile curriculum where Indigenous students built and programmed an e-textile quilt square which incorporated sensors, lights, and Arduino controllers. Each quilt square represented local plants important to tribal communities and comprised a community quilt. Similarly, an additional study implemented a STEM design challenge curriculum, which involved prototyping, constructing, and racing snow snakes (a curved piece of wood) (Miller & Roehrig, 2016). Snow snakes were rooted in cultural practices of the local Ojibwe tribes, and a tribal elder was involved throughout the curriculum implementation.

Aside from connections to students' cultures, one study identified potential curriculum topics in environmental education related to popular culture interests of students, mainly fast food and associated kids' meals toys (Edwards et al., 2015). Early childhood educators brainstormed educational topics related to food products, such as decomposition and composting, living things, packaging, and growing food. Brown et al. (2018) described curriculum that introduced the concept of funds of knowledge to in-service teachers and illustrated how they could adapt it to their science teaching. The curriculum focused on funds of knowledge as related to student cultural practices, rather than student interests.

Three studies discussed curriculum formats designed to elicit student funds of knowledge (Gonsalves, 2014; Mills et al., 2019; Tan et al., 2018), which provided students greater agency in defining their own projects and sharing from their personal lives. For example, Gonsalves (2014) involved girls in an after-school program filming a mini-documentary to explore the meaning of science, particularly everyday science. The idea of cell phones as science was recurring in their documentary. Mills et al. (2019) used a social-media platform called Science Everywhere in their after-school program curriculum, which allowed students to post about activities in their daily lives connected to science. Examples of student posts included making pizza, the construction of housing, and attendance at a professional soccer match. The curriculum in Tan et al. (2018) taught students how to use ethnographic methods related to funds of knowledge (e.g., interviews, entering the community) to understand what problems were impacting their communities. Students completed engineering design projects around community problems, such as creating a light-up football and umbrella.

While almost all studies mentioned curriculum development at some level, two studies shared significant details of the iterative nature involved with design-based research and curriculum design (Durá et al., 2015; Mills et al., 2019). Durá et al. (2015) detailed two years of their food pedagogy curriculum, describing how the curriculum changed between and during the years based on their learnings. Key adjustments included having a recurring topic for Year 2 (i.e., corn) and involving families before the unit began, as opposed to mid-way through. Mills et al. (2019) found it was sometimes difficult for teachers to recognize the connections between science and funds of knowledge in students' postings on the Science Everywhere platform without additional context. The authors provide suggestions to improve platform use, such as the addition of features to automate scientific questions related to student posts with the goal of helping teachers connect student posts more readily to topics of science learning and inquiry.

Several studies investigated various ways that students engaged with curriculum designed to attend to their funds of knowledge. Andréé and Lager-Nyqvist (2012) examined how students drew on their funds of knowledge when engaging in an inquiry-based science curriculum about fat in foods. Upon receiving a negative test result for fat in 1.5% milk, students negotiated the meaning and validity of the test result based on their knowledge that milk contains fat, leading to a class discussion on measurement detection limits. Similarly, Miller and Roehrig (2016) reported unusually high student engagement in their snow snake curriculum, reflected by students' interest in prototyping activities and the participation of families. While students may be engaged in funds of knowledge activities, they may not necessarily view them as counting as science, particularly in out-of-school settings (Gonsalves, 2014). Students reported this viewpoint due to the lack of "wire and connections" or "chemicals" (p. 201). In one study, students were more interested in drawing on their funds of knowledge from personal interests, rather than the culture of their community (Kafai et al., 2014). When given the choice, students created e-textiles based on television shows instead of their Indigenous culture.

While not coded as curriculum, several qualifying studies provide additional context in their methods sections related to curriculum designed around funds of knowledge. Examples of curriculum include community immersion experiences (Handa & Tippins, 2013) and in-service/pre-service teacher curriculum introducing funds of knowledge (Gallivan, 2017; Graue et al., 2015).

### Teaching

Fifteen studies examined funds of knowledge within the context of teaching, often with a focus on teachers. Studies examined how teachers incorporated funds of knowledge practices within their classrooms, how they understood the concept funds of knowledge, or how they drew from their own funds during teaching. Studies took place within the classroom, in after-school settings, or during teacher training sessions. Both in-service and pre-service teachers served as

study participants. The main themes were instruction, lesson planning, teacher perceptions of funds of knowledge, and teacher funds of knowledge.

Four studies reviewed how teacher classroom instruction attended to student funds of knowledge in the classroom (Borgerding, 2017; Cribbs & Linder, 2013; Irish & Kang, 2018; Tan & Calabrese Barton, 2010). Teachers constructed opportunities for students to discuss topics related to their interests, creating spaces for students to share their funds of knowledge in the moment. In Cribbs and Linder (2013), an elementary math teacher asked students directly about their experiences and knowledge during instruction, such as during a lesson which used household items to illustrate capacity. Similarly, a middle school science teacher gave students space to talk about their lives and interests, respecting their viewpoints and thoughts and further probing when they drew upon their funds of knowledge (Tan & Calabrese Barton, 2010). During a potentially controversial unit on evolution, a high school biology teacher modified his instruction based on the funds of knowledge of rural, religious students (Borgerding, 2017). The class discussed both creationism and evolution, engaging in conversations about how the two topics can coexist. However, instruction efforts related to funds of knowledge were not always successful. In Irish and Kang (2018), middle school science teachers attempted to support student funds of knowledge and life experiences in their instruction by using examples, analogies, and questions. While several students acknowledged their teachers' efforts, they ultimately expressed being unable to relate to the content or activities designed.

Five studies focused on how teachers designed and adjusted lesson plans based on previously identified student funds of knowledge (Aguirre et al., 2012; Ciechanowski et al., 2015; Diaz & Bussert-Webb, 2017; Gallivan, 2017; Kier & Khalil, 2018). Teachers identified student funds of knowledge by using observations, interacting and talking with students, or visiting student communities. For example, teachers at an after-school program designed a science lesson based on the Mexican wrestler Rey Mysterio after they observed two students practicing their wrestling moves (Ciechanowski et al., 2015). During the lesson, students investigated differences between sports drinks and water, relating ingredients to the chemistry involved with energy processes in the body. In Kier and Khalil (2018), a middle school teacher designed a lesson about clean water around students' interest in Jay-Z, showing a video clip of the artist interviewing residents of Rwanda about lack of clean water before connecting clean water issues to the Flint water crisis. In Diaz and Bussert-Webb (2017), pre-service teachers helping at an after-school tutoring program designed math and science lessons around gardening. Students calculated mathematical values needed for garden planning, such as the distance between plants, daily volume of water needed for the plants, and perimeter of the walking path for their hands-on gardening project.

In two studies, pre-service teachers were evaluated on how well they connected their lesson plans to student funds of knowledge (Aguirre et al., 2012; Gallivan, 2017). In Gallivan (2017), pre-service middle school teachers revised a mathematics problem based on funds of knowledge they identified for an assigned student. For example, a unit price and budgeting problem about patio blocks was revised to focus on choosing grocery store ingredients of different pricing and sizes to minimize cost of following an Indian recipe, after learning from their assigned student of the cultural importance placed on cooking. Similarly, in Aguirre et al. (2012), mathematics lesson plans created by pre-service teachers were evaluated based on their connections to student funds of knowledge, categorized as emergent, transitional, or meaningful. Many lessons were categorized as emergent, indicating that topics were integrated at very surface-level connections to student interests or communities. In an example of an emergent lesson, students were asked to determine different ways \$12 could be spent on a list of toys from Family Dollar, without pre-service teachers previously engaging with students about their experiences shopping at the store.

Four studies examined teacher perceptions of the concept of funds of knowledge, including their understandings and opinions of its utility (Graue et al., 2015; McLaughlin & Calabrese Barton, 2013; Mejia et al., 2019; Stoehr & Civil, 2019). All four studies were situated in contexts where in-service or pre-service teachers were learning about funds of knowledge and how to incorporate it into their teaching practices. For example, Mejia et al. (2019) focused on how STEM summer camp facilitators made sense of funds of knowledge, finding that facilitators frequently confused it with prior knowledge but nonetheless valued the concept. Facilitators expressed difficulties finding opportunities to identify and connect student funds of knowledge during pre-set activities and a fixed curriculum. Similarly, in Stoehr and Civil (2019), pre-service teachers valued conversations with Latina mothers during their mathematics methods course, where they learned about the home lives of students. The teachers reflected on the importance of avoiding assumptions about students and recognized that specific details of their interests matter. Contrasting with the previous two studies, early childhood educators initially struggled with the idea of funds of knowledge upon its introduction into their PD curriculum, particularly those who were developmentalists (Graue et al., 2015). They viewed conducting home visits with select students as an inequitable practice and disliked interfering with children's free play to emphasize the mathematics concepts present. Pre-service teachers in a science methods course also held mixed opinions on the utility of funds of knowledge in science teaching, with some recognizing it as an opportunity for meaning making and positioning students as experts (McLaughlin & Calabrese Barton, 2013). However, almost half of the pre-service teachers viewed funds of knowledge as an instructional hook, while others perceived it as unsupportive of science learning due to lacking or conflicting knowledge held by students.

Two studies positioned funds of knowledge as possessed by teachers, rather than students (Kern et al., 2012; Ryu et al., 2018). These studies explored how teachers drew upon their own funds of knowledge during teaching activities, such as instruction and lesson planning. Ryu et al. (2018) looked at how pre-service teachers in an integrated STEM course used their funds of knowledge to design lessons based on their own interests and experiences, such as a rollercoaster lesson they remembered from high school, positioning their discipline (e.g., science or engineering) as central in their lesson plans. Another study examined how the background and experiences of a Vietnamese immigrant science teacher impacted his instruction and teaching practices (Kern et al., 2012). His beliefs in the value of hard work and education, along with his past exposure to teacher-centered classrooms, resulted in the design of passive learning activities and disappointment with his perceived level of student effort.

### Learning

Eight studies discussed funds of knowledge in relation to student learning processes. Students and their actions were central to these studies, rather than teachers or curricular design. Most studies focused on student funds of knowledge present during active learning or student sense making, while two studies formally assessed student learning after instruction was altered to attend to student funds of knowledge (Borgerding, 2017; Walkington, 2017). The main themes were learning in action, making connections to STEM concepts, and assessment of learning.

Four studies examined how students used their funds of knowledge when actively participating in learning activities, such as projects, games, or assigned problems (Bose, 2017; Fox-Turnbull, 2015; Kajamaa et al., 2018; Razfar, 2012). In Kajamaa et al. (2018), Finnish students extended makerspace project tasks based on their funds of knowledge, such as creation of a felt shirt for a cat during an LED circuits activity. Students also collaborated and debated with each other during projects, using their collective knowledge to design faucets and create a working definition of what counts as a *big house*. In Razfar (2012), Latinx students drew upon math-based games played at home and informal conversations in Spanish with peers and parents to learn probability strategies during a game in after-school math club. For example, the lower probability of rolling 10 with a pair of dice was described using the phrase *casi no sale el diaz*, or “10 rarely leaves.” Similarly, elementary school students in New Zealand used their funds of knowledge during an Olympic prop-creation technology project (Fox-Turnbull, 2015). Students recognized that props may be designed for multiple uses based on past attendance at theater performances and understood different material properties based on parental employment in construction. When solving fractional currency problems, middle school students in India often drew from practices seen in local shops, such as the use of a base-16 unit systems and the lack of change returned from shopkeepers (Bose, 2017). While students could mathematically solve the problems, many students lacked knowledge regarding visual representation of fractions.

Two studies reviewed how students drew upon their funds of knowledge during sense making activities, or more specifically, when questioned about different STEM concepts (Borgerding et al., 2017; Milne & Edwards, 2013). In both studies, researchers asked students to explain how certain processes or objects functioned. For example, Milne and Edwards (2013) questioned kindergarteners on how chocolate products were made, both before and after a field trip to a chocolate factory. Before the visit, students often mentioned familiar materials, such as glue, cotton, and string, and single process steps, such as the drawing and cutting of shapes involved in making gingerbread cookies, during their explanations. After the visit, students detailed multiple process steps more frequently, often including types of machinery, appropriate vocabulary (i.e., molds), and the step of packaging, while continuing to rely on home experiences during their sense making. Similarly, Borgerding et al. (2017) asked pre-service teachers to explain physical science concepts involved with playing football. Many pre-service teachers without a scientific background referenced scientific concepts, such as momentum, force, and thermal expansion, and drew from personal experiences, such as deflated footballs or knowledge of college and pro football players, during their explanations. However, students also struggled with misconceptions related to scientific concepts, such as incorrectly thinking football deflation would result in a change of weight, rather than a change of mass.

Two studies assessed student learning following various instructional adaptations involving student funds of knowledge (Borgerding, 2017; Walkington, 2017). Borgerding (2017) was previously included in the teaching category, where a high school biology teacher modified instruction for rural high school students during an evolution unit. While students reacted positively to the modified instruction, learning assessments (i.e., essay, multiple-choice tests) showed that their understanding of evolution was impacted by previously held religious beliefs. Students with strong religious beliefs tended to reject the idea of evolution and performed poorly on the end-of-unit assessments. In Walkington (2017), teachers personalized math problems for eighth-grade students in algebra and pre-algebra courses based on previously identified student funds of knowledge. Using experimental and control groups, students in the personalized problems condition showed statistically significantly higher content learning post-test scores, with greater benefit for pre-algebra students.

## Discussion

Forty-two STEM education studies were included in our funds of knowledge scoping review, which met our inclusion criteria of empirical, peer-reviewed work in STEM published from 2010 to 2019, citing Moll et al. (1992) or González et al. (2005). All qualifying studies explored funds of knowledge in a significant way and drew from unique data sources. We analyzed the characteristics of each qualifying study, such as methods, research setting, and participant populations. Additionally, we examined how studies applied the funds of knowledge framework in their research, in the aspects of identification (9 studies), curriculum (11 studies), teaching (15 studies), and learning (8 studies). Overall, the qualifying studies applied funds of knowledge in a variety of ways, which we illustrate by providing specific examples from each study. The differences between qualifying studies further emphasize the extent to which funds of knowledge has been taken up in STEM education, highlighting the many unique and innovative applications of the framework.

### *Trends of qualifying study characteristics (RQ #1)*

Three key trends emerged as we looked across studies. First, while we did not conduct any formal quality assessment, aspects of the study characteristics suggest an overall high quality of papers and breadth of funds of knowledge within STEM education. The prevalence of data triangulation in many qualifying studies emphasizes the quality of research and development of robust methods. Thirty-two studies (75%) collected at least two types of data, most often through observations and interviews. This triangulation indicates that experienced researchers are confirming their interpretation of the data in multiple ways, which opposes critiques of equity research as lacking rigor. For breadth, the publication venues differed greatly, with the 42 qualifying studies published in 38 different journals and conferences. The range of publications emphasizes how widespread the funds of knowledge framework is used within STEM education, including a balance between STEM-specific and non-STEM-specific venues. Additionally, funds of knowledge has been applied internationally in STEM, beyond the United States where it originated. Nine studies took place in non-U.S. settings, including Europe, Asia, and Australasia.

Second, in general, qualifying studies strongly adhered to the original intentions behind Moll et al. (1992). Specifically, studies used ethnographic methods to identify (*identification*) and incorporate student funds of knowledge into educational settings, through *teaching* (i.e., instruction and lesson plans) and *curriculum*. Teachers were central in many studies in our dataset, with several focused on training teachers on the concept of funds of knowledge. Very few studies concentrated on post-secondary STEM students, echoing the K–12 teaching intention of the original work. Almost all qualifying studies used qualitative research methods, aligning with the idea of funds of knowledge as a theoretical lens to guide qualitative inquiry in Moll et al. (1992). Elements of design-based research were particularly common, as design-based research and funds of knowledge both focus on “solutions to problems of educational practice” (Kelly, 2014, p. 499).

Finally, our analysis demonstrates that funds of knowledge has been taken up in a variety of different ways, which aligns with the findings in a prior review (Hogg, 2011). For example, there are many different physical spaces where the theory has been applied, including out-of-school learning spaces. The number of studies situated outside of classrooms suggests potential benefits of starting funds of knowledge interventions in extracurricular programs, where there is greater flexibility to focus on topics and formats that resonate with students. It may be easier for classroom teachers to develop creative lessons and curriculum around student interests that meets school standards after seeing what works in out-of-school spaces. However, students may be less willing to view out-of-school funds of knowledge interventions as “real science,” as seen in Gonsalves (2014). As another example of variation between studies, participant households were conceptualized in different ways, both as family units and as communities, often those of specific cultural groups.

### *Engineering-specific findings*

In considering the use of funds of knowledge within engineering, several additional trends emerge. Notably, only five studies had a specific focus on engineering education (Kafai et al., 2014; Kier & Khalil, 2018; Smith & Lucena, 2016; Svarovsky et al., 2017; Wilson-Lopez et al., 2016). The limited number of engineering studies aligns with the findings of Verdín et al. (2016) in a prior review and also suggests an important future direction for the field. Studies examined funds of knowledge within the context of design and making. In one study, teachers shared engineering problems facing communities to connect to student funds of knowledge in the classroom. Notably, the role of undergraduate students’ funds of knowledge in the workplace, that is, engineering internships, were explored only in engineering studies. Similarly, reflecting expected disciplinary differences, aspects of equity and inclusion were discussed most often in engineering and least often in mathematics studies. All engineering studies focused on nondominant groups within engineering, primarily on race/ethnicity (e.g., Latinx, Black, and Indigenous) and low-income, first-generation students. Settings were often situated outside of school, varying from science museums, summer camps, and after-school programs. Participant ages also varied, ranging from middle school, high school, and undergraduate students to teachers and local families. We coded three engineering studies as *identification*, one as *teaching*, and one as *curriculum* during qualitative coding.

However, while most studies were situated in science (16 studies), math (11 studies), or STEM (8 studies) contexts, many K–12 science and STEM studies contained elements of engineering, which we would have missed by searching solely for engineering studies. For example, students engaged in discussions about testing and measurement detection limits during a science inquiry curriculum (André & Lager-Nyqvist, 2012); testing serves as an essential step in the engineering design process. Similarly, in Handa and Tippins (2013), pre-service science teachers explored the use of different methods for rice cultivation in a Filipino village, evaluating the benefits and drawbacks of newer technologies. Studies with STEM design challenges also often involved key elements of engineering, such as problem identification, prototyping, and construction (Miller & Roehrig, 2016; Tan et al., 2018). Given the efforts to add engineering throughout secondary curricula, there is potential value in engineering education researchers expanding attention to funds of knowledge in K–12 settings.

### ***Types of funds of knowledge identified (RQ #2)***

There were many different types of funds of knowledge identified in the qualifying studies, some of which we provided as examples in Findings. Recurring examples included a focus on food and nutrition, gardening activities, money-related transactions, and different types of sports. All four recurring examples include STEM activities more likely to be seen at home or in students' daily lives, with a slight emphasis on life sciences (food and nutrition, gardening) and math (money-related transactions). However, these examples were not limited to a single discipline. In the qualifying studies, gardening was related to irrigation systems (engineering), volume and area calculations (math), and plant characteristics (biology). Several recurring examples strongly aligned with categories provided in Moll et al. (1992), particularly the categories of household management and agriculture.

In addition to a variety of examples, many different themes were reflected in our qualitative coding, which often examined different facets related to funds of knowledge. For example, in addition to focusing on topics based on students' funds of knowledge, *curriculum* formats can also be designed to elicit student funds of knowledge, allowing students to choose their own topics and explore their interests. Additional findings related to *teaching* funds of knowledge include teacher perceptions of the theory and its usefulness and how teachers used their own funds of knowledge during instruction and lesson planning. Studies also began to consider how students use their funds of knowledge during active participation in *learning* and sense making. Further, *identification* studies examined different aspects of funds of knowledge, including communities, home life, and student interests.

### ***Gaps and opportunities in funds of knowledge application (RQ #3)***

This review also identifies a number of gaps and opportunities to apply funds of knowledge in STEM education in future work. First, a gap remains in understanding how students react to funds of knowledge interventions, particularly related to long-term impacts. While there were many examples of interventions, particularly in curriculum and teaching practices, only two studies (Borgerding, 2017; Walkington, 2017) assessed student learning and interest following the intervention. These studies employed Likert scales related to interest, self-efficacy, and perceptions; essay, multiple choice, and story problem tests; and state standardized assessments. As the two studies showed mixed results related to assessment of student learning, it is particularly important to further understand how to implement funds of knowledge in ways that promote learning. More frequently, other studies assessed levels of student engagement. Overall, there were also limited assessments related to theories of STEM identity, sense of belonging, or self-efficacy, despite the goals of each implicit in the funds of knowledge framework. With the continued marginalization of various groups within STEM, it is important to assess how nondominant students view themselves within STEM after experiencing funds of knowledge interventions. The case for funds of knowledge would be further strengthened by examining how curriculum and aspects of teaching impact students, both immediately and in the long-term. It may be useful to start assessment in out-of-school settings, including engineering after-school programs aimed at increasing engineering identity, as it can be difficult for researchers to gain access to school communities for long periods of time.

Second, the ethnographic methods primarily used in funds of knowledge may not easily lend themselves to assessment, which could have negative implications for determining whether funds of knowledge resonates with students as intended. Many studies followed the iterative process involved with design-based research, updating aspects of interventions based on observations and student feedback following implementation (Kelly, 2014). While the methods used align strongly with those in Moll et al. (1992), it is difficult to evaluate student outcomes without the use of assessment. Further assessments related to funds of knowledge may be particularly important in engineering education for two reasons. First, engineering education tends to have greater focus on preparing students for a future profession, especially when compared to other K–12 STEM disciplines. When skills are being taught for future employment, it is particularly important to assess student learning. Second, the field of engineering is less diverse in terms of race and gender than several in the sciences, meaning it is critical from an equity perspective to understand how identity is impacted by funds of knowledge interventions.

Finally, some qualifying studies focused on cultural practices of communities, while other studies looked at race more broadly. However, the idea of different communities rarely extended beyond culture or race, with the exception of low-income, first-generation college students (Smith & Lucena, 2016). While this focus aligns with Moll et al.'s (1992) study of Latinx households near the U.S.-Mexico border, there is an opportunity to apply the funds of knowledge approach to additional groups who remain nondominant in engineering, such as students with disabilities.

### ***Equity considerations***

Qualifying studies highlighted the need for equitable, inclusive practices within STEM education, particularly for nondominant students. The ability to connect to culture and home lives within STEM learning environments may decrease barriers to engineering careers, which has important implications for funds of knowledge to promote equity as intended. One way to do this, as shown in qualifying studies, is through student-centered projects designed to facilitate student exploration of their own interests within engineering (Tan et al., 2018). Teaching such ethnographic methods to engineering undergraduates may promote inclusivity during problem identification and solution development of their design projects, which could impact how they approach problems and attend to communities during their employment as professional engineers.

However, students did not always connect to activities despite the best intentions of teachers and educators, which highlights the specific nature of funds of knowledge interventions. For example, in a few studies, attempted connections to student culture (Kafai et al., 2014) and home lives (Irish & Kang, 2018) did not resonate with students. Further, it is important that we, as educators and researchers, avoid cultural essentialism by making assumptions about individual students based on their cultural group (Alvaré, 2017). While attending to culture is an excellent starting point, educators need to understand how students in their classrooms and programs personally identify with culture and what meaning they ascribe to different aspects of their own culture. Individuals inhabit culture differently, and it is important that educators engage with that complexity. This complexity has important implications for engineering education researchers seeking to use funds of knowledge to promote equity as intended, as poorly managed interventions could further alienate nondominant students from participation.

### ***Extensions and overlap with other theoretical frameworks***

From the qualifying studies, it is apparent that funds of knowledge involves extensions and overlap with other theoretical frameworks. For example, the construct of third space combines the first space of daily life (defined by funds of knowledge) and the second space of school and other institutions to create ideal learning environments for students (Moje et al., 2004). Several of our qualifying studies included examples of funds of knowledge but were guided overall by the theory of third space. Similarly, the construction of figured worlds, a separate theory, was supported through attention to funds of knowledge (Tan & Calabrese Barton, 2010). Funds of knowledge has also been used as the partial basis for creation of new frameworks, such as the *designing disruptions* framework in mathematics (Ma, 2016) and *democratic science pedagogy* (Basu & Calabrese Barton, 2010). New methods have been created to further understand student funds of knowledge, such as the development of a survey instrument to capture funds of knowledge of first-generation engineering college students (Verdín et al., 2019). Future review articles might examine how these theories relate to each other and to funds of knowledge in STEM education broadly as well as in engineering education specifically.

Despite the widespread application of funds of knowledge in STEM education, findings are not necessarily generalizable to other settings. While a funds of knowledge approach has been successful in many settings, each group of students is different, and funds of knowledge is not a one-size-fits-all approach. Unlike many other education approaches, funds of knowledge curricula cannot be adopted as easily in other settings once developed. However, we believe the diversity of examples will nonetheless inspire others to adopt the approach of identifying their own students' funds of knowledge and spark new ways for engineering education scholars and educators to create more inclusive learning environments.

### **Conclusion**

In this scoping review, we illustrated how funds of knowledge has been taken up and applied in STEM education and engineering specifically. Overall, the funds of knowledge framework is well-developed, with extensive examples of different applications within STEM contexts. Qualifying studies consisted of high-quality research and widespread applications in a variety of settings, strongly adhering to the intentions behind Moll et al.'s (1992) original theory. We explored study characteristic trends and themes within our qualitative codes of *identification*, *curriculum*, *teaching*, and *learning*. Specific examples involving a variety of settings, grade levels, student populations, and STEM disciplines are provided. In particular, we found engineering examples of funds of knowledge in design, measurement, and testing, which were not always framed by the authors as engineering. We discovered that funds of knowledge works in many different ways, with the potential to address equity issues pervasive in engineering through greater connections to the lives of students.

## Appendix

Table A1: Characteristics of qualifying studies.

Authors (Year)	Publication type	Participant population	Research setting	Methods	Types of data collection	STEM discipline
Aguirre et al. (2012)	Journal	Pre-service teachers	4-year institution	Qualitative	Artifacts	Mathematics
Albrecht and Upadhyay (2018)	Journal	Somali immigrant mothers of school-aged children	Community	Qualitative	Interviews	Science
Alvaré (2017)	Journal	In-service elementary school teachers from the U.S. and Trinidad and Tobago	Professional development program	Qualitative	Interviews and observations	Science (environmental science)
Andréé and Lager-Nyqvist (2012)	Journal	Middle school students and teachers	Middle school in Sweden	Qualitative	Observations	Science
Borgerding (2017)	Journal	High school students and teacher at a rural school	High school	Mixed methods	Interviews, observations, artifacts, surveys, and content tests	Science (evolution)
Borgerding et al. (2017)	Journal	Pre-service teachers in social studies, science, and physical education; a college football player	4-year institution	Qualitative	Interviews and a focus group	Science (physics)
Bose (2017)	Conference	Sixth-grade students	Middle school in India	Qualitative	Interviews	Mathematics
Brown et al. (2018)	Journal	In-service teachers in graduate program	4-year institution	Qualitative	Interviews, observations, and artifacts	Science
Ciechanowski et al. (2015)	Journal (practitioner)	4-H staff, pre-service teachers, and Latinx 3rd–5th grade students	After-school program	Qualitative	Observations and artifacts	STEM
Cribbs and Linder (2013)	Journal	Teacher and students in a 5th-grade math classroom	Elementary school	Qualitative	Interviews and observations	Mathematics
Diaz and Bussert-Webb (2017)	Journal	Latinx pre-service teachers (math, science, kinesiology, and English) and native Spanish-speaking elementary, middle, and high school students	After-school tutoring program (part of 4-year institution course)	Qualitative	Paired interviews, observations, artifacts, and a focus group	Science and mathematics
Durá et al. (2015)	Journal	Latinx elementary school students and family members	After-school program	Qualitative	Interviews, observations, artifacts, and focus groups	Science (food)
Edwards et al. (2015)	Journal	In-service early childhood educators (four-year old kindergarten)	Professional development program in Australia	Qualitative	Artifacts	Science (environmental science)
Ewing (2014)	Journal	Adults and children from a Torres Strait Islander community	Community meeting & workshop in Australia	Qualitative	Conversations, observations, and artifacts	Mathematics (sorting and partitioning)
Fox-Turnbull (2015)	Journal	Elementary school students in 2nd and 6th grade	Elementary school in New Zealand	Qualitative	Interviews, observations, and artifacts	Technology

(Contd.)



<b>Authors (Year)</b>	<b>Publication type</b>	<b>Participant population</b>	<b>Research setting</b>	<b>Methods</b>	<b>Types of data collection</b>	<b>STEM discipline</b>
Gallivan (2017)	Journal (practitioner)	Elementary education pre-service teachers in mathematics methods course	4-year institution	Qualitative	Interviews and artifacts	Mathematics
Gonsalves (2014)	Journal	Female high school students	After-school program	Qualitative	Interviews, observations, and artifacts	Science
Graue et al. (2015)	Journal	In-service teachers with early childhood certification	Professional development program	Qualitative	Interviews, observations, and artifacts	Mathematics
Handa and Tippins (2013)	Journal	Pre-service teachers in chemistry and physics	Community immersion (part of 4-year institution course)	Qualitative	Interviews, observations, and artifacts	Science
Harper (2016)	Journal	Karen refugee families	Community	Qualitative	Interviews, observations, artifacts, and a focus group	Science (sustainability)
Irish and Kang (2018)	Journal	In-service middle school teachers	Middle school	Qualitative	Interviews and observations	Science
Kafai et al. (2014)	Conference	Indigenous 7th and 8th grade students	Middle school & summer camp	Qualitative	Interviews, observations, and artifacts	Computing & engineering
Kajamaa et al. (2018)	Journal	Elementary school students taking an elective course at the makerspace	Makerspace at an elementary school in Finland	Qualitative	Observations	STEAM
Kern et al. (2012)	Journal	Vietnamese immigrant teacher	High school	Qualitative	Interviews and observations	Science (physical science)
Kier and Khalil (2018)	Journal	Black middle school in-service teachers	Professional development program	Qualitative	Interviews, observations, and artifacts	Engineering
McLaughlin and Calabrese Barton (2013)	Journal	Pre-service teachers in a science methods course	4-year institution	Qualitative	Artifacts and focus groups	Science
Mejia et al. (2019)	Conference	In-service teacher and undergraduate and graduate student STEM facilitators (all nondominant in STEM fields – Black, Latinx, and/or female)	Summer program for incoming 6 <sup>th</sup> grade students (primarily Latinx ELLs)	Qualitative	Interviews, daily survey reflections, and focus groups	STEM
Miller and Roehrig (2016)	Journal	Ojibwe elementary school students, families, and tribal elder	After-school program and elementary school	Qualitative	Interviews and observations	STEM
Mills et al. (2019)	Journal	A participant family with high school, middle school, and elementary school aged children	After-school program	Qualitative	Interviews, observations, and artifacts	Science
Milne and Edwards (2013)	Journal	Five-year-old elementary school students	Field trip in New Zealand	Qualitative	Interviews	Technology
Razfar (2012)	Journal	Bilingual, Latinx 5th-grade students	After-school mathematics club	Qualitative	Observations	Mathematics

(Contd.)

<b>Authors (Year)</b>	<b>Publication type</b>	<b>Participant population</b>	<b>Research setting</b>	<b>Methods</b>	<b>Types of data collection</b>	<b>STEM discipline</b>
Ryu et al. (2018)	Journal	Pre-service teachers in integrated STEM teachings methods course	4-year institution	Qualitative	Interviews and artifacts	STEM
Ryu et al. (2019)	Journal	Burmese refugee high school students	After-school program	Qualitative	Observations	STEM
Smith and Lucena (2016)	Journal	Low income, first-generation undergraduate students	4-year institution	Qualitative	Interviews and observations	Engineering
Stoehr and Civil (2019)	Journal	Pre-service teachers in a mathematics methods course	4-year institution	Qualitative	Artifacts	Mathematics
Svarovsky et al. (2017)	Conference	Local families who identified as Black, Latinx, Dakota, Ojibwe, and/or Hmong	Science museum	Qualitative	Interviews, observations, artifacts, and focus groups	Engineering
Tan and Calabrese Barton (2010)	Journal	Latinx and Black 6 <sup>th</sup> grade students and teacher	Middle school	Qualitative	Interviews, observations, and focus groups	Science
Tan et al. (2018)	Journal (practitioner)	Low income elementary school students (4th–6th grade)	After-school making program	Qualitative	Interviews, observations, and surveys	STEM (making)
Walkington (2017)	Conference	8th grade students in Algebra I and regular math classes	Middle school	Quantitative	Pre-/post-test and pre-/post-survey	Mathematics
Williams et al. (2016)	Journal	Parents of Latinx elementary, middle, and high school students	Participant homes	Qualitative	Interviews and observations	Mathematics
Wilson-Lopez et al. (2016)	Journal	Latinx high school students fluent in Spanish and recently enrolled in ESL courses	After-school program	Qualitative	Interviews, observations and artifacts	Engineering
Worthington and van Oers (2016)	Journal	Three- and four-year-old children at nursery school	Nursery school in England	Qualitative	Observations and artifacts	Mathematics

## Competing Interests

The authors have no competing interests to declare.

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