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Systematic Review of the Funds of Knowledge Framework in STEM Education

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Introduction

For over two decades, there have been significant and consistent calls to increase the quantity and diversity of engineering graduates to not only support the workforce demand but also to improve engineering solutions to better reflect the demographics of the U.S. population.[1–4] However, the call to increase the diversity of engineering often has been centered on simply increasing the percentages of underrepresented groups in engineering. Once these underrepresented group members enter an engineering profession, they are often asked to conform to a particular ideal of engineering without regard for the unique lived experiences and perspectives that they bring with them.

> To be taken as an engineer is to look like an engineer, talk like an engineer, and act like an engineer. To engage in using tools, tearing apart machinery, and building things: A fascination with and desire to talk at length about these activities is part of the interactional display of the culture of engineering (p. 355).[5]

This passage highlights the existence of a distinct culture in engineering, raising many questions about the culture of engineering, specifically what does it mean to look like an engineer, talk like an engineer and engage in engineering related activities? As the demographic of engineering continues to shift to incorporate more diversity, we should continue to reconsider what the types of identities, within the culture of engineering, we ask all types of students to take on in their development as engineers.

The historical roots of engineering have been that of a “prototypical masculine profession” (p. 351),[5] defined not just from the male perspective, but specifically through a White Western male perspective. This history is intimately linked with the history of science. The culture and tools for learning within science reflect this history dominated by a single group and, “the science that composes the bulk of the science curriculum today was largely written by White Western males” (p. 283).[6] While science and science practices can be traced back to many different cultures, the universal view of science is one that has eliminated any cultural fingerprints from its results and research.[7] Students learn the universal view of science through curriculum instruction, any notions of science or scientific practices they have learned from their culture or family background that does not fit the accepted universal standard is dismissed. Scholars have argued that education is favoring a particular way of knowing, and “does little to recognize differences among individuals or their distinctive cultural practices and instead promotes the educational reproduction of the dominant culture” (p. 3).[8]

Similarly, what counts as engineering and engineering practices has been defined though a curriculum that was created by a select and elite group of people. Thus, engineering, as a whole, excludes practices, ways of knowing and homogenizes the field of engineering. Researchers have concluded, “Education is more efficacious when there is an increase in congruence between social cultural dispositions of students and social cultural expectations of the school” (p. 38).[9]

As the calls for a more diverse engineering population are raised, it is not only important to focus on recruiting more diverse students into engineering, but also to change the ways of knowing that are valued within engineering as a discipline. This shift in value can provide opportunities for traditionally marginalized students to engage with engineering and feel like the culture of engineering is inclusive. A focus only on “moving the needle” ignores the White, masculine hegemonic culture that students face after choosing engineering as a profession.

Research studies have stated that increasing the number of underrepresented students in engineering *allows all* members of the field to draw from innovative perspectives towards problem solving, improve engineering outcomes, and address the issue of equal access to all.[2,10,11] However, what has not been stated is how these students’ backgrounds and/or experiences inform their understanding of STEM concepts. Eliciting students’ background experiences is framed as tapping into their *funds of knowledge*.

In the first section of this paper, we define the construct—funds of knowledge—using literature from the work of Gonzalez, Moll, and Amanti,[12] among others. In the next section, we discuss the systematic review method used to analyze literature about how funds of knowledge has been used in STEM education at the secondary and post-secondary level. Finally, we discuss the results of this systematic literature review and the implications of prior research on valuing a student’s culture, history, and prior knowledge that fall outside of traditionally valued skills and understanding in engineering.

Defining Funds of Knowledge

To define funds of knowledge, we examine literature from Gonzalez, Moll, and Amanti,[12] a group of researchers located in Tucson, Arizona in the early 1990s, who coined the approach through studies of household and classroom practices on working-class Mexican communities in the U.S.-Mexico borderland. The term *funds of knowledge* was used to refer to the “historically accumulated and culturally developed bodies of knowledge and skills essential for households or individual functioning and well-being” (p. 133).[13] For example, household knowledge was a diverse collection of information, including material and scientific knowledge, agriculture, mining, economics, household management, religion, medicine, or knowledge about construction to name a few.[12,13] Most notably, the funds of knowledge approach was taken to understand “how household members use their funds of knowledge in dealing with changing, and often difficult, social and economic circumstances… how families develop social networks that interconnect them with their social environments, and how these social relationships facilitate the development and exchange of resources” (p. 73).[12] This approach challenged teachers’ perceptions of the knowledge base minority and working-class children had that allowed them to accomplish their goals.[14] Funds of knowledge served to counter the pervasiveness of cultural deficit theorizing—approaches that point to the underachievement of ethnic minority students due to alleged deficiencies regarding their culture, families, and themselves.[15]

According to Moll, Amanti, Neff and Gonzalez,[13] funds of knowledge was developed by studying participants in their daily lives. Through an ethnographic approach, the research team in collaboration with local teachers (as co-researchers) found students’ households contained abundant cultural and cognitive resources, which had potential for use in classroom instruction to connect their cultural understanding with traditional STEM learning.[13] Aligning student's home experiences with their school-related experiences required the research team to solicit students' background and knowledge to develop participatory pedagogy in which teachers collaborated with students to enhance their learning environment. For example, the study revealed that families had developed social networks, among other households, and these social relationships enabled the development and exchange of resources (e.g., knowledge, skills, and labor) "that enhance[d] the households' ability to survive or thrive" (p. 133).[13] The aim of the research was to capitalize household and community knowledge in order to develop innovative teaching practices that exceed rote-like instruction; connecting student's unique experiences and those of their families.[12–14] Thus, tapping into students' experiences helped legitimize their current knowledge as valid knowledge within classroom practices "to enhance learning in science, mathematics, and other content areas" (p. 43).[12]

The practical implications of using the funds of knowledge framework for STEM education are of particular interest as the focus on diverse students continues to be an important topic in education research. The National Science Foundation has identified women, minorities, first-generation students, and students with disabilities as underrepresented in STEM.[16] In this paper, we focus on the use of funds of knowledge in STEM research and focus specifically on first-generation students, a population that may significantly benefit from valuing other cultural ways of knowing within STEM classrooms. We believe a systematic review is appropriate to obtain an informed perspective on the funds of knowledge concept focused on math, science, and engineering, as well as identify how this concept has been applied to the first-generation college student population. In essence, the purpose of this systematic review is to understand how funds of knowledge has been used in STEM education literature by examining the following questions:

> 1) How is the funds of knowledge framework being utilized to understand math, science and engineering concepts at the secondary and post-secondary level?
>
> 2) What are implications for the use of the construct—funds of knowledge—in research related to a) first generation college students, in general, and b) first-generation college students in engineering?

Study Methods and Findings

A systematic literature review is a methodology for "making sense of large bodies of information" and a way of contributing answers to questions "about what works and what does not" among other types of questions (p. 2).[17] Additionally, it is "more fit for the purpose of answering specific questions and testing hypotheses than the traditional review" (p. 10).[17] Systematic literature reviews have been widely used in various disciplines (i.e., public health, medicine, psychology, sociology) and are an established formal method of review. Formal organizations such as Cochrane Collaborations, Campbell Collections, Evidence for Policy and Practice Information and National Co-ordinating Centre (EPPI_Centre), and the What Works Clearinghouse are national and international organizations that have created conventional methods or tools for gathering data and conducting systematic reviews. The conventions crafted by the aforementioned organizations were created for mature disciplines; however, engineering education research is acknowledged as an emerging field drawing on literature and theory from multiple, well-established fields. Thus, the need to create a systematic review approach for engineering education was established by Borrego, Foster, and Froyd.[18]

Systematic Reviews in Engineering Education

Systematic reviews have been identified as a way for engineering education researchers to advance research, offering a method for "conceptual and theoretical development, research methodologies, progression, model publications, seminal publications, and implications for practice" (p. 66).[19] The interdisciplinary nature of engineering education requires a facilitated method for analyzing literature from multiple disciplines, obtaining a critical and objective review of previous efforts in order to identify new directions for research. Synthesizing previous work enables engineering educators and researchers to identify best practices for teaching and learning and new directions for rigorous research. A systematic review is a formal process, as opposed to narrative reviews requiring more formalized procedures for search, selection, coding, and synthesis methodologies.[18] In this paper, we have used the steps outlined by Borrego and colleagues[19] for conducting a systematic literature review: 1) deciding to do a systematic review; 2) identifying scope and research questions; 3) defining inclusion and exclusion criteria; 4) finding and cataloging sources; 5) critique and appraisal and; 6) synthesizing. The quality of a systematic review is contingent on the reliability and appropriateness of the research questions, selection criteria and synthesis method,[19] administering the aforementioned procedures will ensure quality in our process. In the following sections, we outline each of the steps and how they were applied in this review of funds of knowledge.

1. *Deciding to do a systematic review*

Petticrew and Robert[17] outlined scenarios where a methodological review would be appropriate, specifically, "when a general overall picture of the evidence in a topic area is needed to direct future research efforts" and "when it is known that there is a wide range of research on a subject but where key questions remain unanswered" (p. 21). While funds of knowledge has been widely applied in K-12 research broadly, there is little known about the application of this framework specifically in STEM contexts. As a first step in understanding this topic to direct future research, we focused on systematically understanding the application of this framework within STEM contexts in secondary and post-secondary education.

To answer this question, we first conducted a literature search on funds of knowledge generally. Results from multiple electronic databases, including Education Full Text (EBSCO) and Scopus, found one prior systematic review conducted on the framework. Hogg[15] stated that, "the review was informed by both systematic and narrative approaches to reviewing literature" (p. 668), and added that making a distinction between the two was arbitrary. Specifically, the analysis in this review consisted of answering research questions around the current scope of funds of knowledge research and the multiple defining approaches to funds of knowledge concept. This review provided a clear historical background of the framework as well as general overview of the framework's application in various educational contexts. Adding to this systematic review, we focus in this paper on understanding the application of funds of knowledge in STEM. Another article "presented a critical review of the funds of knowledge literature to discuss the within and beyond school pedagogies revealed in the settings represented in these studies" (p. 88), as well as explicitly pointing out "the power relations and dynamics" (p. 88) that appear when implementing this approach.[20] Rodriguez's analysis offers a critical look at funds of knowledge, with the goal of achieving "equal" educational outcomes. However, it did not offer implications for STEM contexts specifically. Other articles exclusively focused on reviewing the book *Funds of Knowledge: Theorizing Practices in Households, Communities and Classrooms*.

The research team acknowledges that the aforementioned reviews of the funds of knowledge framework are valid and beneficial to the community of researchers at large; however, in this work, we focus on a contextualized understanding of how funds of knowledge has been applied in STEM with a focus on first-generation students. This narrower investigation allows us to understand how students that may be traditionally marginalized in STEM can be supported. We postulate that this framework has the potential to add value to the curriculum instruction of secondary and post-secondary students and may attract more students in engineering and, broadly, STEM. By understanding current practices with this approach, we can move towards implementing more funds of knowledge approaches to teaching and learning engineering. In addition, by connecting student's lived experiences and household funds to discipline-specific contexts (i.e., math, science and engineering) students may be able to strengthen their beliefs that they can be math, science and engineering people.

2. *Identifying scope and research questions*

The purpose of this research article is to explore in a systematic way, how the funds of knowledge concept has been used, at the secondary and post-secondary level, in specific educational contexts such as mathematics and science, with the ultimate goal of drawing awareness to its use in engineering. Another area of interest is how, if at all, the conceptual framework had been applied to the first-generation college student population. Our interest in studying students at the secondary and post-secondary level arose from a study tracking 6,860 U.S. students' career interest at four points in time: middle school, the beginning of high school, the end of high school and starting college.[21] This study found that the majority of students who reported being interested in engineering in middle school lost interest between the beginning of high school and beginning of college.[21] While other students who had not originally reported interest in engineering increased from the beginning and end of high school. The authors credited the low attrition in engineering, as opposed to other disciplines, to "identity-building activities" (p. 13).[21] We believe the funds of knowledge framework has potential to link student's identity formation in science, math, and engineering, which could lead to implications for future career aspirations. However, before creating a link between identity formation and the funds of knowledge framework, we first need to understand studies that have used the framework in the STEM context. We used the parameters described in Table 1 to define our research questions, create inclusion and exclusion criteria and to inform stages of our investigation. Table 1 outlines the PICOS (Population, Intervention, Comparison, Outcome, and Study Design) that informed our research question and analysis. We treated the funds of knowledge framework as an intervention for in-and-out of classroom settings, thus, we focused on sources that adhered to this criterion.

Table 1. PICOS Framework for Structuring Research Questions and Analysis

PICOS Components	Considerations for this study
Population	Secondary and post-secondary students in the United States school system Special interest in first-generation college students, but not limited to this population No specific gender
Intervention	Funds of knowledge framework used in mathematics, science and engineering In-and-out of classroom setting
Comparison	Traditional approaches to curriculum development and implementation
Outcome	Effectiveness of intervention
Study Design	Reviewing all empirical and analytical studies with a focus on experimental data collection method

3. ***Defining inclusion and exclusion criteria***

Defining the inclusion and exclusion criteria for literature in our study was conducted in parallel with the method of finding and cataloging sources. The process was performed in parallel to ensure only sources that informed our research question were included. As previously stated, our initial screening of the funds of knowledge framework yielded an overwhelming number of results, thus monitoring the inclusion and exclusion criteria while cataloging sources was essential to making meaning from prior applications of funds of knowledge.

Examining our research question—*How is the funds of knowledge framework being utilized to understand math, science and engineering concepts at the secondary and post-secondary level?* —we decided to focus on sources that used experimental data. Our goal is to understand how funds of knowledge can be used to change teaching practices. Therefore, empirical research studies including quantitative, qualitative, and mixed methods were considered in our initial screening if the research informed how students connected their cultural and family knowledge to STEM subjects. Studies that used funds of knowledge as a form of intervention for analyzing student's understanding of concepts (i.e., mathematics, science, and engineering) were considered primary sources in our analysis.

The second research question—*What are implications for the use of the construct, funds of knowledge, in research related to a) first generation college students and b) first-generation college students in engineering?,* proved to be a difficult question to answer through this method. Only one article explicitly stated their population was first-generation college students within engineering. This approach highlighted the dearth of research on this growing population. We will return to this question as part of the focus of our discussion.

Our focus is to obtain a comprehensive understanding of how funds of knowledge has been used in research centered on math, science, and engineering for secondary and post-secondary students. For the purpose of this systematic review, we excluded any source that was only theory, teacher professional development (again because the focus is on students), or teacher-researcher reflection papers. Additionally, most of the literature stemming from the research group who pioneered the funds of knowledge approach is nearly absent in our review because a large portion of their work was conducted on elementary students. Thus, we consider primary sources, sources that help answer our research questions. A detail explanation of the types of sources that we excluded from this study are outlined in the next sub-section.

4. *Finding and cataloging sources*

In the fall of 2015, papers indexed in the following five electronic databases were searched 1) Engineering Village, 2) Scopus, 3) Academic Search (EBSCO), 4) Educational Full Text (EBSCO) and 5) the ASEE PEER database. Table 2 outlines the exact search strings that were used in all five of the electronic databases. For each database, we indicated that the search string should be found in the title, abstract or subject of the articles to allow for accurate and relevant findings.

Table 2 Examples of Search Strings Used

"funds of knowledge" AND "Math"
"funds of knowledge" AND "Science"
"funds of knowledge" AND "Engineering"
"funds of knowledge" AND "STEM"
"funds of knowledge" AND "STEM" NOT "Math" NOT "Science"
"First generation college students" AND "funds of knowledge" AND "Math"
"First generation college students" AND "funds of knowledge" AND "Science"
"First generation college students" AND "funds of knowledge" AND "Engineering"
"First generation college students" AND "funds of knowledge" AND "STEM"

Our initial search for the phrase funds of knowledge resulted in an overwhelming number of articles (826 sources). We limited our search to articles related to science, math, engineering and broadly, STEM. Breaking down the criteria into subject related disciplines (i.e., math, science and engineering) allowed for rich and specific results (215 sources). All qualitative and quantitative work published between 1990 and 2015 were considered for this synthesis review. Figure 1 presents a review of how studies were screened, assessed for eligibility, and included in the formal review. In our study, we excluded 195 sources; the rationale behind why these sources were excluded is addressed in the next section.

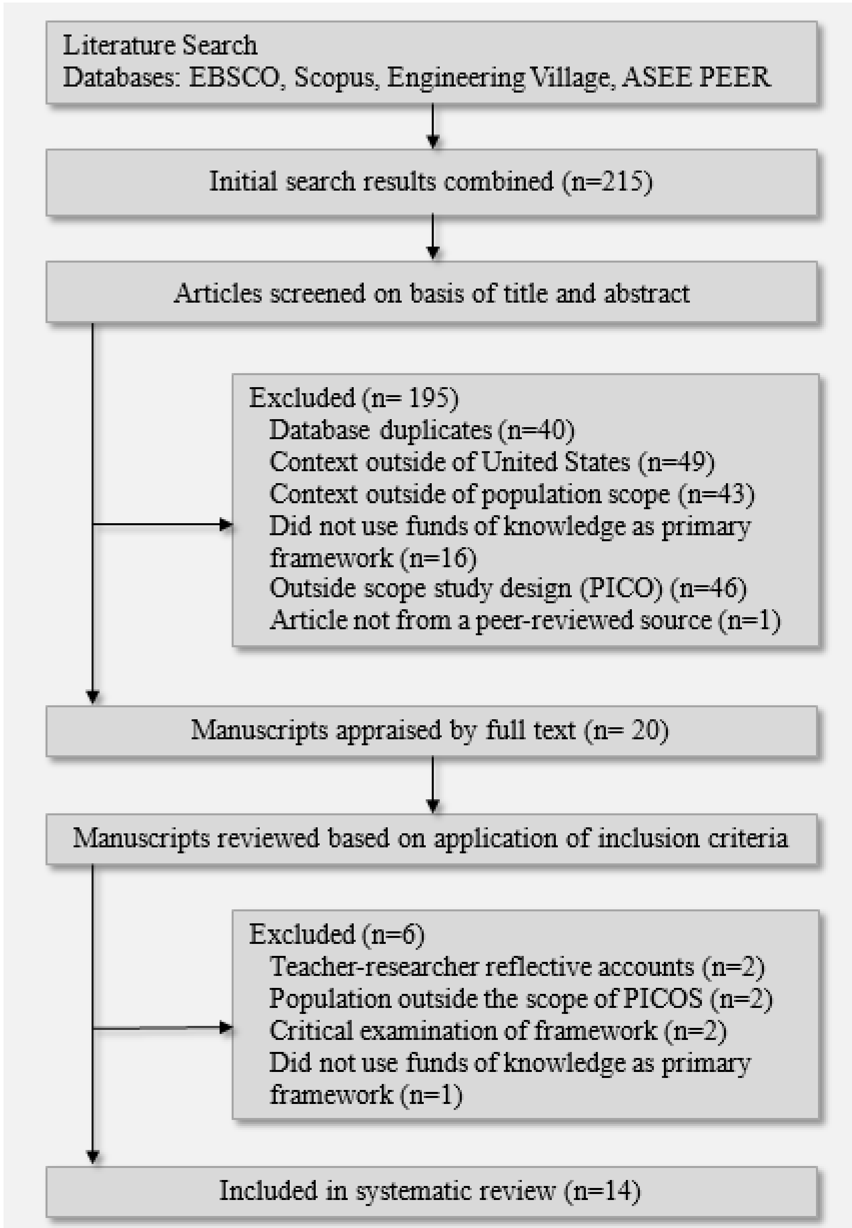

Figure 1. Flow Diagram of Study Selection

5. *Critique and appraisal*

This section of our analysis consists of evaluating sources. Upon screening abstracts that appear to meet our criteria, we found numerous factors that were considered outside the scope of our study. The factors have been outlined in Figure 1 and discussed fully in this section. This section highlights the reasons why sources were excluded from our synthesis.

We found a large number of international researchers conducting studies using funds of knowledge for their populations, which acknowledge the broad application of the framework. However, we excluded them from our analysis because of the different educational policies and standards they adhere to in comparison to the United States. Moreover, our underlying interest in studying funds of knowledge is to assess how this framework can be incorporated to learn and teach engineering at institutions across the U.S.

Scanning the full text, from literature from the Tucson research team, we excluded studies that did not focus on secondary or post-secondary students and studies that were focused on parents' funds of knowledge,[12–14,22] thus much of their research does not appear in our analysis. More specifically, the book *Classroom Diversity: Connecting Curriculum to Students' Lives* illustrates teachers' and researchers' reflective accounts of how they used students' everyday household items, parents' funds of knowledge, and students' funds of knowledge as resources for learning formal education content.[14] While the book offers rich insight on how teachers as researchers "build on the deep connections between the classroom curriculum and the knowledge and practices of students and their households," the accounts were presented as reflective pieces rather than scientific research accounts. That is, they were not presented as studies, but rather as narratives of how teachers bridged student's funds of knowledge with standard academic content. The purpose of this study is to analyze how data was collected using the funds of knowledge framework, thus, reflections and stories do not offer the methodological basis we are seeking to understand. We also noticed a portion of the research conducted on funds of knowledge by the Tucson research team was on community and familial knowledge, thus, the studies were on parents and community members rather than students themselves. While these studies highlight the essence of capturing household knowledge, our basis for excluding them from our review is because we want to explore the knowledge students bring to the classroom. Our goal is to expand funds of knowledge to post-secondary education. In light of this goal, we want to understand the knowledge that students bring to the college classroom rather than potential sources of knowledge from their parents that could be cultivated in the classroom. The focus of many funds of knowledge studies in elementary and middle school education is on these possible funds of knowledge from parents rather than on students' funds of knowledge. Similarly, several articles pertaining to teachers' experiences and reflections on using the funds of knowledge approach were excluded because it was outside of the context of our research design. We would like to note that we are not questioning the validity or utility of the aforementioned reflections; rather we are bounded by the inclusion/exclusion criteria established earlier in our study and the future direction we envision for this framework

We also excluded articles that did not use funds of knowledge as their primary theoretical method. For example, we found several studies referring to the term "funds of knowledge" in their abstract and text; however, upon closer review, these articles were not actually grounding their study on the theoretical framework we have been highlighting.[23,24] Several articles used the ideas behind funds of knowledge (e.g., asset-based approaches, valuing students' knowledge, etc.) to support and/or build on other theoretical lenses, thus, we concluded that these articles were outside of our inclusion criteria.[25,26] We found sources that were considered outside of the scope of our research design (see Table 1). For example, articles that were centered on critically examining the theoretical framework and its implications for teaching, learning, social justice or culturally relevant pedagogy, to name a few, were excluded because most were critiques.[27–30] Additionally, some of the sources were exploratory accounts of how the funds of knowledge framework draw upon theories of capital, cultural difference theory, third space/hybridity and practice theory.[31,32] We found several articles that appeared to be connected to science or math education, however upon closer review were actually focused on content learning and content literacy learning.[33]

After screening all sources and determining which ones adhered to the criteria in Table 1, twenty sources, ranging from journal articles, conference proceedings, to thesis reports, were selected as our first round of data extraction from primary sources. However, upon thoroughly reviewing the content we had to make another round of exclusion. Specifically, we found two articles that were centered on the parents' funds of knowledge, even though *keywords* highlighted students. Appraising the full text helped us realize participants being studied were the parents, with the understanding that their funds of knowledge would translate over to their children. Many initial sources appeared to be about students, but, in fact, were focused on their parents' funds of knowledge, thus they were considered outside the population scope.

Lastly, we determined there is an inherent weakness in the electronic databases we used to search our keywords. While the search strings that were used—"funds of knowledge" AND science, for example—were limited to the article title, abstract and keywords a large portion of sources generated did not incorporate the strings in these three fields. Rather, if an article referred to the concept funds of knowledge in its closing remarks or funds of knowledge appeared at a surface level, it was mistakenly included in our count. Thus, the lack of precision in the search engines exaggerated our initial results.

6. ***Synthesis***

This step consists of multiple sub-steps, with the purpose of "pooling and exploring the results to provide a 'bottom-line' statement regarding what the evidence supports and what gaps remain in our current understanding" (p. 60)[19]. We began by mapping our sources; the process of mapping organizes studies and describes characteristics (i.e., purpose, outcome, population, setting, study design, and data collected). This comprehensive summary can be found in Table 3 at the end of the paper. In this table, we list characteristics that were pertinent to answering our research question—*How is the funds of knowledge framework being utilized to understand math, science and engineering concepts at the secondary and post-secondary level?* To answer this question, we will separate our findings into subject-related areas.

Funds of Knowledge in an Engineering Context

The results of our search yield two sources both published in the *American Society for Engineering Education Conference Proceeding*, which elicited students' funds of knowledge in an engineering context. The first paper focused on documenting three Latino adolescents' funds of knowledge through a community-based engineering design problem.[34] This study sought to identify "values, interests, workplace skills, language skills, experiences with household maintenance, and other funds of knowledge" (p. 1),[34] and how they were used in each stage of the engineering design process. The study noted "students struggled to move along the engineering design cycle" (p. 14),[34] which may be appropriate given the lack of "formal" exposure to engineering design. The second study by Smith and Lucena[35] focused on extracting funds of knowledge from students in order to understand "their unique contributions to engineering problem definition, solving, and design" (p. 5). The focused of this study was on students in higher education who were low-income first-generation college students (LIFGs); the research team was interested in learning how LIFGs experiences and knowledge fostered innovation and creativity in engineering problem solving.[35]

Although not explicitly stated as a finding, this study found an underlying tension between household funds of knowledge—knowledge obtained through parents—and funds of knowledge obtained through "formal" education. That is, the funds of knowledge exchange participants had with their parents were one directional, meaning parents transmitted knowledge to their children, but knowledge transmitted from child to parent was difficult, mostly due to the different levels of education between parents and children.

Both studies conducted research on populations that are considered marginalized in engineering (i.e., English Language Learners, low-income, and first-generation college students) which is consistent with the purpose of the funds of knowledge framework—combating deficit thinking. However, since the participants were at different stages of their lives, adolescence as opposed to college students, there was divergence in the focus and types of data collected. The study on the three adolescent boys created a scenario centered on engineering design, for which funds of knowledge was drawn upon, while the study on college students pulled from their existing engineering-related experiences to elicit funds of knowledge. However, both studies supported community-based design projects as valuable methods for drawing on students' funds of knowledge.

Referring back to our research question—How is the funds of knowledge framework being utilized to understand engineering concepts at the secondary and post-secondary level? —both examples centered on the engineering design process; however, the method for drawing on student's funds of knowledge was different, perhaps because of the grade levels and exposure to engineering. Smith and Lucena's[35] study on college students connected funds of knowledge with their current life experiences, particularly experiences in choosing engineering jobs and majors. Mejia and Wilson's[34] study created a setting where they can observe funds of knowledge being utilized in an engineering context. Both of these studies diverge from the traditional approach of studying household knowledge.

Funds of Knowledge in a Mathematics Context

Two articles pertaining to how funds of knowledge may be used to spark interest in mathematics met the scope of our research design. The article by Walkington and Bernacki[36] hypothesized that "posing personalized problems can elicit students' interest and help students see the utility of learning algebra" (p. 172), thus leveraging students' funds of knowledge, students would be able to acquire a deeper understanding of algebraic concepts. This study administered a pre-/post-assessment about students' attitudes towards algebra and knowledge of algebraic concepts, in addition to students posing their own algebraic problem. By allowing students to create their own problem, based on their interest, this approach "improve[d] students' problem-solving skills, attitudes and confidence in mathematics, and contribute to a broader understanding of mathematical concepts and the development of mathematical thinking" (p. 172).[36] The study found that students' funds of knowledge with respect to their interest areas acted as a significant scaffold in conjunction with their prior knowledge of algebraic concepts. Specifically, the intervention used in the study—allowing students to personalize their own algebraic problems—"has potential to increase student's interest in and perception of the utility of learning mathematic" (p. 186).[36] Walkington and colleagues,[35] the second article identified, explored why personalizing students' interest is effective and sought to identify how teachers "can make connections to students' interests to make algebra ideas stick" (p. 274). They utilized an experimental design procedure, one group of students were the experimental group while another group of students was the control group. The experimental group received general algebra story problems and the control group received tailored algebra problems according to their interest. The results indicated that the experimental group "performed better and learned faster than the control group during the instructional unit, [and] four units later they were still performing better on more complex, nonpersonalized problems" (p. 274).[37] Using an experimental approach to elicit students' funds of knowledge is ideal for college settings, which is where our research focus is primarily situated.

Based on the two studies highlighted in this section, the underlying theme was personalized learning by drawing on students' individual funds of knowledge. Students needed to see abstract concepts 'come to life,' or rather connect with their everyday life. As one study points out, "the activation of students' funds of knowledge about their interest may have allowed them to better engage in the challenging cognitive processes involved in posing novel algebra problems" (p. 187),[36] this notion is reflected in both studies related to mathematics and the Mejia and Wilson's[34] study related to engineering design.

Funds of Knowledge in a Science Context

There were a greater number of sources pertaining to students' funds of knowledge in the science context. Nine sources met the scope of our research design (see Table 1); we observed that four sources were dissertations and four other sources were published in the *Journal of Research in Science Teaching*. There is a lengthier history of research in the science education community as opposed to engineering education, for example; thus, even though only nine papers met the scope of our research design, overall there were an overwhelming number of articles connecting science education and funds of knowledge, specifically at the elementary level.

Several commonalities emerged from the sources in this section; the overarching themes included engaging students' interest in science, connecting and creating authentic experiences, understanding concepts through discourse, "ways of knowing, doing, talking, interacting valuing, reading, writing, and representing oneself that are always and everywhere social" (p. 51),[38] and sharing authority with students. For example, Antonellis,[39] explored how students at a Tribal college connected with funds of knowledge in their science classroom and more specifically how students made meaning of concepts through dialogue. The author developed culturally relevant science curricula by "drawing on students' prior knowledge… students' language and culture to make the academic content accessible and meaningful for all students" (p. 79),[39] this curricula served as the foundation for eliciting students funds of knowledge. One of the findings in this paper highlighted how dialogical interactions were the preferred method of developing an understanding of physics concepts.

> "The students had voiced that they wanted a verbally-oriented curriculum and assessment structure, and the fact that they could succeed in this structure, as evidenced by the conceptual understanding they demonstrated in oral exams and informal dialogues, meant that the course as a whole had succeeded" (p. 309).[39]

This passage also ties into the idea of sharing authority with students, a process that may be negotiated when using the funds of knowledge approach. Similarly, an article by Tan and Calabrese Barton[40] explored teaching science for social justice, which takes "an anti-deficit stance towards students;" in this study they also expanded the "roles [students] play[ed] in science classrooms by providing ample opportunities for them to negotiate their participation and share authority" (p. 39). This study reported that the approaches are taken "gently, but firmly challenged students towards deeper and more public participation" (p. 53)[40] Another study that focused on dialogical processes for tapping into students funds of knowledge was Cook[41] In this study "the goal was to create an opportunity for students to legitimately participate in… a real campus problem" (p. 28)[41] through the use of photovoice—a method for capturing images of environmental issues in their community. Students engaged in "discovering science in their own home and communities and dialoguing with those in a position of power with regard to those issues" (p. 28).[41] This project while eliciting students' funds of knowledge also empowered them to talk to community members about environmental issues they were observing in their neighborhoods. All the studies that have been mentioned thus far have elicited authentic learning experiences as a method for drawing on students' funds of knowledge, as well as issues of power. We postulate that if teachers, instructors can share their classroom authority, then students may be able to draw on their funds of knowledge in an organic manner. Additionally, students may be able to personalize their learning experiences and scaffold from their pre-existing funds of knowledge.

Limitations

This study was our first attempt in conducting a systematic review; the lessons learned from this study will serve to guide us in our future research endeavors. Limiting our population to secondary and post-secondary students excluded numerous sources from our review; it is worth noting that another systematic review with the elementary student population may be of benefit to the research community. This study was our first exposure to funds of knowledge literature, thus, we were unaware of the multiple lenses that have been used in conjunction with funds of knowledge. Studies using multiple lenses were excluded, resulting in a smaller amount of sources to review. For this systematic review, we decided to exclude articles that were teacher reflective accounts; while these sources may be beneficial to practitioners, we were conducting this study through the perspective of an empirical researcher. Our focus was narrowly defined to explore the experimental ways in which the funds of knowledge framework was used; however, practitioners may gain more insight by reading the reflective accounts.

We acknowledge that considerations for how the funds of knowledge framework has been incorporated or intertwined with other lenses (i.e., hybridity theory, creating third space or sociocultural theory to name a few) were not taken into account. Sources that offer multiple frameworks may have unique findings; they should be reviewed by researchers interested in conducting investigations around funds of knowledge.

Conclusions and Areas Identified for Future Work

Across the sources that we examined, we found an overwhelming number focused on students in middle school. In these papers, funds of knowledge was utilized to tap into students' interest, which connected to their pre-existing knowledge. It is important to note that for middle school students to engage their funds of knowledge with the content (i.e., math, science, and engineering) they must have a grasp of the norms associated with these subject areas, according to the studies referenced. However, becoming a part of these STEM norms may create conflict between their own funds of knowledge and traditional teaching methods.

The fewest number of studies focused on students in high school, a critical point at which many students make decisions about whether to choose engineering in college. While students may lose interest in STEM-related subjects in middle school, high school is a period in which many students are experiencing advance science courses like chemistry and physics for the first time. From prior work, a physics identity has the largest effect size when predicting engineering choice in college.[21,42,43] However, physics is one of the science disciplines most dominated by White, male figures and is perceived as least inclusive among science disciplines.[44] This review highlights the need for more research on different ways to connect students' funds of knowledge with course content and the impact this makes on students' career trajectories.

Additionally, most of the studies focused on post-secondary students were not in traditional engineering spaces. These studies focused mainly on students at Tribal colleges or at community colleges in rural areas or areas with large numbers of low-income first-generation students. These studies demonstrated powerful findings that a funds of knowledge approach supports a large variety of underrepresented students. However, there is a notable lack of studies at the post-secondary level with a focus on engineering. Clearly, more research is warranted in this arena. Questions such as: In what ways do community college students in rural areas utilize their funds of knowledge to advance interest in and understanding of engineering? How do community college instructors leverage students' funds of knowledge to inform instruction and/or curriculum development?

Finally, there is only one paper that focused specifically on first-generation students within the sources we have highlighted in this review. First-generation college students often have vastly different cultural experiences and families that do not fully understand what it is like to be enrolled in college. A funds of knowledge approach would tie together traditional subjects, like engineering, with these rich and valuable resources that students bring with them into the classroom. Possible research questions might include but are not limited to the following: What kinds of funds of knowledge do first-generation students bring to their undergraduate engineering courses? When and how do first-generation students tap into their funds of knowledge? How do first-generation students mediate their own funds of knowledge with traditional undergraduate engineering programs? Do first-generation students' funds of knowledge shift or change as they assimilate to their undergraduate engineering programs? We believe that future work in this area will significantly improve retention for first-generation students within engineering and open ways for them to feel like they fit in engineering.

Table 3. First Round of Data Extraction for Primary Sources

Title/Author(s)	Source	Purpose of Study	Type of Study	Setting/ Population	Data Collected	Summary of Findings
Antonellis (2013). "Energy Is...life": Meaning Making through Dialogue in a Tribal College Physics Course	ProQuest	This research was intended as an exploration of meaning making through connections to students' funds of knowledge in a tribal college science classroom. Specifically, within the context of a physics course designed to be culturally relevant, how did students make meaning of physical concepts through dialogue?	Qualitative Indigenous methodologies similar to qualitative methodologies with an emphasis on holism, and developing understanding through creating a detailed picture of a phenomenon, whether through narrative, performance, visual arts, or whatever medium will best tell the story.	Tribal college: Physics course	Interviews, observations, reflective journals Audio recordings of fourteen class sessions—student voice during class dialogues emerged as a crucial element in the co-construction of the curriculum	(1) Dialogical interactions were the students preferred means of developing understandings and attaching meaning to physical concepts. (2) The student participants created meaning around physical concepts through connections to their cultural and personal funds of knowledge. (3) The students made meanings of the nature of science that meshed with their identities and created a space for them to identify as scientists. (4) Students made meanings of science that viewed science as part of their cultural heritage. (5) The students' meaning making around the physical concept of energy flowed from an understanding of energy as life, and life as the central purpose of the Universe. (6) Each student used different meaning-making strategies, despite being from the same cultural backgrounds.
Baus, Calabrese Barton (2007). Developing a sustained interest in science among urban minority youth	Journal of Research in Science Teaching	What are the connections between the funds of knowledge a student brings to science learning and the development of his or her sustained interest in science?	Critical Ethnography- framework to document, analyze and act on the discriminatory practices supported by schooling (particularly urban schooling)	After-school program focused on invention and exploration Urban low-income students	This study relied primarily on three forms of data: reflection notes and participant observation; interviews; and collection of student work	We found that youth developed a sustained interest in science when: (1) their science experiences connected with how they envision their own futures; (2) learning environments supported the kinds of social relationships students valued; and (3) science activities supported students' sense of agency for enacting their views on the purpose of science.
Calabrese Barton, Tan (2009). Funds of Knowledge and Discourses and Hybrid Space	Journal of Research in Science Teaching	In this manuscript, we address two research questions: What funds of knowledge did students bring into 6th grade science and how did students leverage these funds in	Qualitative Methodological approach of design of experiments	Low-income urban middle school Sixth-grade science class	Case study, observations, interviews, and grounded theory approach Examined food and nutrition unit to make sense of why the	The 6th grade science classes who participated in the design experiment performed significantly better on this unit than other units throughout the school year, as indicated by

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		support of deeper engagement in science? In what ways did the incorporation of student funds of knowledge impact or transform the discourse and engagement of the 6th grade learning community and its members?			lessons seemed to draw upon students' cultural knowledge and experiences and to adapt a set of lessons in the unit to more explicitly recruit what we imagined would be a rich source of funds of knowledge from Mr. M.'s next cohort of 6th graders. Students completed four assignments, two major and two minor: a comprehensive nutrition guide (major), a poster describing and explaining the healthy appetizer competition (major), snack competition explanations (minor), and the healthy appetizer activity sheet (minor).	student work scores and assignment completion rates. We also noticed that more students participated in class discussions, including those who were previously less engaged or silent. The second pattern we noticed was that students used items from this unit to include in their 6th grade portfolio more than any other science unit, demonstrating a level of care and commitment to work performed in this unit.
Civil (2014). STEM learning research through a funds of knowledge lens	Cultural Studies of Science Education	This article examines STEM learning as a cultural process with a focus on non-dominant communities.	Three vignettes around in-school and out-of-school mathematics	Mixture of sixth, fifth graders and adults	No data was collected, this study was an analysis using existing vignettes from a previous study.	These vignettes serve to highlight the complexity of moving across different domains of STEM practice—everyday life, school, and STEM disciplines.
Irish (2012). Argumentation and Equity in Inquiry- Based Science Instruction: Reasoning Patterns of Teachers and Students	ProQuest	This study explores issues of equity in science education through an examination of how teachers' reasoning patterns compare with students' reasoning patterns during inquiry-based lessons. It also examines the ways in which teachers utilize students' cultural and linguistic resources, or funds of knowledge, during inquiry-based lessons and the ways in which students utilize their funds of knowledge, during inquiry-based lessons.	Qualitative Multiple case study approach	57 middle school students Three middle school teachers	Collected during inquiry-based lessons through classroom observations, multiple interviews with each teacher and with small groups of students. Data that were utilized in this study include documents such as teachers' curriculum materials, instructional materials, and examples of student work.	The findings indicate that the students are capable of far more complex reasoning than what was elicited by the lessons observed or what was modeled and expected by the teachers, but that during the inquiry-?-based lessons they conformed to the more simplistic reasoning patterns they perceived as the expected norm of classroom dialogue. The findings also indicate that the students possess funds of knowledge that are relevant to science topics, but very seldom use these funds in the context of their inquiry-?-based lessons. In addition, the teachers in this study very seldom worked to elicit students' use of their funds in these contexts. The few attempts

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						they did make involved the use of analogies, examples, or questions.
Cook (2014). Beginning a Classroom Inquiry: Using Photovoice to Connect College Students to Community Science	Journal of College Science Teaching	The goal was to create an opportunity for students to legitimately participate in and ultimately have the potential to affect a real campus problem. Through *photovoice*, learners may engage in discovering science in their own home and communities and dialoguing with those in a position of power with regard to those issues.	Participatory tools Photovoice process Used the method SHOW tool to guide students in generating captions, tell the story of the pictures, and identify the issues and themes that emerged	College undergraduates taking a science course for education majors	Collected data through *photovoice*—a method by which educators provide cameras to participants so that they may document issues important to them through the use of photography. Students were asked to write about what was happening in the picture, why they took the picture, and/or what it meant to them.	Rather than creating a project around a contrived or "fake" issue, Photovoice allowed students to deepen their connection to the science that was taking place around them by allowing them to reflect on science-related topics of interest to them. Their photographs and resulting narratives indicated their desire to learn more about the science behind their chosen environmental issue.
Lloyd (2010). Eliciting and Utilizing Rural Students' Funds of Knowl edge in the Service of Science Learning: An Action Research Study	ProQuest	The core of the study was the development of an after school environmental club, designed to engage rural students in authentic, meaningful and productive science learning experiences in their local contexts—a context rich with potential for eliciting and capitalizing on rural students' funds of knowledge. The major research questions this study addressed are: 1. What science—related funds of knowledge do rural high school students have? 2. How were these funds of knowledge capitalized on to support science learning in an after school setting? 3. Which of these funds of knowledge could be used in a living environment course and under what conditions?	Qualitative: Grounded theory approach Action Research	After-school club grades 9-12	Group discussions, student interviews, surveys, blog posts, project presentations, creation of digital scrapbooks, and teacher log	This study found that this group of rural student had a unique set of funds of knowledge that could be identified and utilized in the service of science learning. These students brought a wide array of interests and aptitudes in science, but all were engaged in our research project through tapping into the instances where their funds of knowledge overlapped the science content of our investigation. Everyone had the opportunity to feel as if they had valid skills and knowledge to contribute to the project. This finding demonstrates the importance of creating opportunities for all students to see themselves as legitimate participators in the discourse of science, something that is often difficult for under-served populations.

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Mejia, Wilson, Hasbun, Householder (2014). Funds of Knowledge in Hispanic Students' Communities and Households that Enhance Engineering Design Thinking	ASEE Conference Proceedings	The purpose of this study was to document the funds of knowledge of three Latino adolescents as they worked on a community-based engineering design problem.	Qualitative approach	High School Students English Second Language (ESL) program	Interviews, observations, group discussions, student products Community-based project, including three components to engineering design (1) identifying need/problem, (2) developing solutions and, (3) selecting best solution	Students struggled to move along the engineering design cycle. Students relied on "word of mouth" from parents and other family members, or parents' experiences.
Rivera, Brown, Grey, Sullivan (2014). Urban middle school students' reflections on authentic science inquiry	Journal of Research in Science Teaching	This manuscript seeks to explore the experiences of six middle school youth with authentic science inquiry (1) How do Fifth grade, urban middle school students describe their experiences with authentic science inquiry? (2) How do experiences with authentic science inquiry shape students' relationships with science and their sustained interest in science?	Qualitative approach Multiple case study design Authentic Science Inquiry Narratives	Six urban middle school students in an authentic science inquiry program	Collected a variety of data, including teaching journal entries, samples of student work, photographs of students and their work, classroom video, semi-structured focus group interviews conducted with pairs of students, six students in total, after they participated in the science inquiry program, and performance assessment data collected at the end of the microscope laboratory sessions and after the authentic science inquiry program	The findings situate authentic science inquiry as an individual and collective characteristic of learners and the learning community. We make the case that authentic science inquiry projects provide students with a greater sense of academic agency, afford students opportunities to gain expertise, and have the potential to challenge students' understandings of science, enhance how they see themselves in relationship to science, and improve their achievement in science.
Smith and Lucena (2015). Making the Funds of Knowledge of Low Income, First Generation (LIFG) Students Visible and Relevant to Engineering Education	ASEE Conference Proceedings	The goal of our research project is to discover how innovation and creativity in engineering problem solving can be fostered by integrating the knowledge and experiences of low-income and first-generation students (LIFGs) into engineering education.	Qualitative: ethnographic study	College (both community college and 4-year university) Students identified as low-income, first-generation college students	Collaborative activities where students worked together to redefine and solve traditional engineering problems. Designed hands-on activities that could be used by professors to teach engineering concepts.	Our research also demonstrates that the funds of knowledge carried by LIFGs are valuable for engineering design, especially in the context of community development projects that require defining and solving problems in the midst of scarcity, experiential knowledges and skills like those needed in EDfD projects, and desires rooted in empathy with marginalized groups.

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Title/Author(s)	Source	Purpose of Study	Type of Study	Setting/ Population	Data Collected	Summary of Findings
Tan, Calabrese Barton (2010).Transforming science learning and student participation in sixth grade science: A case study of a low-income, urban, racial minority classroom	Equity & Excellence in Education	We hope to show explicitly, how a teacher engages in teaching science for social justice by taking an anti-deficit stance toward his students, expanding the roles they play in science class by providing ample opportunities for them to negotiate their participation, and sharing authority with students by giving them the freedom to assemble a personal science portfolio that counts toward their final grades.	Ethnographic case studies	Low-income urban middle school Sixth grade science	Data collection methods included field notes from participant observation, video footage of science lessons, and 20 semi-structured interviews with Mr. M and focus group students.	By drawing from and validating such nontraditional funds of knowledge (e.g., popular culture, personal experiences, counting the science portfolio toward student assessment), Mr.M engages in anti-oppressive science teaching. With his strategies and in-depth understanding of his students through engaging with them in different figured worlds, Mr. M is well positioned, as the findings have shown, to gently but firmly challenge his students toward deeper and more public participation.
Van Niel (2010). Eliciting and Activating Funds of Knowledge in an Environmental Science Community College Classroom: An Action Research Study	ProQuest	My work suggests that college learning experiences can be tailored to specifically take advantage of those funds of knowledge to the benefit of the students in the class. This study will focus on skills or bodies of knowledge that are beneficial for the individual's functioning and well-being as it relates to class performance.	Qualitative Action research	Community college environmental course Implemented an intervention; Phase 1 involved eliciting funds of knowledge from my students while Phase 2 involved utilizing funds of knowledge in the selected course.	Data collected during the intervention included the audio-recorded small-group session where funds of knowledge were elicited, surveys compiled by all students to point to potentially relevant life experiences and practices, audio taped classroom lessons where funds of knowledge are utilized, audio taped and written feedback during a final class reflection on the experience, written responses to prompts regarding any new practices students' took up as a result of the intervention, and my own Teacher Log.	Findings highlight the breadth of relevant funds of knowledge present in a given class as well as strategies shown to be effective for both elicitation and activation of these funds. Implications are drawn for future research into funds of knowledge as well as for other instructors wishing to explicitly draw on students' funds of knowledge to enrich their learning experiences.

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Title/Author(s)	Source	Purpose of Study	Type of Study	Setting/ Population	Data Collected	Summary of Findings
Walkington and Bernacki (2015). Students authoring personalized “algebra stories”: Problem-posing in the context of out-of-school interests	The Journal of Mathematical Behavior	We hypothesize that posing personalized problems can elicit students’ interest and help students to see the utility of learning algebra. We also propose that by leveraging students’ prior knowledge of their interests, students can develop a deeper understanding of algebra.	Semi-mixed methods Pre-/post-assessments Semi-structured interviews	Two groups: 10 students in eighth grade 14 students enrolled in grades 6-10	Pre-/post- assessment on attitudes towards algebra and learning of algebraic concepts Students were asked to identify algebraic rule involved in the provided story and then solve Students were asked to pose a similar problem that incorporated their own interest and solve	Using six cases of more successful and less successful students, we uncovered three themes: students’ “funds of knowledge” about their interest areas acted as an important scaffold, as did prior knowledge of algebra and a grasp of school norms related to story problems.
Walkington, Sherman, Howell (2015). Personalized Learning in Algebra	The Mathematics Teacher	In this article, the authors explore two questions 1) why is personalizing of students' interests so effective and 2) how can teachers begin to implement this approach in their classrooms? Their aim was to reveal ways in which teachers can make connections to students' interests to make algebra ideas stick.	Experiment using one control group and experimental group	First-year algebra students	Control group received the algebra story problems already in the unit. Experimental group received problems tailored to their interests.	The experimental group, who received personalized problems, perform better and learn faster than the control group during the instructional unit. Four units later the experimental group were still performing better on more complex, non-personalized problems.

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