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Transnational Latinx Youths' Workplace Funds of Knowledge and Implications for Assets-Based, Equity-Oriented Engineering Education

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Abstract

Due to economic inequality in society, millions of Latinx high school youth work after-school jobs and summer jobs in order to provide additional income for their families. The purpose of this qualitative study, conducted with transnational Latinx youth, was to identify the engineering-related skills and bodies of knowledge they developed and applied while in different workplaces. This study is framed in complementary theories of funds of knowledge, Vygotskian theories of mediated action, and theories of resistant capital. Specifically, this study is based in the premise that youth can develop engineering-related funds of knowledge through tool-mediated, goal-directed activities jointly conducted with family members and others, and that workplaces can be important sites for the development of funds of knowledge. Workplace activities are situated within sociohistorical contexts in which Latinx workers are often exploited and thus mobilize forms of resistance. A multiple case study was conducted with 20 transnational Latinx youth who currently or previously worked one or more jobs to supplement family income. Data sources included workplace observations, occupational interviews, and semi-structured interviews. We first divided the data by category of business ownership (family-owned businesses versus corporate-owned businesses) to explore whether different types of workplaces, characterized by different hierarchical relations, fostered different types of skills and bodies of knowledge. Constant comparative analytic methods were used to describe the engineering-related bodies of knowledge and skills, including critical resistant skills, that the youths applied in the context of workplace activities. Across different occupations, all youth developed and applied knowledge and skills related to industrial and operations engineering, including the iterative development of processes designed to maximize efficiency and to promote health and safety. While applying funds of knowledge toward their employers' goals, they also applied these funds of knowledge to make counter-spaces that were more humane, and they expanded technical processes to include a deep consideration of the emotions and well-being of people and animals. Ultimately, the youth mobilized and hoped to mobilize these funds of knowledge and forms of resistance toward more humane workplaces, better living conditions in their homes and communities, and more economically secure futures for themselves and their families. This study does not romanticize exploitative economic conditions experienced by suggesting that Latinx youths' workplace experiences are positive, but it offers better understandings of the wide range of complex and rich engineering-related funds of knowledge developed in the context of different workplace activities. Educators who understand and recognize these funds of knowledge as assets may be able to design more equitable learning environments that position working youth as experts and core contributors. Educational implications include recognizing youths' workplace experiences as epistemological resources, and critiquing and transforming systems through expanded visions of engineering. These visions of engineering can include but extend beyond the design of physical technologies, to encompass the design of interacting processes, technologies, and systems. Ultimately this type of education could repurpose workplace-derived funds of knowledge (from serving employers or corporations) toward more equitable futures (serving youths' personal trajectories and communities).

Keywords

funds of knowledge, Latinx youth, high school, engineering education, equity

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Abstract

Due to economic inequality in society, millions of Latinx high school youth work after-school jobs and summer jobs in order to provide additional income for their families. The purpose of this qualitative study, conducted with transnational Latinx youth, was to identify the engineering-related skills and bodies of knowledge they developed and applied while in different workplaces. This study is framed in complementary theories of funds of knowledge, Vygotskian theories of mediated action, and theories of resistant capital. Specifically, this study is based in the premise that youth can develop engineering-related funds of knowledge through tool-mediated, goal-directed activities jointly conducted with family members and others, and that workplaces can be important sites for the development of funds of knowledge. Workplace activities are situated within sociohistorical contexts in which Latinx workers are often exploited and thus mobilize forms of resistance. A multiple case study was conducted with 20 transnational Latinx youth who currently or previously worked one or more jobs to supplement family income. Data sources included workplace observations, occupational interviews, and semi-structured interviews. We first divided the data by category of business ownership (family-owned businesses versus corporate-owned businesses) to explore whether different types of workplaces, characterized by different hierarchical relations, fostered different types of skills and bodies of knowledge. Constant comparative analytic methods were used to describe the engineering-related bodies of knowledge and skills, including critical resistant skills, that the youths applied in the context of workplace activities. Across different occupations, all youth developed and applied knowledge and skills related to industrial and operations engineering, including the iterative development of processes designed to maximize efficiency and to promote health and safety. While applying funds of knowledge toward their employers' goals, they also applied these funds of knowledge to make counter-spaces that were more humane, and they expanded technical processes to include a deep consideration of the emotions and well-being of people and animals. Ultimately, the youth mobilized and hoped to mobilize these funds of knowledge and forms of resistance toward more humane workplaces, better living conditions in their homes and communities, and more economically secure futures for themselves and their families. This study does not romanticize exploitative economic conditions experienced by suggesting that Latinx youths' workplace experiences are positive, but it offers better understandings of the wide range of complex and rich engineering-related funds of knowledge developed in the context of different workplace activities. Educators who understand and recognize these funds of knowledge as assets may be able to design more equitable learning environments that position working youth as experts and core contributors. Educational implications include recognizing youths' workplace experiences as epistemological resources, and critiquing and transforming systems through expanded visions of engineering. These visions of engineering can include but extend beyond the design of physical technologies, to encompass the design of interacting processes, technologies, and systems. Ultimately this type of education could repurpose workplace-derived funds of knowledge (from serving employers or corporations) toward more equitable futures (serving youths' personal trajectories and communities).

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Introduction

Due to systemic economic inequality, millions of Latinx youth (ages 15-18) work jobs after school, over the summer, or full time in order to provide additional income for their families (Hamersma & Kim, 2016; Hirschman & Voloshin, 2007; US Bureau of Labor Statics, 2019). Many of these jobs act as mechanisms for inequitable social reproduction when Latinx youth, due to economic necessity, devote substantial time to underpaid labor that may not lead to subsequent financial security (Solomon & Weller, 2018). Although Latinx youths' labor is undervalued and often unknown or invisible to educators in the youths' lives (Orellana, 2001, 2009), formal and informal workplaces can be sites where youth develop powerful engineering-related skills and bodies of knowledge that can be mobilized toward purposes that matter to them, including the creation of more just and equitable futures. It is therefore imperative that engineering educators and educational systems recognize and value the skills that Latinx youth develop in these workplace sites in which they spend so much of their time.

The purpose of this study, which was conducted with transnational Latinx high school youth, was to describe how youth developed engineering-related funds of knowledge in the context of different workplace activities, and how they subsequently mobilized these funds of knowledge toward more equitable futures for themselves, their families, and their communities. For the purpose of this study, we use the term "transnational" to refer to people in the USA who formerly lived in Central or South American countries and revisited them; who maintained close ties with relatives and others in these countries through communication technologies and media; and/or who identified with two or more cultures from their native and adopted countries (Lam, 2004; Skerrett, 2015). Following Moll et al. (1992), we begin with an initial definition of "funds of knowledge" as "historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual functioning and well-being" (p. 133). By identifying the types of funds of knowledge that transnational Latinx youth developed through waged labor, this study has implications for the design of learning environments and systems in engineering education in which the expertise of working youth is foregrounded and mobilized toward purposes that matter to them.

Workplaces and Funds of Knowledge

The concept of funds of knowledge was originally developed to challenge deficiency models (Vélez-Ibáñez & Greenberg, 1992) in which educational systems position white middle-class practices as "standard" while positioning the linguistic and cultural practices of minoritized youth as deficient (Baker-Bell, 2020; Carter Andrews et al., 2019). In contrast to these educational models, pedagogies based on funds of knowledge begin with the fundamental stance that Latinx youths' funds of knowledge are "important and useful assets in the classroom" (Vélez-Ibáñez & Greenberg, 1992, p. 313). When the concept of funds of knowledge was developed over three decades ago (Vélez-Ibáñez & Greenberg, 1989) and subsequently applied to pedagogical approaches (González et al., 2005; Moll et al., 1992), labor histories were central to understanding the development and nature of the funds of knowledge of transnational families. For example, in their early definitional work on funds of knowledge, anthropologists Vélez-Ibáñez and Greenberg (1992) described Hortencia, a devoted matriarch on the USA–Mexico border, who developed computational skills as a bank-teller and subsequently played games at home that taught similar computational skills to her children and grandchildren.

Later, when applying the concept of funds of knowledge to formal educational settings, Moll et al. (1992) partnered with teachers to explore funds of knowledge through "analyzing the social history of the households, and *most prominently for our purposes, the labor history of the families*" (p. 133; emphasis added). After learning more about the labor histories of families on the USA–Mexico border, the teachers from Moll's study developed instructional units that connected these histories with existing curricula and standards. For example, fifth-grader Carlos and his family produced and sold candies, and his teacher used this as the basis for student-driven investigations that taught "many areas of the curriculum…math, science, health, consumer education, cross-cultural practices, advertising, and food production" (p. 138). In theorizing funds of knowledge for STEM (science, technology, engineering, and mathematics) education, Civil (2016) likewise foregrounded workplaces as vital to understanding the development of transnational Latinx families' funds of knowledge. Her work with families on the USA–Mexico border led to a "realization" that occupational interviews, or focused interviews about practices specific to workplaces, were core data generation tools required to deeply understand familial funds of knowledge (p. 52).

As with the example of Hortencia, transnational Latinx parents and other relatives may develop skills in workplaces, which they subsequently teach to children through shared practice in the household. Not uncommonly, their children work alongside them in community spaces as they procure personal or family income (e.g., López, 2001; Orellana, 2001), such as when Carlos sold family-made candies to his neighbors. Thus, while funds of knowledge can be acquired across many settings, we conducted this study under the assumption that work in formal or informal spaces provides sustained

opportunities for Latinx youth to develop and apply complex engineering-related bodies of knowledge and skills, as supported by parents, other relatives, and neighbors.

Although scholars who work with transnational Latinx youth (e.g., Civil, 2016; Moll et al., 1992) have emphasized the importance of workplace-derived funds of knowledge, many other scholars (e.g., Calabrese Barton & Tan, 2009; Hedges, 2011; Moje et al., 2004) have emphasized funds of knowledge derived from peers, media, or household tasks—such as knowledge about family food traditions, experiences with ordering and eating fast food, informal peer activities, or popular cultures. This emphasis is understandable because Moll and colleagues (1992) broadly defined funds of knowledge as "historically accumulated and culturally developed bodies of knowledge and skills" (p. 133), a definition that clearly extends beyond workplaces. At the same time, in framing this study, we return to early assumptions that work provides an important, if not central, source of funds of knowledge for transnational Latinx families, and we seek to better understand the engineering-related skills and practices that Latinx youth develop while working.

Importantly, although this study explores how Latinx youth develop engineering-related funds of knowledge in workplaces, we do not wish to portray formal workplaces, or the economic conditions that force transnational Latinx families to engage in labor in informal markets, as forces that benefit Latinx youth. On the contrary, we explicitly acknowledge the labor exploitation and unjust economic conditions experienced by millions of transnational Latinx youth and their families (Sánchez, 2014–2015). At the same time, in the face of economic inequality and injustice, transnational Latinx youth can develop a deepened sense of agency, shared power, and a feeling of connection with their families as they contribute financially to their families, prevent their younger siblings from facing food insecurity, and learn important life lessons from their parents in their workplaces (Estrada, 2019; Hamersma & Kim, 2016; López, 2001; Orellana, 2001). It is our intention in this article to highlight the strengths, resources, and skills that transnational Latinx youth develop at work, often as supported by caring relatives, in spite of, and not because of, exploitational labor conditions or economic systems.

Funds of Knowledge Specific to Engineering

Although early descriptions of funds of knowledge were not explicitly connected to engineering education, Moll et al.'s (1992) seminal taxonomy included funds of knowledge that are highly relevant to many branches of engineering: knowledge of labor laws, building codes, construction, maintenance and repair, and ethics, to name a few. For this reason, scholars (Wilson-Lopez, Sias, Smithee, & Hasbún, 2018) have posited that engineering education as a discipline, as contrasted with other academic disciplines, holds unique potential for foregrounding and leveraging Latinx youths' funds of knowledge. In subsequent decades, other scholars have sought to describe funds of knowledge that are more specific to engineering. Notably, Verdín et al. (2019) designed a scale to ascertain the funds of knowledge of undergraduate engineering students, with the ultimate purpose of better supporting low-income, first-generation students through leveraging their funds of knowledge in engineering coursework.

To develop this instrument, they drew from their previous studies based on ethnographic interviews with low-income, first-generation undergraduate students (Smith & Lucena, 2015, 2016). While most of these study participants were identified as white, Smith and Lucena also conducted interviews with undergraduate immigrants from Latin American countries. From these interviews, they developed six major themes that were subsequently used to develop their scale (Verdín et al., 2019). These "funds of knowledge themes" included *connecting experiences* by drawing from hobbies or home environment activities; *tinkering knowledge* derived "from home or from work"; *perspective taking*; *reading people*; *mediational skills*; and *community networks*, including "co-workers." Of note, two of these themes explicitly mention workplaces, indicating the importance of workplaces to funds of knowledge. Although workplaces were not called out as a specific category in their scale, those authors' previous studies indicate that workplaces were important to the participants, such when Faith developed "funds of knowledge about mechanics…through multiple low-paying jobs" (Smith & Lucena, 2016, p. 13).

Whereas Smith and colleagues' studies described the funds of knowledge (including those developed in adolescence) of adults who were already interested in pursuing engineering careers, our own previous research (Wilson-Lopez et al., 2016) examined the engineering-related funds of knowledge of Latinx youth who were not necessarily interested in engineering, in order to develop pedagogies that explicitly connected these funds of knowledge with engineering practices at an earlier age. This research, too, resulted in descriptions of workplace funds of knowledge, but included other categories such as household management, volunteerism, sports, and popular culture. This study found that workplace funds of knowledge fostered engineering-related skills and habits of mind, such as when 16-year-old Federico engaged in systems thinking and engineering design processes when he developed a multifaceted solution to decrease the bacteria count in milk at the dairy farm at which he worked.

We draw two conclusions when reflecting on previous work in understanding Latinx transnational youths' engineering-related funds of knowledge, conducted by ourselves (e.g., Wilson-Lopez et al., 2016) and others (e.g., Verdín et al., 2019). First, workplaces may be important sites wherein engineering funds of knowledge are developed, but they have not been addressed separately and in their own right, as recommended by prominent theorists of funds of knowledge who have worked with transnational families. Second, operationalizations of funds of knowledge are inconsistent (cf. Hogg, 2011), both within and across individual studies of science and engineering-related funds of knowledge. Some researchers operationalize funds of knowledge as actions, such as *cooking* and *repairing* (Svarovsky et al., 2017); as traits, such as *talents* (Calabrese Barton & Tan, 2009); as relationships with others, such as *solidarity* (Calabrese Barton & Tan, 2009) or *community networks* (Verdín et al., 2019); as sources of knowledge acquisition, such as *news media* and *print magazines* (Moje et al., 2004); as objects, such as *toys* (Svarovsky et al., 2017); as *experiences* (Verdín et al., 2019; cf. Tan et al., 2018); and as *skills and bodies of knowledge* acquired within particular *sites* such as homes (Wilson-Lopez et al., 2016). For the purpose of our study, we return to the original Vygotskian tenets that undergirded Moll and colleagues' initial research in order to provide clarity on how we operationalize funds of knowledge in the context of transnational Latinx youths' workplaces. We also connect tenets from LatCrit theory to expand Vygotskian theory to further operationalize funds of knowledge in the context of Latinx youths' workplaces.

Funds of Knowledge and Vygotskian Theories

In developing the concept of funds of knowledge, González et al. (2005) asserted "Vygotskian ideas are found in our work" (p. 18) in multiple ways, most notably because their work foregrounded how goal-directed activity, mediated by tools in the context of social relationships, supports individuals' development. Moll's previous and subsequent work (Moll, 1990, 2002, 2014; Moll et al., 1997) likewise built upon and expanded theories of socially situated, tool-mediated learning, as introduced by Vygotsky (1978) and later articulated by scholars such as Wertsch (1991, 1998) and Cole (1996). Thus, while we acknowledge and respect that different types of intergenerational bodies of knowledge can be transmitted in different ways (such as through oral stories), the concept of funds of knowledge originated through studies of shared, tool-mediated activity between children and adults.

In writing of the formation and transformation of funds of knowledge of families on the USA–Mexico border, Vélez-Ibáñez and Greenberg (1992) described Tomás, a maintenance mechanic for army planes and helicopters, who believed that there was "no better exercise" than "the labor in which one's hands shape an object from scratch" (p. 320). Tomás transmitted funds of knowledge to his children and grandchildren through engaging them in shared activity and experimentation as they jointly renovated a house, and as they repaired and built household items in his well-stocked woodworking shop. Vélez-Ibáñez and Greenberg emphasized that transnational Latinx children, such as Tomás's grandchildren, were expected to ask questions while experimenting with new tasks through which funds of knowledge were transmitted—in this case, funds of knowledge related to construction and repair.

The concept of "mediated action," described in detail by Wertsch (1998; Wertsch et al., 1993), can be applied to this example. Wertsch (1998) asserted that mediated action entails *agents*, such as the children and Tomás, who use *mediational tools* in order to achieve shared *goals* (cf. Cole, 1996), such as repairing an object. Vygotsky (1981) distinguished between *technical tools*, which directly influence physical objects (e.g., saws), and *psychological tools*, which include symbolic representations such as gestures and oral language. Both tools are also used to achieve culturally defined goals; through increased mastery of these interconnected tools, thinking and development occur.

From our reading of Vélez-Ibáñez's work, we speculate that for Tomás's grandchildren, the development of funds of knowledge happened through both types of mediational means: They used Tomás's responses to their questions (e.g., his language and perhaps gestures as psychological tools), while they experimented with equipment (e.g., hammers as technical tools) as they sought to achieve a goal (e.g., constructing an object). In the context of a caring relationship with their grandfather, these psychological and technical tools mediated the development of their "bodies of knowledge and skills" (Moll et al., 1992) or funds of knowledge, related to repair, such as knowledge about the function of different tools, and the capacity to use them expertly to solve problems.

Wertsch (1998) also asserted that scenes, or the "background" and "situation" in which activities occur, can aid in theorizing mediated action. In this case, the scene may have been comprised of a woodshop in a backyard in Tucson, a city on the USA–Mexico border, in the 1980s. In subsequent writings, Wertsch (e.g., Wertsch et al., 1995) asserted that the terms "mediational means" and "cultural tools" can be used "interchangeably" (p. 21) because mediational means, including technical and psychological tools, are sociohistorically derived and are used within culturally situated contexts. Therefore, Vygotskian theories support Moll's assertion that funds of knowledge are "culturally developed". They occur within sociohistorically situated *scenes*; they are developed through culturally derived *mediational tools*; and they are transmitted by *agents* (whose relationships to each other are also shaped by sociohistorical forces) who seek to achieve situated *goals*. Given

the tight interconnections among these elements of mediated action, it is no surprise that many operationalizations of funds of knowledge emphasize different subcomponents, with some focusing more on the action (e.g., repairing); on the mediational tool (e.g., news media; toys); on the relationships between agents (e.g., solidarity); on the scene (e.g., workplaces, homes situated within communities at particular points in time); or on the individual development that results from mediated action (e.g., skills or bodies of knowledge).

By using Vygotskian theories of mediated action, we seek to contribute clarity to a growing body of work on funds of knowledge in science and engineering. As noted previously, we focus on different workplaces as important *scenes* because they have been understudied, despite theoretical literature and a small body of empirical literature that would suggest these funds of knowledge are important to engineering. For each workplace, we describe core activities in which Latinx youth engaged (e.g., painting walls), and the ways in which mediated action (including adult relatives as co-agents, and goal-oriented tool use) supported the development of the youths' funds of knowledge, or "bodies of knowledge and skills" which are culturally derived and historically accumulated (Moll et al., 1992). Thus, we retain Moll's definition of funds of knowledge as "bodies of knowledge and skills" that result from sociohistorically situated, tool-mediated action.

Funds of Knowledge and LatCrit Theories of Resistant Capital

Whereas Wertsch (1998) emphasized the role of mediational tools in promoting the development of skills or knowledge, other scholars (e.g., Hernandez-Truyol, 1997; Solórzano & Delgado-Bernal, 2001) have instead foregrounded the socially constructed systems, characterized by racialized and gendered oppression and injustice, in which skills and knowledges are developed, validated, invalidated, or exploited. In other words, whereas Wertsch underemphasized the role of scenes in some of his writings (e.g., Wertsch, 1998), these later scholars have foregrounded how racialized systems act as contexts (or to use Wertsch's term, scenes) in which mediated action occurs. These racialized systems permeate all aspects of mediation: who has access to different mediational tools; the nature of the relationship between co-agents (e.g., one person might experience microaggressions from another on the basis of race); and the goals of the agents (e.g., the goal of minoritized working youth might be to resist dominant and oppressive structures whereas the goals of employers might be to make a profit by paying the youth as little as possible).

In later writings about funds of knowledge, Rios-Aguilar et al. (2011) asserted there were particularly close connections between *capital* as a theoretical construct and *funds of knowledge* as a theoretical construct. In their words, "bridging funds of knowledge and capital has the potential to advance theory and to yield new insights and understandings" (p. 163). To provide these connections, we draw from Yosso's (2005) theories of capital, developed through the lens of critical race theory, which have been used to understand the forms of capital mobilized by minoritized youth. Based on what we learned from transnational Latinx youth working under exploitative conditions, we specifically seek to highlight *resistant capital*, defined as "knowledges and skills fostered through oppositional behavior that challenges inequality" (Yosso, 2005, p. 80; cf. Solórzano & Villalpando, 1998). Here we note similarities between *funds of knowledge* and *capital*. Both have been defined in part as "skills and knowledges" developed through action—in the first case, through shared, tool-mediated action designed to enhance the well-being of households, and in the second case, through opposition to injustice. Moreover, concepts of funds and knowledge and capital have been used to shine light on the strengths and assets possessed by historically minoritized youth.

We focus specifically on resistant capital because several scholars have emphasized the importance of resistance when understanding the strengths of Youth of Color. In the words of Solórzano and Delgado Bernal (2001), "We need to listen more closely and more often to…experiences of resistance as we also develop critical educational studies and related stories from a strength- or asset-based perspective" (p. 336). Critical resistant navigational skills are a form of resistant capital that allow Youth of Color to succeed within and across institutions and settings that enact dominant cultures and values (Solórzano & Villalpando, 1998). In describing different types of resistance, Solórzano and Delgado Bernal asserted that youth and adults can use *transformational resistance* to critique oppression and move toward social justice. By contrast, Youth of Color who enact *resilient resistance* may not overtly challenge or seek to change structures of domination, yet they still apply skills and strategies that help them survive and succeed in hostile environments (cf. Yosso, 2000). In both cases, resistant capital includes skills and bodies of knowledge, developed through action, which enable minoritized youth to withstand or challenge exploitative or oppressive systems. We propose that enactments of resistance—when developed in the context of sociohistorically situated, tool-mediated action and relationships—meet Moll's definition of funds of knowledge in the sense that these enactments result in sociohistorically situated skills and bodies of knowledge that enable individuals to survive and thrive. Accordingly, this study also describes the youths' engineering-related resistant capital in the context of exploitative workplaces.

Mobilizing Funds of Knowledge

In describing how theories of capital and theories of funds of knowledge might be productively combined, Rios-Aguilar et al. (2011) argued that theories of capital emphasize "activation/mobilization," whereas "the mere recognition of funds of knowledge has not translated into better educational and labor market outcomes" for minoritized students (p. 178). In other words, many theories of capital describe how capital is mobilized to accrue more capital (e.g., better labor market outcomes), whereas many theories of funds of knowledge have not emphasized mobilization toward outcomes outside of individual or household functioning. Following Rios-Aguilar et al.'s (2011) recommendations, we draw from the concept of mobilization, central to theories of capital, to understand how youths activated their funds of knowledge to actualize more humane and just experiences and outcomes. For engineering education to be fully equity-oriented, we believe that it is not only important to recognize and foreground youths' funds of knowledge and assets, but it is also important for educators and educational systems to critically consider the larger purposes toward which these funds of knowledge are mobilized.

Moll and colleagues (1992) initially asserted that funds of knowledge are primarily applied toward achieving "household or individual functioning and well-being." This application of funds of knowledge remains essential: engineering-related funds of knowledge can make a difference in the quality of life of families and individuals through the improvement of devices, processes, and systems in their households and lives (Wilson-Lopez et al., 2016). However, we agree with other scholars that funds of knowledge can achieve purposes beyond household and individual functioning, such as when they are mobilized toward advancing social justice in communities and in society at large (Tan et al., 2018). Moreover, whereas some scholars have described how funds of knowledge were mobilized to support children's learning of existing standards and curricula (Moll et al., 1992), others have asserted that funds of knowledge should instead be mobilized to sustain linguistic and cultural plurality (Paris, 2012). Still others (e.g., Moje et al., 2004) have called for hybrid pedagogical approaches: ones that mobilize funds of knowledge toward supporting youth learning relative to educational standards, while simultaneously using funds of knowledge to challenge the normative assumptions canonized in standards, with the intention of sustaining the cultural practices of minoritized youth.

We outline these different views to highlight that, after they are developed, funds of knowledge can be mobilized toward different purposes in formal and informal educational settings, such as homes, schools, or after-school engineering clubs. These purposes themselves may or may not lead to equitable consequences for transnational Latinx youth, their families, and their communities, who have historically experienced inequity in the form of economic injustice and exploitational systems in which their underpaid and undervalued labor is used to advance the interests of dominant groups (Golash-Boza, 2015). In recognition that it is also important to consider how funds of knowledge are mobilized toward purposes, we sought to learn from Latinx youth regarding how they mobilized or hoped to mobilize the extensive skills and bodies of knowledge they acquired in their workplaces toward desired futures, under the belief that youth themselves should identify purposes for education that are consequential and meaningful to them.

In the context of this theoretical and empirical framing, this study sought to answer the following three research questions:

1. What engineering-related funds of knowledge did transnational Latinx youth develop in the context of different workplaces?
2. How did they develop these funds of knowledge?
3. Toward what purposes did they mobilize, or hope to mobilize, engineering-related funds of knowledge developed in workplaces?

By identifying funds of knowledge of working youth and the ways in which they hope to mobilize these funds of knowledge toward more equitable futures, this study has implications for the design of learning environments in which funds of knowledge are actively elicited and mobilized toward purposes that matter to youth and in ways that advance equity.

Context of the Study

For the past decade, we have worked with transnational Latinx youth, primarily in rural and semirural areas in the western United States, in the context of after-school engineering programs, STEM-oriented programs such as MESA (Mathematics, Engineering, and Science Achievement), and programs designed to foster leadership among Latinx youth, such as Latinos in Action. This work has included research with groups of youth who identified problems in their neighborhoods or communities and addressed them through engineering practices (including through their engineering-related funds of knowledge). Early on, we quickly learned that many of the high school youth in these programs held one or more jobs after school and used their experiences in their jobs to inform their solutions to problems. Informed by theoretical literature on the importance of funds of knowledge derived through labor histories, and consistent with the principles of emergent design

in qualitative research, we wanted to learn more about the engineering-related funds of knowledge developed in the youths' workplaces. Accordingly, we conducted occupational interviews and workplace observations to better understand the skills and bodies of knowledge that the youth developed at work.

Participant Description

Youth participants in this study were part of a larger project designed to explore the funds of knowledge of Latinx youth (Wilson et al., 2012). This study includes previously unanalyzed data from this project by describing the workplace-related data of 20 transnational Latinx youth (ages 15–18) who worked one or more jobs for the purpose of obtaining individual or family income, either formally or informally, in the past or at the time of the study. We define workplaces broadly as sites of activity designed to generate personal or family income. For example, some youth worked in fast-food chains, whereas others helped their families make items for selling while at home. A few participants also held structured internships and mentorships designed to bridge over to paid employment with the interning institution. We included these sites as workplaces for the purpose of this study.

When analyzing the data, we noticed differences between funds of knowledge developed in the context of family-owned businesses versus corporate-owned businesses, as described more in our findings section below. To highlight these differences, Table 1 describes youth occupations relative to family-owned businesses, whereas Table 2 describes youth occupations relative to corporate-owned or affiliated businesses. As noted in each table, we used both the original words of the participants (italicized), as well as definitions from the U.S. Bureau of Labor Statistics' (2018) *Standard Occupational Classification* to identify type of work. As noted in the tables, several participants noted that they "did everything" or "was everything" at work. When a single job could have been assigned with multiple BLS classifications (e.g., waiter and cashier), we used only one job classification that aligned with the activities that they reported doing the most often. When a participant worked at multiple jobs, s/he was named under multiple rows and BLS categories. As indicated by the tables, the participants worked in a range of occupations, all of which are overrepresented by Latinxs (Catanzarite & Trimble, 2008).

Research Methods

In accordance with our research questions, we conducted a multiple comparative case study of the workplace funds of knowledge of 20 transnational Latinx high school youth. A single case was comprised of a participant's sociohistorically situated, tool-mediated actions, often performed with co-agents, resulting in the development of the participant's funds of knowledge (skills and bodies of knowledge) within one single workplace. If one participant worked in two places, we treated that as two cases. We analyzed data relative to individual cases, then compared and contrasted the individual cases by exploring whether there were similarities and differences related to business ownership (family-owned or corporate-owned).

Data Sources

To learn more about the youths' engineering-related funds of knowledge (research question one) and how they developed these funds of knowledge (research question two), we conducted workplace observations, occupational interviews (Civil & Andrade, 2002), and retrospective interviews (Sosniak, 2006). To explore how the youth mobilized and hoped to mobilize youths' funds of knowledge (research question three), we conducted semi-structured interviews that used previous findings as the basis for follow-up questions (Rubin & Rubin, 2012). We elaborate more on each of these data sources below.

Workplace observations or alternatives

To learn more about the funds of knowledge acquired in different workplaces, we visited youths' workplaces and asked the youth to describe what they were doing and why they made particular decisions to us as they engaged in core activities (if possible). If it was not possible for the youth to narrate what they did while they worked, then we used the field notes or audio recordings from these observations as the basis for follow-up interview questions in which we asked the youth to recall what they were doing and their decision-making processes. We conducted workplace observations in seven different cases.

Most participants who worked at corporate-owned businesses indicated that workplace observations would not be possible; some participants stated that workplace conditions were unsafe and employers would not want researchers there. When this occurred, we used one of two alternative data sources. First, with permission, two participants shared an audio and video recording they had taken of a focused workplace activity. These data helped inform our understanding of their workplace practices. Second, when possible, the participants explained their decision-making processes in similar settings

Table 1
A description of the jobs worked by youth in the context of family-owned businesses.

Pseudonym	Participant description of job worked	Family co-workers	BLS category
Food preparation- and serving-related occupations			
Carlos	*I was everything; I cooked and I cleaned and was a waiter* in two family-owned restaurants	Aunt and stepdad	Cook, restaurant
Pedro	*I'm in charge of all the bread, all the water* in a restaurant of a close family friend	N/A	Cook, restaurant
Margarita	*I would help her* [mother] *cook everything, and put everything up, put the tables out, just do everything* in a family-owned restaurant	Mother and siblings	Cook, restaurant
Ana	*We make and sell popcorn* in a family-owned stand	Mother	Food preparation worker
Farming, fishing, and forestry occupations			
Carlos	*I helped him* [my grandfather] *grow avocadoes.* [I would also] *go out and sell them*	Grandfather	Farmworker and laborer: crops
Antonio	*Beef cattle, that's all we raised…All we do is we feed them and just the calving and after that we usually sell them to auctions* on a family-owned ranch	Father	Farmworker: animals
María	*I move pipelines or the cattle; feed the chickens, feed the horses, the pigs, the goats* on ranch owned by uncle	Siblings and cousins	Farmworker: animals
Sales and related occupations			
Nancy	*I get the car's information* for family-owned mechanic shop	Father	Counter clerk
Elizabeth	*I was a cashier kind of at my dad's restaurant*	Father and siblings	Cashier
Silvia	*If we needed cilantro, limes, or onions, I would go buy that. I was also the cashier* in a family-owned restaurant	Parents and siblings	Cashier
Healthcare support occupations			
Patricia	I help my grandmother *take care of old people; like she'd give them showers*	Grandmother	Personal care aide
Personal care and service occupations			
Ricardo	*I babysit for my mom's friend; there are three kids*	N/A	Childcare worker
Patricia	*I was just like babysitting*	N/A	Childcare worker
Building and grounds cleaning and maintenance occupations			
Alejandra	*He* [my father] *cuts lawns, so sometimes I help him* in a family-owned landscaping company	Father	Landscaping and grounds-keeping worker
Construction and extraction occupations			
Marco	*I was painting…we do all the preparation for it, like fixing the walls and everything, we do it* in a family-owned painting business	Father, uncle, brother	Painter
Production occupations			
Carlos	*We've done skirts and blankets, and we sell them together*	Aunt	Sewer, hand
Installation, maintenance, and repair occupations			
Arturo	*It's a mechanic shop, and I help him* [my boss], *like he told me, "you're taking an engine out."*	N/A but father helped from home	Automotive service technician and mechanic

outside of their workplaces. For example, Marco painted the interior of houses, a job that entailed giving estimates to customers. Though we did not observe him painting a house, we asked him to explain how he would give an estimate to a customer in the context of a specific room and a specific type of paint, and how he would approach the task of painting the room with the help of his co-workers.

Interviews

The youth participated in an average of four total 60-minute interviews. First, for the 18 youth who were currently working, we conducted occupational interviews (Civil, 2016; Civil & Andrade, 2002), which are designed to elicit narratives around the processes of learning and engaging within specific occupations. During these interviews, the youth shared narratives regarding recent workplace experiences (e.g., stories about events or interactions with co-workers); they also described recent and typical workdays. Consistent with our theoretical framework, for each core activity identified (e.g., picking berries), we asked youth to elaborate on how they worked with others (*agents*); the overall *goals* of the activity; and the *tools* they used. To explore power dynamics within each scene, we asked the youths to describe their relationships with their co-workers. To address research question two, we also asked them to describe how they learned core tasks or activities at which they were already proficient.

Two of the participants were not working at the time of the study. Additionally, among those who currently worked, three had previously worked in Mexico before moving to the United States. To learn about workplace practices that had occurred

Table 2
A description of the jobs worked by youth in the context of corporate-owned or corporate-affiliated businesses.

Pseudonym	Participant description of job worked	Family co-workers	BLS category
Food preparation- and serving-related occupations			
Martín	*I wash the dishes and wash the floor* at a hotel restaurant	N/A	Dishwasher
Ricardo	*I worked in the grill* of a national fast-food chain and in a second fast-food chain	N/A	Cook, fast food
Laticia	*I did everything. I was cashier, and I was floor and I was food and I was everything* at a national restaurant	N/A	Fast-food and counter worker
Farming, fishing, and forestry occupations			
Elizabeth	*I was picking berries*	Aunt and siblings	Farmworker and laborer: crops
Silvia	*I've picked blueberries and strawberries, and those are better than raspberries*	Mother and siblings	Farmworker and laborer: crops
Marco	*I help them carry hay and feed the calves* on a farm	Father and uncle	Farmworker: animals
Arturo	*I work as a dairy farmer*	Father	Farmworker: animals
Teresa	*We take out the chickens from the cages and then put them in this compartment*	Father	Farmworker: animals
Alicia	*We usually move chickens and we're in these chicken farms*	Father	Farmworker: animals
Sales and related occupations			
Antonio	*We help out the customer when they come, like if they don't know if they have rented the equipment before then you like show them how it works* at an equipment rental company	N/A	Counter and rental clerk
Ricardo	*I sell clothes* at a national clothing company	N/A	Retail salesperson
Patricia	*I had a newspaper route*	N/A	Door-to-door sales worker
Laticia	*I rearrange furniture* [for display]*; we would just play around with what we liked* at a furniture store	N/A	Demonstrator and product promoter
Healthcare support occupations			
Rosa	*I am a Certified Nurse's Assistant* at a residential home. *We go in and we help them with their needs that they can't do by themselves*	N/A	Nursing assistant
Nancy	*I just help with the vet assistant so sometimes we have to get the cat's weight and temperature and give them medicine*	N/A	Veterinary assistant and laboratory animal caretaker
Personal care and service occupations			
Carlos	*I really like doing hair, cosmetology* as an intern in a salon	N/A	Cosmetologist
Building and grounds cleaning and maintenance occupations			
Marco	*I would help them mow, put the machines in the trailers, or just attach the trailers to the truck, or break cement* at a landscaping company	N/A	Landscaping and grounds-keeping worker
Construction and extraction occupations			
Verónica	*My dad works in construction so I help a lot with building*	Father	Roofer

in previous years, we conducted retrospective interviews (Sosniak, 2006), which are designed to elicit how people developed skills and bodies of knowledge from previous work. As before, we asked about the roles and relationships among co-workers, the goals of the work, the tools they used, and how they learned to perform core activities.

Finally, for all participants, we conducted semi-structured interviews designed to explore how they mobilized and hoped to mobilize their engineering-related funds of knowledge. Consistent with principles of emergent design in which researchers use findings from previous data to develop new research protocols (Rubin & Rubin, 2012), we used findings from earlier interviews or observations to ask questions regarding how the youth mobilized or hoped to mobilize specific engineering-related, workplace-acquired funds of knowledge toward current goals and future aspirations (research question three). For example, in a previous interview, Arturo had expressed that he hoped his job as a mechanic would help him to become an electrical or mechanical engineering major in college, and we asked him to tell us more about that statement.

Data Analysis

To answer research questions one and two, we used our theoretical frameworks as a lens for understanding the data. Specifically, for each major workplace activity (a term which we use synonymously with commonly performed *mediated actions*), we sought to understand and describe the agents, mediational tools, goals, and resulting skills and bodies of knowledge as described by the participants. We also sought to understand how systemic inequality influenced the different scenes in which the participants worked through attending to power relations between co-agents; competing goals among

different co-agents; and issues of access to mediational tools. To answer research question three, we used constant comparative analytic methods to develop themes describing how the youth mobilized and wanted to mobilize funds of knowledge. Tables 3 and 4 provide examples of codes developed in response to the research questions using these methods.

Positionality and Ensuring Research Quality

The first author identifies as white while the second author identifies as Latinx. Milner (2007) asserted that there are dangers—including color- and culture-blind research—when white people conduct research with People of Color. To avoid these dangers, the white author used Milner's questions for cultural self-reflection during the data analysis process, as part of a process of acknowledging the role of race, ethnicity, language, and culture in the research design, findings, and applications of findings. The white author also sought to build and prioritize caring relationships with the participants over time through actions such as writing letters of recommendation: holding dinners with them at her house and in their preferred restaurants; talking with their parents about life events; and driving them to work or home when their transportation plans were disrupted. Through prioritizing relationships and through self-reflection, the first author sought to avoid an exploitational research process.

Additionally, both authors actively sought to establish quality in qualitative engineering educational research with linguistically and culturally diverse participants (Wilson-Lopez, Washburn, & Hasbún, 2018). These processes expanded upon Walther et al.'s (2013; cf. Walther et al., 2015, 2017) commonly cited framework for establishing quality in interpretive engineering educational research, by outlining strategies for foregrounding the languages, cultures, and perspectives of research participants from historically minoritized groups. Specifically, we sought to establish theoretical validation, defined as a fit between social reality as well as an asset-based theoretical lens, through building from the theoretical and methodological work of prior scholars (e.g., Luis Moll and Marta Civil) whose research designs accounted for, and whose theories were generated with and from, work with transnational Latinx youth.

We sought to establish procedural validation, defined as transparent procedures designed to establish overall quality, through sharing our interview questions and early findings with transnational scholars who have conducted research with transnational Latinx families. These scholars provided feedback on how we could modify our interview protocols to increase the likelihood that they honored the participants and did not trigger stereotype threat or other trauma. We sought to establish communicative validation with participants through conducting interviews in their preferred languages and through offering to share emerging findings with them. Additionally, the resulting codes were co-developed, reviewed, and confirmed by a scholar, and author, with lived experience and expertise in Latinx communities, engineering and technology education, and engineering educational research.

We sought to establish pragmatic validation, or claims that withstood exposure to social reality, through foregrounding activity in naturalistic settings such as workplaces. Ethical validation permeated all aspects of research as we interrogated our own assumptions through conversations with others; as we modified the research design to be responsive to research participants (e.g., not conducting workplace observations for many); and as we sought to produce a study that had applications to practice for educators of working Latinx students. Gutiérrez and Penuel (2014) asserted that applicability to practice is a primary criterion for determining the quality of research, and we ultimately hope to contribute to pedagogies that deeply foreground the ingenuity that transnational Latinx youth have developed in partnership with relatives and co-workers, and to advance pedagogies which respect youth-driven purposes for the application of an expansive set of engineering-related bodies of knowledge and skills.

Findings

We contextualize this study with our sense of awe and respect for the extraordinary dedication and hard work of the youth participants. After a full day of classes at their high schools, several reported working until 11:00 at night in order to "save enough for college," to "pay for the car bills and house bills," to save money for items or services for themselves, and to help their parents save for their younger siblings' college funds. In addition to working before or after school, many worked long hours during the summers as well. Arturo described his summer schedule as "During the summer, that's what I did. Woke up every single day at three in the morning, and then Saturdays and Sundays, woke up at three in the morning and went until ten. And then after that I was dead." Other youth worked shorter shifts, for example, in the mornings on Saturdays and Sundays throughout the school years and summers. Regardless of time worked, all participants developed engineering-related bodies of knowledge and skills at their workplaces.

In this Findings section, we divide the results according to family-owned businesses and corporate-owned or affiliated businesses. Under each heading, we use our theoretical frameworks to describe the youths' engineering-related funds of knowledge (research question one) and how they developed (research question two). We then conclude the Findings section

Table 3
Examples of codes related to co-agents, goals, and mediational tools.

Descriptions of codes	Illustrating data
Co-agents: people employed at the same workplace who taught participants how to engage in the workplace activity; who participated in workplace activities with the youth; and/or who were trained by the youth	
Teacher, or person who explicitly taught youth how to perform workplace tasks	Well, my boss he pretty much taught me everything. Because when I started working, he taught me how to drive a tractor; he showed me what he does to be faster. He told me what he went through and I guess that kind of helped me because like he would tell me if I had like a calf dehydrated, if I were you I would put a little more water in the middle [of the trough].
Goals: purpose(s) for engaging in the activity	
Minimizing time spent on an activity, in this case, minimizing time spent outdoors in the cold when taking indoor trash to the outdoor garbage can	We would have to walk in the cold and it was just really horrible. It was like really a block away. […] You have to make two trips because there are four garbage cans. So you take two first, then you walk back with those two garbage cans and you put them back where they're supposed to be, then you take the other two garbage cans, empty them and bring them back to the restaurant. […] So we would do one trip and we would fill four garbage cans and we would have to take all four to the big garbage can.
Mediational tools: technical or psychological tools used by agents to achieve intended goals	
Memorized steps or procedures for performing the activity, in this case, steps for making horchata	It was easy for me to memorize it [the process for making horchata] actually. I still have it all in my head. There was like this huge bucket kind of thing and then they would have lines and they have four lines. I would have to fill it up to the third line and I would have to put like six cups of horchata and then mix it. And then it's really heavy too so we have to pour it in, you have to get on a chair and pour it in to this machine and that really hurts your back. And then you would just close the machine and then they'll be done in like two hours. The machine just mixes it and it keeps it warm. When you get horchata, it's supposed to be warm, so you put ice in it first to make it cold.

with a description of how the youth mobilized or sought to mobilize their engineering-related funds of knowledge (research question three).

Family-Owned Businesses

We begin this section with a quote by Carlos, which highlights the types of responsibility shouldered by some of the youth in this study. "I was all by myself in the morning and took care of everything by myself. The restaurant opened at 11, so I would get there at 9, and I started cooking and making everything for the day," he said, "like burritos and the chicken and beans and rice. I had to make the guacamole; I made the Pico." In the absence of formalized procedures or processes (which might have specified which type of food should be prepared first, in what manner, and in what amount), Carlos developed a series of processes for food preparation designed to result in safe, consistent good-tasting food for customers, ready when the restaurant opened. Additionally, he intended that the business enterprise as a whole would result in revenue for his family as businesses owners.

According to theorists of industrial engineering, "almost always, the goal of industrial engineering is to ensure that goods and services are being produced or provided at the right quality at the right time at the right cost" (Hicks, 2001, p. 1.85). Many Vygotskian-inspired sociocultural theories (Cole, 1996; Leont'ev, 1981) emphasize the roles of *goals* as primary drivers in human development because people design and use psychological and technical tools with the purpose of achieving those goals. Many youth who worked in family-owned businesses, such as Carlos, worked to achieve the family goal of producing quality products and services at the right time and for the right cost. Consequently, we assert this goal fostered the development of skills and bodies of knowledge similar to those recommended by industrial engineers. In this section, we use Vygotskian theories and theories of funds of knowledge to describe the engineering-related skills and bodies of knowledge developed by youth who worked in family-owned businesses.

Ana: Iteratively Designing and Improving Processes

Tenth-grader Ana described a set of procedures that she and her mother co-developed in the four years that they co-managed a mall kiosk that sold popcorn. Initially, they read the instructions that came with the popcorn machine, but later, most of the product innovations they developed, such as different flavors of popcorn, came through testing the

Table 4
Examples of engineering-related funds of knowledge.

Descriptions and explanation of codes	Illustrating data and excerpt
Examples of skills and bodies of knowledge related to industrial engineering	
Designing processes: Developing processes to ensure quality, quantity, timing, and price while working within constraints (Saito & Yokota, 2001) Explanation: Margarita mentioned working within constraints (e.g., only having four burners on a stovetop) to deliver consistent results at a specific time: 6:30. She mentioned the importance of consistency in quality through maintaining the same-size cuts, as well as timing different processes to maximize the use of the burners	We first cooked the chicken because that takes the longest. We only had a normal stove that had like, four, like only four burners on the top. So we would put that first. Once that is done, we start working on the carrots and potatoes. […] Like you cut them into little squares, and we would have to make a lot of that, because it is like a lot of people and so we would do that, and you would have to make a certain sauce for that too. First you would boil it until it got soft, and then you would put it into another can and put it in a little thing, and then make the sauce for that, and then that would be done, but then it takes like forever to do that. It takes forever to cut it, and it is just so much work to do that. Also they had to be like perfect because you didn't want them too big or small, and if they were too small when you boiled them it wouldn't work, and if they are too big then it just won't work you know. And then the chicken will be done by the time that I am done with cutting the carrots [which would then be boiled with the potatoes. Further explains processes to ensure that consistent food is provided by 6:30 when customers arrive].
Forecasting: Developing valid predictions of standard times, materials, equipment, and costs needed to perform operations, and using these data to predict profits (Aft, 2001) Explanation: Marco considered different factors needed to predict timing and cost, such as the inclusion of primer/no primer and multiple colors versus one color; type of paint brush needed for the wall texture and color; necessary supplies such as tape; and time spent on labor for various aspects of the process (e.g., labor spent in taping, putting on primer, painting in one or multiple colors with a specified type of painting implement; surface area of wall). He also considered the need for maintaining a competitive price to attract customers as part of a solvent business	Interviewer: So let's say how much red paint would you need for that wall do you think? Marco: Well it depends because that's red paint so we would use a spray gun because that type of red with the wall is not too good…If it's that color or a darker color we put primer. So it just depends. But let's say we use primer for just a darker color, I think pretty much like a gallon or two and the primer, just tape, and that's it so 30 or 40 dollars for it. Interviewer: How do you know that? Marco: Well I know how much the paint costs us so I know how much that would be and for just us working, for the labor, that would take us maybe, that would be about $60. Yeah it would be about $60 so maybe like $110 to do this whole wall…this whole room would take maybe three hours to do it with preparation and stuff. Like if it's different colors like it is right now, but if it's the same colors, then it's really quick. So it's just more materials because like on big houses that take us like a whole week it's more expensive because, well the house that we're doing right now it's $4000 to paint but it's like $900 in material […] On the estimate, he [my boss] pretty much thinks up how much primer or paint he is going to use. So he doesn't want to use too much or the price will be too expensive, but he can't have too less or he won't have enough […] He's teaching me how to estimate.
Promoting worker safety: Identifying and analyzing sources of potential injury for workers and/or developing procedures or technologies for promoting worker safety (Bloswick & Sesek, 2001) Explanation: Marco identified the cause of an injury and a solution that would prevent the injury	It was raining so I was touching the cow and telling her to get up but she wouldn't get up, so I was touching her trying to shock her. My hand was touching the cow and it [the electric current] ran back to me. And I had done it always, I had always done it, but I had cotton gloves so of course it didn't go through. But this time I didn't have no gloves on.
Sequencing operations: Determining the order needed to carry out a set of operations or tasks (Sassani, 2017) Explanation: Ricardo enacted a series of sequenced operations and he understood the importance of following this sequence for preventing contamination	At first, of course you have to wash your hands to use the grill and to get the meat out of the little freezer. You have to have the gloves on. You always have to have gloves…You have to have your normal doctor gloves. They have those. Then you put the blue gloves over those white gloves to get the meat to put on the oven. You have to throw away the blue ones, but you have to throw them away right after you touch the meat so you don't actually discontaminate.
Examples of general engineering skills and bodies of knowledge	
Ingenuity: Demonstrating creativity, inventiveness, originality, or resourcefulness in meeting challenges (Greenberg et al., 2020) Explanation: With minimal available materials, Laticia developed a resourceful solution to challenges she faced when carrying out the garbage	Laticia developed processes for more quickly transporting heavy garbage cans by connecting them and lifting them with a lever. In her words, "there is one can and it has wheels and then another garbage can that has wheels but they don't connect so when you're walking you have to like sort of hold them together so it will stay with you," so she made something that "would just have like wheels at the bottom and lever sort of thing so you could pull it and it would be easier and it would hold a bunch of stuff".

Table 4
(Continued)

Descriptions and explanation of codes	Illustrating data and excerpt
Technical orientation: Seeking feedback from the material world (Apedoe & Ford, 2010) Explanation: Arturo tested different physical objects or processes and identified how modifications affected outcomes	We put everything in, and we put the harness in, we had to test it to see if the connections were the right stuff. We did airbags, ABS system, water pumps, your gas pump, and everything, gas lines, break lines, your E break, suspension, basically everything, put the brand new engine in it, and right now we're to the point where it's just the little details.
Optimizing: Improving solutions through trading off less important features for those that are more important and that maximize desired outcomes (Achieve Inc., 2013) Explanation: Marco explained the importance of finding the right "spot" that minimized the amount of food given to the cows while maximizing the amount of milk they produced	So then if you switch out their [the cows'] diet, they're gonna completely start messing up, they're not gonna produce the right amount of milk, their milk is gonna come out a lot slower… so you have to find a spot where they like their food and they're still producing a lot of milk, and he's [the farm owner is] not spending a lot of money on food [for the cows].
Troubleshooting/problem solving: Identifying the cause of problems and/or developing solutions that fix the problem (Crismond & Peterie, 2017) Explanation: Arturo consulted different sources to identify the cause of a problem with a car and identified a possible fix for this problem	I've been trying to see how we can fix that. And I think it might be a—I looked at the schemes, one they gave me, and there's a cable that is black with brown, and I think it should to be hooked up to the ignition switch, and I think it is not put on correctly.

outcomes that occurred when they experimented with different ingredients and processes. Ana described the process of making popcorn:

Ana: First you open the door of the popcorn maker, and you lift up a metal thing that is inside, and then you put in the corn. Then you put in three, I don't know the measurement that the cup is, and you put in three, and then two of oil.
Interviewer: Okay, oil for popcorn. Is it special oil?
Ana: Well, you can use normal oil, but if you use the popcorn that has color, then you only put one and a half, like half of what you would do with normal popcorn. If you use normal oil, you only use one, but if you use oil for popcorn, then you don't put on salt because it has it in the oil.
Interviewer: Okay, so salt and normal oil go together?
Ana: Um hmm (yes).
Interviewer: And the popcorn oil, just that? [goes by itself?]
Ana: Yeah, and when you put in normal oil you first push a button. There are three buttons. One is always on because it is the light for the machine, the other for when you put in normal oil, and the other for the salt. But when you put in the oil for popcorn, then you push both at the same time, and then you put them in the bag to serve them.
Interviewer: And do you make it with popcorn oil, normal oil, or both?
Ana: Both because since we sell in the city, if we run out of the popcorn oil, then we use the normal oil.
Interviewer: And what is the difference between the two?
Ana: It stays better with the popcorn oil. It stays on different and it tastes better. And the machine [word unclear in recording] when we use normal oil, and it gets dirty too.
Interviewer: Oh, is it because of the normal oil or the salt?
Ana: The oil, because the salt with the one [oil] for popcorn doesn't affect the machine either.

In the context of managing the popcorn stand, Ana developed and demonstrated different funds of knowledge related to industrial engineering, including the application of *process design* that reliably produced consistent and quality results. Specifically, she and her mother iteratively developed, tested, and improved processes and ingredients for producing popcorn. She considered different factors needed to produce intended results, including maintaining consistency of (a) sequencing of procedures, (b) machine operations and maintenance, and (c) measured ingredients. Ana also developed engineering-related skills such as *troubleshooting*, or analyzing causes of undesirable results in the context of a system through isolating variables, when she identified that the normal oil, and not the popcorn oil or different types of salt, would dirty the machine, and that it would lead to worse-tasting popcorn.

Vygotskian theories would suggest these funds of knowledge, or skills and bodies of knowledge, develop through tool-mediated, goal-oriented activity with others. In this case, Ana developed skills related to process design and troubleshooting, through using a popcorn machine as a technical tool and through developing, using, and evaluating different sets of procedures as a psychological tool that helped her to achieve the goal of consistent, quality popcorn. In this

context, Ana and her mother, as co-agents whose relationship was characterized by care and respect, were co-learners as they jointly experimented with the outcomes associated with changing different variables together, and as they discussed the results and the implications for subsequent popcorn preparation. In a demonstration of respect for Ana's knowledge and skills, Ana's mother trusted her to manage the kiosk by herself where Ana continued to enact processes in the context of self-guided experimentation.

Pedro: Forecasting to Optimize Space

Like Ana, eleventh-grader Pedro also developed skills and bodies of knowledge related to industrial engineering when he worked as a host and baker in a two-room restaurant managed by a family friend out of a home. Because the space was so small, the restaurant owners preferred that people make reservations. Pedro helped up to set up the restaurant by organizing tables in different spatial arrangements prior to opening time; he also escorted people to their tables and served them water. When escorting people to their tables, he decided which table to escort them to, whether to rearrange tables of different sizes, and which tables to rearrange. In his words:

> **Pedro:** You have to memorize all the tables and the numbers for the tables. So I guess up to a certain point the, and you also have to, based a lot of counting. A lot of counting is involved. Because like say, three tables come in and they all leave at the same time, theoretically you've sat all three at the same time, so you have to count like how many and then you have to see if someone's reserved, for example if there's a table for four, normally like four spaces, but only two people have a reservation, like just a reservation for two people, you have to like take that into consideration, just placing them in the right spot. Because you don't want to like, you don't want to put too many people, you don't want to put them in one of the bigger tables because then if a big party comes in, you have to take out all the other small tables and put them together.
> **Interviewer:** So that sounds kind of complicated. Like trying to figure out…
> **Pedro:** Like how long people are going to eat for, so you have to like, for Valentine's Day, that was crazy, it's like, we could only allow parties of four or less, no parties of more than four. And we had to take into consideration the times that it takes people to eat, so it's like, okay, we have this amount of tables, to put these people on these tables, and then you have to like call people to let them know that they should come at this time approximately so, I don't know, it's a little complicated sometimes. It depends. I guess, if you took all, for example for one week, all the people came in groups of around three, but we [have] lots of two-top tables […]
> **Interviewer:** So how do you plan for that? I mean I guess you kind of can't because you never…
> **Pedro:** We plan as much as we can. So, we plan as much in advance as we can, so as soon as we know that for example [name of business] calls about once a month and they're like, "we need a table of 16," which is kind of a hassle to get, like set up tables for 16 people. But typically they are all right because they typically call about four days in advance. It's complicated. We probably get in one night more two person tables than other tables.

Like Ana, Pedro demonstrated skills and bodies related to industrial engineering, including using *process design* intended to result in a profitable business. Specifically, Pedro developed processes for helping him make decisions regarding where to place people when seating them: first, prioritizing people on the reservation list to ensure they had an appropriate-sized table ready at the right time; second, using his knowledge of past trends to set up remaining tables (people usually ate in groups of two, followed by groups of four, and they usually ate for 1.5 hours); then third, meeting the needs of walk-ins who did not fit in the available tables of two or four by moving tables that would require the fewest number of tables moved and the smallest possible tables moved.

Additionally, he demonstrated the skill of *forecasting*, which is core to many types of industrial and operations engineering (Sassani, 2017), by using recent data (number, size, and time of groups on current reservation list); historical data (typical group size and time it took to eat dinner); and up-to-the-moment changing data (number of walk-ins) to ongoingly make and adjust projections and decisions regarding whether, when, and how many new customers should enter the restaurant and where they should be placed. Finally, he also demonstrated the skill of *optimizing*, which is highlighted as an important engineering skill in national high school science standards (Achieve Inc., 2013), by strategically maximizing available space through table arrangement and minimizing the number of empty chairs. In turn, his optimization resulted in a more profitable business as more paying customers could sit in the restaurant.

In this example, Pedro developed funds of knowledge, including skills that are central within industrial engineering, through tool-mediated, goal-directed activity. He helped his friends, the restaurant owners, to achieve their goal of maximizing the number of customers in a limited space with different-sized tables. To this end, he developed a set of procedures as a psychological tool that enabled him to quickly make complex, on-the-spot decisions entailing a

consideration of variables. Unlike Ana, who described a process of co-learning with her mother, Pedro described the process of learning to host as largely self-guided. While a family friend initially explained the hosting process to him, much of the complex decision-making, guided by his procedures for prioritizing, was developed through self-guided experimentation.

Arturo: Troubleshooting and Iteratively Developing Processes to Make Work Go Faster

Eleventh-grade Arturo worked in a car mechanic shop owned by a family friend. Although his father did not work with him, Arturo reported that his father helped him to be a better mechanic through fixing cars with him at home. In his words:

> We fix them but we learn together. Like we'll get into the computer and research for a little bit and watch a YouTube video or something. Then we go outside and it takes us like five hours to fix a simple thing, but we work together and see like different things that we could do and then, and kind of fix it. So we learn at the same time and then work together.

He reported that this process of fixing cars at home with his dad made him a better employee in the car mechanic shop, where he also learned together with a supportive "boss" and family friend. He described the process of learning how to fix cars with his boss:

> Yeah, we're kind of figuring it out as we go. Cause he knows a lot about it. And we're probably taking the car in pieces like 3 or 4 times. We'll put it together, and then we'll realize we did something wrong in the beginning so we have to take out the seats, take out the floor mat, take out everything, and then get to the part, and put everything back together. Then we figure out if something was wrong again, and then take it all out again, but every time we get quicker. The first time we put it back together, it took like 2 or 3 hours, and now in like an hour and a half, we could take the whole car apart and put it back together.

Arturo later explained that disassembling and reassembling a car required a series of carefully performed procedures: "You've got gas lines; you've got all your fluids; you've got hoses that go to your engine; you've got all the wiring that goes to it. So you have to be careful that when you take out the engine, you're not ripping all those wires, so you have to disconnect every single wire and everything." Through a process of experimentation with his father and boss, coupled with YouTube tutorials, he developed a series of procedures for reinstalling an engine that had been removed. These procedures included first putting the engine inside the car, then adding bolts, then reattaching hoses and wires, "then hope the car turns on." This set of procedures reduced the time spent in disassembly and reassembly from 5 hours to under 1.5 hours.

In his work at the mechanic shop, supported at home by his father, Arturo developed engineering skills related to *troubleshooting*, as he and his boss together identified the reasons behind why cars performed suboptimally and developed solutions to those problems. Like the other participants, he also developed skills related to *sequencing operations* as he designed a series of sequential steps for removing and reinstalling engines with the goal of minimizing time in labor while maximizing the likelihood of a functional car. In Vygotskian terms, the sequential steps he developed were a psychological tool that enabled him to meet goals of minimizing time in labor and thereby maximizing profit, while the technical tools that he used included a variety of general tools as well as "special tools" specific to different brands (e.g., Honda, Volkswagen). In this example, as in others, Arturo developed skills that are valued within industrial engineering, and engineering in general, through his ingenuity at the workplace and through opportunities to co-learn, through a process of experimentation, with caring adults as co-learners.

Summary of Findings Related to Family-Owned Businesses

In these workplace examples and others, the youth developed funds of knowledge that are germane to industrial engineering, including the capacity to design processes and/or sequential operations that maximized profit, ensured consistency and quality of results, and minimized waste of time, labor, space, or materials. Their technical tools varied widely—from popcorn machines, to wrenches, to chairs. However, the psychological tools bore similarities in the sense that, across worksites, youth developed procedures or processes that fostered efficiency and quality at work. They often developed these engineering-related skills and bodies of knowledge in the context of co-experimentation with caring adults, especially parents, but these funds of knowledge were also further developed through individual experimentation in which the youths "tried things out" on their own.

In family-owned business contexts, youth were usually positioned as experts who were trusted to manage substantial parts of the business themselves. When entrusted with these responsibilities, the youth demonstrated exceptional ingenuity in meeting complex challenges and helping their families to earn income. While many of these skills resembled hallmarks

of industrial engineering, the youth also developed skills that cut across branches of engineering as well, such as troubleshooting, optimizing, and demonstrating a technical orientation through seeking feedback from the material world. In many cases, their engineering-related ingenuity and skills were vital to the business's success.

Corporate-Owned or Corporate-Affiliated Businesses

We begin this section with a quotation from Laticia who described her experience working in a national fast-food chain, which she did from 4:00 p.m. until 11:00 p.m. every evening after school. "It puts a lot of stress on your body especially if you're not used to it, and I wasn't used to it." She continued, "Most of the time I was by myself. It was hard. When I was training, I had someone there with me, but then when she was gone, it was like a shock to me because it was so hard." When asked what stressed her body, she described lifting heavy garbage bags and carrying them far distances, as well as pouring heavy mixes into beverage machines. In her words, "It's really heavy too so we have to pour it in, you have to get on a chair and pour it in to this machine and that really hurts your back. Like I feel I was growing so old and having all those back pains and stuff, it was crazy, and because I wasn't used to being on my feet that much, like just standing there… I started getting cramps in my legs."

This experience mirrored those of several other participants who worked in corporate-owned or corporate-affiliated businesses. Even when the participants reported learning useful skills in the context of corporate workplaces, they often described a range of injuries they had sustained, unsafe workplace conditions, threats of being fired, and/or underpayment. To use Wertsch's term, these workplaces constituted *scenes* characterized by asymmetrical power relationships and exploitation, yet oftentimes the youth felt obligated to persist to help their parents "pay for the car bills and house bills." In the face of these exploitative circumstances, the youth developed multiple types of resistant capital (Solórzano & Delgado Bernal, 2001; cf. Yosso, 2000), or skills and bodies of knowledge that enabled them to survive or challenge uncaring, inhumane, or hostile contexts.

In Laticia's case, she developed procedures for minimizing the time spent in carrying garbage through connecting the garbage cans so she could move multiple cans at once; she also used a lever as a technology for helping her lift the garbage. Both actions constituted forms of ingenuity, and they illustrate how youth such as Laticia resisted uncaring environments by finding ways to make difficult circumstances more bearable. The following section describes how the youth demonstrated resistant capital, which simultaneously constituted engineering-related funds of knowledge.

Patricia: Maximizing Efficiency to Get More Sleep on a School Night

Twelfth-grade Patricia lived in a rural area where many houses were relatively far from each other and where many people still relied on receiving the newspaper each day as a major source of news, in part because they had inconsistent or no wireless Internet access. Patricia worked as a carrier to deliver newspapers to these homes, including during the six months when it snowed in her town. In her words:

> **Patricia**: We would get the papers at four and have to have them all out before six, and then they would give us the paper like so we would have to like roll them up and tie them. And I think that they would give us like 50, so we had to walk around and take it to the people in the neighborhood.
> **Interviewer**: And then after that you had to go to school?
> **Patricia**: Yeah.
> **Interviewer**: Wow, so how did you, like when you were doing that how did you know what route to follow, or how to do it?
> **Patricia**: Well like it was, the route is usually like three blocks this way and three blocks this way, and so I would just go in like a snake type thing and make it so I would end up at my house. So I would like go around and then end up at my house.
> **Interviewer**: So do you think that was like the most efficient way to do it?
> **Patricia**: Yeah, because I tried a lot of ways, mostly because I didn't want to do it that early in the morning, so I would wake up at five and be done by six. And then I had to go to school at seven, so I would try to do it different ways to make it faster, and I think that was the fastest way that I found.

In this example, Patricia engaged in *optimization* strategies through designing a sequential order for visiting houses, which minimized the amount of time that it took her to complete her paper route. Moreover, she iteratively tested different sequences for household delivery and improved them based on results from data, in this case, data related to the time spent for each sequence.

Here we note that in both family-owned businesses and corporate-affiliated businesses, the youth developed sequential procedures or processes as psychological tools to achieve the goal of improving efficiency while maintaining quality. However, in the context of corporate-owned businesses, the participants often developed another goal: to make workplace conditions more humane. In Patricia's example, her employer had recommended that she pick up newspapers at 4:00 a.m., and they insisted that all newspapers be delivered by 6:00 a.m. Through optimizing sequences, Patricia was able to successfully challenge the employer's recommendation to pick up newspapers at 4:00, while still meeting the mandate of delivering papers by 6:00. This optimization allowed Patricia to meet a personal goal that countered her employer's recommendation: giving herself a much-needed extra hour of sleep on a school night, not to mention minimizing the time spent outside on freezing, bleak winter mornings.

Through a practice common to industrial engineering (optimizing sequences to improve efficiency), she successfully challenged a workplace stipulation (pick up the newspapers at 4:00). We argue that this optimization of sequences was therefore also a form of resilient resistant capital in the sense that it represented a skill that enabled her to resist, challenge, and more fully thrive in the face of difficult workplace conditions, while still keeping her job and generating income for herself and her family. She developed these optimization skills through self-guided experimentation as her employer did not recommend different routes.

Alicia: Developing Humane Processes to Calm Animals During Transport

Twelfth-grade Alicia also developed processes to achieve goals for more humane workplaces, both for herself and for animals, during the six years that she worked on a farm with her father. She described her work as:

> We go into the chicken farm and then there's trucks and trucks and truckloads of like chickens in little cages, I guess. And they take out the, they open the cages, take out the chickens and hand them to us and then we put the chickens in their new cages.

She noted that "everybody's different and how they put chickens is different." She developed her own set of procedures for transporting chickens from the truck cages to the farm cages by watching others and "learning pretty quickly from them," and then experimenting for herself regarding what worked best in terms of minimizing fatigue or injury to herself, minimizing the time it took to transport the chickens, and fostering a sense of "calmness" among the chickens.

Alicia explained a process whereby first she grabbed chicken by their legs, then by their bodies, then slid them into cages using a series of physical actions that varied by type of cage. She preferred the cages with the slides because the chickens could not come out, whereas with other types of cages, chickens would "usually come out," for which she developed physical routines to prevent their escape. When deciding how many chickens to hold with each hand during transport, she considered factors such as type of chicken (red chickens were heavier than white chickens) and cage size. Because most cages could hold four chickens and because she usually carried white chickens, she typically maximized efficiency in transportation by choosing to carry four chickens in each hand, which was also the maximum number of chickens she believed she was strong enough to carry. Finally, she explained, "If you want them to calm, what I do, I just put it against my legs and just like hold their feathers, hold their wings. That's what helps me. Just like pull them next to my thigh and just like calm them down […] I don't get mad at them. There's some people who like kill them [out of anger]."

In this example, Alicia, like other participants, demonstrated skills related to *process design* when she developed a series of physical routines for carrying chickens, which took into account a range of variables, such as size of chicken, type of cage, and how strong she felt that day. Because she received no formal professional development on safe transportation, she developed these processes largely on her own through *iteratively testing* different processes and observing their results, for example, whether they resulted in an escaped chicken or fewer injuries from pecking. She also *optimized* both time and physical effort by spending the least amount of time possible in transportation, but not trying to carry so many chickens at once (in her efforts to save time) that it strained her body beyond what it could bear. As with Patricia, we argue that her process optimization and iterative testing constituted a form of resilient resistance because they were skills she developed to enable her to endure extremely physically taxing workplace conditions.

We also believe that Alicia's example demonstrates transformative resistance, or resistance that could lead to the transformation of workplaces and of industrial engineering itself. Alicia demonstrated a deep concern, not just for maximizing efficiency, but for the lives, well-being, and emotional state of the animals. She described a workplace wherein people killed chickens when they were angry at them, inadvertently stepped on young chicks in opaque potato sacks and crushed them without caring, and engaged in other actions that demonstrated a culture of disregard for animals by viewing them only as a means to profit. She sought for ways to counter this disregard, for example, through suggesting transparent sacks so that people could see whether chicks were inside and therefore could avoid stepping on them. She also tested and

enacted physical processes (e.g., pressing the chickens against her thigh), whose purpose was to calm chickens and make them feel less afraid. We argue that her example represents a transformation of some industrial engineering educational cultures (e.g., Sassani, 2017) by prioritizing well-being and emotion in contrast to profit and efficiency.

In Vygotskian terms, like other participants, she developed and applied a set of routinized yet flexible processes as a psychological tool, which served as a primary mediational tool that enabled her to complete a very physically demanding and difficult task. Yet as with the other youth who worked for corporate-affiliated businesses, she both met her employers' goals while meeting counter-goals of her own. Specifically, she met her employers' goal of maximizing profit through quickly carrying chickens to their cages, but she also developed her own goal, one that ran counter to her workplace culture, of keeping the chickens calm. She demonstrated ingenuity through developing processes that simultaneously met both goals.

Most importantly, we also underscore that, like Patricia and Laticia, she developed ways to make her workplace more humane for herself as a worker: Calmer chickens meant fewer pecks and less physical strain from holding flapping chickens. This commitment to self-care, in the face of uncaring conditions, can also represent a form of transformational resistance that challenges the status quo by more fully centering the well-being of Latinx workers, rather than viewing their labor primarily as a means for maximizing corporate profit.

Rosa: Expanding Workplace Procedures to Connect with the Elderly

Eleventh-grade Rosa worked in a residential home for the elderly as a Certified Nurse's Assistant. Unlike Patricia and Alicia, who did not receive any formal professional development regarding how to perform their job, Rosa's job provided her with extensive education, mentorship, and close supervision over the course of several months. This professional development required her to memorize and apply a series of specific procedures for minimizing the spread of infections, as well as procedures for helping clients out of bed and into wheelchairs, out of wheelchairs and into shower chairs, and so forth. Additionally, this professional development heavily emphasized "medical math," which she described in part as:

> **Rosa:** When we feed the residents, we have to chart like how much they ate, so you have to have a feeling of like mathematically how much is whole, how much is three fourths, and stuff like that…We have to chart how much they ate, like their intake and what they would eat, and like their outtake, like when they were done. I don't know how to say it in a nice way.
> **Interviewer:** Like when they use the bathroom?
> **Rosa:** Yes, in the restroom, we would try to see like if it was normal or not normal. And we would take their temperature.

In accordance with legal and institutional standards and expectations, Rosa acted as a conscientious, detail-oriented employee who kept a range of meticulous and accurate records via required charts, and who closely followed procedures for minimizing infection, helping the elderly move from place to place, and detecting possible problems at an early stage. Moreover, she could explain how each of the required procedures promoted safety.

At the same time, within this environment that emphasized procedures and documentation, she repeatedly foregrounded connecting with others and the alleviation of suffering. When asked why she entered the medical profession, she stated, "My mom used to be a nurse in Guatemala. And really, just the focus of helping others. That's my main thing why. You can save lives or help people who are in pain." Consistent with this purpose, she emphasized building "a connection with the resident. You can establish a communication." She acknowledged that her job was physically demanding at times, for example, when helping somebody out of a shower chair, but she believed:

> I just think about the person who is going to use it. Like even if I had to do it for a job as the caregiver, for us [caregivers] say it would be nice if it [the shower chair] was taller, but for us we could still do it [help them out of the shower] either way. But the person who is in the chair is the one that suffers. We don't suffer at all…For them it's a long-term thing, and they're going to live with that. So I think about the person, and not the person that gives care.

As part of her ethos of selfless service, she prioritized the residents' physical comfort above her own, and she considered how they might be feeling. In her words:

> Obviously like when you're elderly, you can't walk as good. So they would feel like we would drop them or stuff like that. So moving to a different device, I feel like that scares them. Like I put me in their situation. If I couldn't walk at all, I'd be scared, like "oh they're going to drop me," because you're trusting the other person.

To alleviate the residents' fear and suffering, and to "establish communication," she developed additional routines, which she inserted into the required, institutionally mandated procedures designed to ensure physical safety and to minimize infection. These routines included talking with the elderly to let them know what she would be doing, especially during transition points, such as moving from one device to another, when they were likely to be scared. These routines also included listening to them, for example, to better understand what food they liked so that she could select that food when she fed them.

Unlike other participants, who described processes for optimizing time, space, or labor, Rosa did not mention processes to increase efficiency, even though she was expected to provide multiple types of care to an expected number of residents each night. Instead, Rosa centered the perspectives and emotions of each resident, and challenged her workplace's efficiency model by taking extra time to listen to, connect, and talk with the elderly.

In this example, Rosa had mastered institutional procedures and policies as psychological tools, and she met her employers' goals of providing a physically safe environment in which actions were documented. Through repeated practice with using these tools, she developed funds of knowledge, such as knowledge of different procedures for ensuring worker and resident safety. At the same time, she sought to achieve an additional goal that sometimes countered her employer's efficiency goals, which entailed using one Certified Nurse's Assistant to serve a given number of clients during each shift. Specifically, Rosa developed skills related to the demonstration of empathy when she sought to meet the additional goal of providing a humanizing environment for the elderly in which they were heard. This empathy constituted transformative resistance in which she challenged a culture that gave primacy to efficiency, procedure, and medical math. While meeting legal and institutional expectations for ensuring safety, she expanded this culture to center human kindness, selflessness, connection, and the alleviation of suffering.

Summary of Findings Related to Corporate-Owned or Affiliated Businesses

Across worksites and job types, participants developed funds of knowledge, or skills and bodies of knowledge, related to designing processes that maximized efficiency; these skills also constituted a form of resilient resistant capital in the sense that they represented strategies for surviving and thriving in difficult or hostile environments. Maximizing efficiency became important because many participants were paid by the task versus paid by the hour, such as twelfth-grade Silvia who described her first day at work in picking berries, "we were there for eight hours and got $12.00" because she was paid per box. Like the other participants, in designing processes for maximizing efficiency, Silvia resisted and challenged difficult or exploitative workplace environments by meeting expected targets in minimal time and with less strain on their bodies. Their resilient resistance also included developing sequences (e.g., sequential order for optimizing the paper route) or technologies (a lever for lifting garbage) that demonstrated a commitment to self-care by countering workplace conditions that were hard on their bodies.

In addition to demonstrating resilient resistance, the youth also enacted forms of transformative resistance in the sense that their actions challenged oppressive, unjust, or inhumane systems. Alicia challenged a system that viewed animals primarily as expendable commodities that were only a means to profit, and instead she developed procedures designed to promote their emotional well-being. Rosa challenged a system that emphasized medical math and data (temperature, intake, outtake), and instead she foregrounded talking with, listening to, and connecting with each resident. In both cases, while meeting their employers' targets relative to efficiency or standards related to safety, they simultaneously challenged workplace cultures through creating spaces that centered care and emotional well-being.

Mobilization of Funds of Knowledge

In addition to describing the types of funds of knowledge that youth developed and the ways in which they developed them (research questions one and two), this study sought to identify the ways in which youth mobilized and hoped to mobilize their funds of knowledge (research question three). Consistent with Moll's assertion that funds of knowledge are essential for "household or individual functioning and well-being," the youth identified instances in which they used their workplace funds of knowledge to help their parents or neighbors to improve their households or yards. Antonio, for example, described how he learned how to make cement mixtures and "how to use the forms that you put the cement into" at his workplace. He described how he had to make sure that:

> The cement and all the dry materials are all the right amount. One thing you have to tinker with is the water level…There's always a set number that you aim for, so then you just kind of go back and forth seeing how the cement is actually coming out. You can just kind of tell if you have to do it dryer or wetter. With experience, you know, it takes a couple of times.

Drawing from this workplace-derived knowledge of processes, materials, and machinery required to make and pour concrete, he helped his neighbors to construct a concrete wall. Others used their knowledge derived from fixing tractors or growing crops, honed at the workplace, to help with household tasks such as repair or gardening.

In addition to mobilizing their engineering-related funds of knowledge toward better households, and better lived experiences for children in their communities, they also hoped that their current workplaces would foster skills (and provide income) that would result in more secure economic futures and better working conditions for themselves in the future. Rosa explained:

> I hear my dad say he had no education. Me and my sister are expected to not just graduate high school but to go beyond that. He has very high standards where we work because he has had a hard work, and he doesn't want us to end up like him; he doesn't want us to have our hands like that he has. He's trying to give us the best education so we have to have better jobs than my dad. They want so much more for us.

Inspired by the sacrifices of her parents, Rosa became a Certified Nurse's Assistant, which she hoped would help her to be admitted to a nursing program in college and subsequently obtain an economically secure job, as well as one that enabled her to help others. Other youth, also inspired by the sacrifices and ethos of their hard-working parents, similarly explained that they hoped the skills and experiences developed in their current jobs would lead to better jobs. Arturo explained why he worked in a car mechanic shop:

> I'm going to go up to [name of college] and study engineering, and it still can be hard to find a job, because most jobs want someone who is experienced on it, and there's not a lot of opportunities to have experience before you find a job. So I think this [job] can help me a lot, because I'm going to learn everything, and by the time I go somewhere, I can be like "Yeah, I have two or three years of experience already and now I've got a degree on this." So it's going to be a lot easier. Plus I'm bilingual, so it's going to be way easier.
>
> […] My parents work, my mom works and they kind of help me out to what I need. Like they don't have to give me the money for college, but they want to help me to go to college, and I'm helping them. And I know once I get my degree in college, I want to give back to them by helping them with my [younger] brothers, because there's two more of us. So I want to help them so they can go to college. Because as I see it now, they're going to help me go to college, and then they have to help my little brother, and then my other brother, so all this working [my parents' working] is just for us, not really for their future. So I want to get that degree and pay back to them.

In summary, several youth participants hoped to mobilize their engineering-related, workplace-derived funds of knowledge, not only toward community or household purposes, but toward more economically equitable futures in which they received higher income for their work and could "pay back" their parents in recognition of their daily sacrifices. Finally, youth mobilized their funds of knowledge toward improving the quality of their lived experiences through transforming the workplaces in which they spent so much of their time.

Discussion and Implications

Many studies of engineering education have focused on how youth learn and do engineering in classroom spaces or in informal educational spaces, such as makerspaces, museums, or after-school programs. This study represents an expansion of this literature by instead describing how youth develop and practice engineering-related bodies of knowledge in the context of their workplaces. Many of the youth in this study spent more time each week at work than at school—for some, they spent more time each *day* at work than at school—and thus it is imperative that workplaces are also understood as important sites in many youths' learning ecologies wherein they learn and apply engineering skills. In these places, the youth developed skills that pertained to high school engineering standards, such as optimization, but also skills that extended beyond these standards to include the types of advanced, complex skills practiced by industrial engineers, such as using multiple types of constantly evolving data to make decisions in the context of complex systems.

When describing how funds of knowledge from informal sources might be translated to educational settings, scholars (Licona, 2013; Vélez-Ibáñez & Greenberg, 1992) have argued that pedagogies based on funds of knowledge are inherently anti-deficit because they foreground marginalized youths' bodies of knowledge and skills when they are used as the starting point and basis for the design of learning environments. These assets-based learning environments are based in the fundamental assumption that youths' experiences and knowledges are essential resources that enrich learning. Pedagogies

rooted in funds of knowledge contrast with deficit-oriented approaches that use the normative practices, values, or standards of dominant groups as the starting point and basis for the design of learning environments, and then portray minoritized groups as having deficiencies relative to these normative standards or practices (Bhopal, 2018).

With respect for this view, the findings of the study complicate or challenge binaries that would assume Latinx youths' workplace funds of knowledge, and canonical engineering practices, are distinctly different. In many ways, youth in this study demonstrated engineering funds of knowledge that are highly valued, particularly in industrial engineering fields, such as skills in optimizing processes to ensure that "goods and services are being produced or provided at the right quality at the right time at the right cost" (Hicks, 2001, p. 1.85). They successfully used these skills and bodies of knowledge to keep their family businesses solvent for years. They also masterfully used these skills and bodies of knowledge to maximize efficiency in corporate-owned businesses as a form of resistance to underpayment or overwork. Thus, we assert that the youth demonstrated canonical skills and bodies of knowledge that are valued within traditional engineering cultures. However, they often used these skills and bodies of knowledge to achieve counter or alternative goals to the profit maximization goals of their employers. Importantly, they also applied funds of knowledge that expanded engineering cultures, for example, those related to empathy, self-care, and centering animal or human emotion or experience. Thus, the ingenuity of the youth in many ways both encompassed and extended beyond traditional conceptions of engineering.

Implications for Assets-Based, Equity-Oriented Engineering Education

In considering the implications of this study for engineering education, we begin by affirming visions of engineering education that are simultaneously "transformative for individuals, communities, and disciplines" (Tucker-Raymond et al., 2016, p. 210). Youths' ingenuity and resilient resistance, developed in the context of workplaces, have much to teach educators and educational systems that seek transformation in the lives of individuals; transformation in how engineering is defined and how engineering education is practiced; and transformation in inequitable societal structures. We outline these implications in three domains: in the context and purpose for engineering design challenges; in the ways that educators and systems recognize youths' skills and ingenuity; and in the critique and transformation of systems as embedded within sociopolitical contexts. We elaborate on each of these three domains below.

Engineering design challenges

Historically, educators who enact funds of knowledge approaches have conducted ethnographic research in households with families, then designed curricula based on what they learned from this research (González et al., 2005). Civil (2002), for example, described interviews with parents whose community held rich funds of knowledge relative to construction. This research resulted in the development of a second-grade mathematics curriculum, grounded in concepts of construction, in which parents were core intellectual resources who shared their experiences with children.

As educators respond to varying institutional and community contexts, we believe a core method for eliciting and foregrounding youths' funds of knowledge may come from the context and purpose of engineering design challenges. Educators, with youth as co-designers of the challenge, can carefully consider the context of the challenge, the skills that are showcased in the process of addressing the challenge, and the purpose of the challenge. As an example, like many Latinx people nationwide, the youth in this study formerly or currently worked in sites wherein employees disproportionately contracted COVID-19 due to unsafe workplace conditions. We imagine that, given their nuanced understandings of problems associated with worker safety, and their ingenuity in developing processes to ensure quality, the youth could develop improved workplace processes to safeguard workers against COVID-19. This challenge includes a context (workplace); purpose (protecting Latinx workers who are disproportionately harmed); and foregrounding of workplace-derived skills (e.g., knowledge of worker safety and procedure) wherein working youths' knowledge and skills could be foregrounded and mobilized toward more just outcomes that are relevant to youth.

When we conducted this study prior to the pandemic, the youth shared the types of problems they would like to solve. They mentioned problems such as addressing traffic flow in problematic areas and developing a better bus schedule on snow days to ensure that students could arrive to school in less time, both of which entail the optimization of processes. Much research on equity in K-12 engineering education has occurred in the context of the creation of physical or digital devices, such as light-up desks (Tan et al., 2019), apps (Restrepo Nazar et al., 2019), or digital and physical art (Tucker-Raymond et al., 2017). Our study suggests that working youth may possess skills related to process design, optimization, and workplace safety. Given this finding, we believe that expanding the types of problems that youth can solve, the contexts in which those problems are situated, and the engineering disciplines that can be used to solve those problems might provide more substantial opportunities for foregrounding workplace-derived funds of knowledge.

Recognition

When minoritized youth are recognized by meaningful others as knowledgeable and important contributors within a discipline, they are more likely to identify with that discipline (Carlone & Johnson, 2007; Rodriguez et al., 2017). Given that working Latinx youth regularly apply engineering-related skills in their workplaces, engineering is an ideal discipline for fostering educational recognition (Esteban-Guitart, 2016) and educational dignity (Espinoza, 2015) among youth whose workplace experiences and contributions are often unrecognized, ignored, or dismissed as low skill within educational systems (Orellana, 2001). To counter trends of under-recognition, engineering educators can publicly recognize working Latinx youths' ingenuity as core to addressing engineering problems. Relatedly, adult advocates in the youths' lives can partner with youth in thinking creatively about how to advance the youths' desired trajectories while fostering continued recognition among other important adults and institutions in the youths' lives. For example, based on her feedback from youth, a school counselor recommended that we give certificates for inclusion on youths' resumes or college applications. These certificates recognized their engineering skills using language designed to foster recognition by college admissions officers or potential future employers, such as certificates indicating the youth had demonstrated effective process optimization skills.

A second type of recognition is also important: the recognition of multiple epistemological resources. Whereas some engineering educational cultures tend to privilege knowledge constructed or tested against principles of formal mathematics or science, the youth developed engineering funds of knowledge largely through necessity-driven experimentation with physical tools and processes as they sought to meet basic human goals such as paying the bills and experiencing less strain on their bodies. This study demonstrates that youths' workplace experiences are an epistemological resource that can be recognized, legitimized, and celebrated as resulting in vital knowledge that contributes substantially to engineering, both as a discipline and as an endeavor.

Teachers who recognize and verbalize the importance of this epistemological resource can position working youth as knowledge producers (Tan et al., 2019). This, in turn, helps to establish relational equity, whereby teachers can position themselves as learners along with their students (DiGiacomo & Gutiérrez, 2015). Many of the youth developed funds of knowledge through co-experimentation with caring adults; we see this as a potential model for engineering education in which educators position themselves as co-learners who can learn from their students' workplace experience as an epistemological resource.

Critique and transformation of systems

In the context of corporate-owned businesses, youth demonstrated resilient and transformational resistance that enabled them to survive in uncaring or hostile workplace environments and to challenge and counteract the very assumptions, processes, and values that characterized these environments. Latinx youths' critical resistant skills (cf. Solórzano & Villalpando, 1998) can thus be a powerful resource for discussions of how workplaces are part of historicized systems, which are characterized by interacting procedures, practices, technologies, and models that undervalue or exploit Latinx people. Latinx youths' resistant skills are also a powerful resource for re-envisioning these systems toward future systems that are more just and humanizing. Youth in this study not only critiqued existing systems, but they actively and effectively developed technologies and processes to make work better for themselves and others. When provided with opportunities to bring these skills into educational settings, we imagine that youth can use them to transform institutions, such as workplaces, as well as to transform disciplines, such as industrial engineering, such that they more fully recognize and foreground justice for workers.

In all, this study extends previous research on funds of knowledge in transnational Latinx families by highlighting that Latinx teenagers, like their parents, develop complex and discipline-specific funds of knowledge through various activities in workplaces. These funds of knowledge are powerful epistemological resources through which youth can powerfully engage in, critique, and transform engineering practices, as historically taught and understood, and they can be mobilized toward purposes of equity in service of more just outcomes for the community, for institutions within society, and for the youth themselves.

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