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Abstract

Multilingual students should have opportunities to learn and do engineering in learning environments that foreground and sustain their cultural and linguistic practices. However, little is known about how middle school engineering teachers enact these environments. To address this gap in research and practice, this comparative case study describes the different ways in which two middle school technology and engineering teachers enacted pedagogies rooted in funds of knowledge and translanguaging. The teachers and research team engaged in a professional learning community, which focused on funds of knowledge and language-based pedagogies, for over one year. The teachers enacted pedagogies that incorporated principles of funds of knowledge and translanguaging, reflected on their teaching, and sought to improve their pedagogy in subsequent iterations of teaching. In this context, the research team analyzed the following data sources: (a) transcripts from classroom observations during a minimum of four engineering design challenges per teacher; (b) teacher artifacts (e.g., lesson plans, curriculum materials); and (c) monthly reflection sessions and interviews with each teacher. Thematic analyses of these data were used to answer the following research question: How did the teachers enact funds of knowledge and translanguaging pedagogies? Analyses indicated similarities and differences in how the teachers enacted funds of knowledge and translanguaging pedagogies. Similarities included (a) providing students with bilingual materials; (b) grounding engineering design challenges in the context of students' communities; and (c) positioning parents as core intellectual resources. While the two teachers enacted pedagogies in similar ways, they also demonstrated differences. Alex, a bilingual teacher who had lived in Peru, enacted funds of knowledge pedagogies through sharing narratives and explaining how they mapped onto the engineering design challenges. He also frequently spoke to students in Spanish. Andrew, a white monolingual teacher who had lived and taught in his community for decades, enacted funds of knowledge pedagogies through experiential and place-based learning, and through incorporating popular culture. Despite his efforts to sustain bilingualism through providing bilingual curriculum materials, English remained the primary medium of instruction within his class, consistent with his school's de facto English-only policy. This study indicates that funds of knowledge and translanguaging pedagogies may be fostered through community-oriented engineering design challenges and through school-level policies and practices that explicitly encourage multilingualism.

Keywords

engineering education, funds of knowledge, translanguaging

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Abstract

Multilingual students should have opportunities to learn and do engineering in learning environments that foreground and sustain their cultural and linguistic practices. However, little is known about how middle school engineering teachers enact these environments. To address this gap in research and practice, this comparative case study describes the different ways in which two middle school technology and engineering teachers enacted pedagogies rooted in funds of knowledge and translanguaging. The teachers and research team engaged in a professional learning community, which focused on funds of knowledge and language-based pedagogies, for over one year. The teachers enacted pedagogies that incorporated principles of funds of knowledge and translanguaging, reflected on their teaching, and sought to improve their pedagogy in subsequent iterations of teaching. In this context, the research team analyzed the following data sources: (a) transcripts from classroom observations during a minimum of four engineering design challenges per teacher; (b) teacher artifacts (e.g., lesson plans, curriculum materials); and (c) monthly reflection sessions and interviews with each teacher. Thematic analyses of these data were used to answer the following research question: How did the teachers enact funds of knowledge and translanguaging pedagogies? Analyses indicated similarities and differences in how the teachers enacted funds of knowledge and translanguaging pedagogies. Similarities included (a) providing students with bilingual materials; (b) grounding engineering design challenges in the context of students' communities; and (c) positioning parents as core intellectual resources. While the two teachers enacted pedagogies in similar ways, they also demonstrated differences. Alex, a bilingual teacher who had lived in Peru, enacted funds of knowledge pedagogies through sharing narratives and explaining how they mapped onto the engineering design challenges. He also frequently spoke to students in Spanish. Andrew, a white monolingual teacher who had lived and taught in his community for decades, enacted funds of knowledge pedagogies through experiential and place-based learning, and through incorporating popular culture. Despite his efforts to sustain bilingualism through providing bilingual curriculum materials, English remained the primary medium of instruction within his class, consistent with his school's de facto English-only policy. This study indicates that funds of knowledge and translanguaging pedagogies may be fostered through community-oriented engineering design challenges and through school-level policies and practices that explicitly encourage multilingualism.

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Introduction

Across many educational settings, multilingual[1] youths' skills, knowledges, and linguistic repertoires often remain under-recognized or marginalized when educators instead recognize and valorize the linguistic and cultural practices historically associated with the white upper middle class (Britsch, 2020; Flores et al., 2020; Lippi-Green, 2012; Ryu, 2015). While this under-recognition occurs across academic disciplines (Adair et al., 2018; Nuñez, 2021; Presiado & Freison, 2021), a growing number of classroom studies (Gamez & Parker, 2018; Schenkel & Calabrese Barton, 2020) have described how Latinx multilingual students' contributions are under-recognized specifically within engineering educational contexts when monolingual teachers position them as incapable, for example, by questioning whether they really came up with design ideas, or by consistently placing monolingual English-speaking students in positions of leadership within and beyond engineering design teams.

There is ample evidence that systemic racism contributes to the minoritization of people based on their linguistic practices (Baker-Bell, 2020; Baugh, 2003; Pimentel, 2011; Smith, 2019), but there is also growing evidence that asset-based educational approaches can provide linguistically minoritized students with expanded opportunities to develop disciplinary identities as they imagine futures and trajectories within a given discipline such as engineering (Bell et al., 2017). Two promising asset-based approaches are pedagogies grounded in youths' funds of knowledge and translanguaging pedagogies. Pedagogies grounded in youths' funds of knowledge use sociohistorically derived familial and community skills and bodies of knowledge as the basis for further learning (Moll et al., 1992), whereas pedagogies grounded in translanguaging are based in the fundamental stance that youths' full communicative repertoires are core resources for learning, doing, and imagining at all times (García et al., 2017). While these educational approaches are gaining prominence, there is a dearth of literature regarding how teachers apply them specifically within the context of engineering education (Denton & Borrego, 2021).

The purpose of this study was therefore to describe how two middle school technology and engineering teachers enacted funds of knowledge and translanguaging pedagogies as they taught multilingual students, whom their school had designated as English learners, in the context of a multiyear professional development experience. The portraits of these engineering teachers illustrate different possible dimensions and challenges related to funds of knowledge and translanguaging pedagogies in engineering, which can be used as considerations for other engineering educators and professional development providers who seek for ways to ground their curricula and pedagogical strategies in multilingual youths' funds of knowledge and home languages. In the following sections, we describe the two pedagogical approaches more fully.

Funds of Knowledge Pedagogies

Several decades ago, Vélez-Ibáñez and Greenberg (1989, 1992) developed the concept of funds of knowledge to highlight the assets that Latinx families bring to educational settings. Funds of knowledge refer to the "historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual functioning" (Moll et al., 1992, p. 133). In their work connecting household funds of knowledge to education in elementary schools, González and colleagues (2005) described how teachers visited students' households to build relationships and learn more about familial practices, and how they subsequently developed curricula that connected these practices with educational standards.

In this work, during her home visits, elementary teacher Ms. Amanti observed fifth-grade Carlos selling candy, and she learned of local parents' skills in making candies. She used this knowledge as the basis for a student-driven curricular unit in which children posed questions about candy, such as "What ingredients are used in the production of candy?" Students answered this question by graphing the frequency of occurrence of the ingredients they found in Mexican and US candy samples, while parents served as core intellectual resources who demonstrated how to make candy and who shared other types of knowledge, such as differences in US and Mexican food consumption and production (Moll et al., 1992).

Since this early work in funds of knowledge, dozens of studies have further illustrated the promise of pedagogies that foreground youths' funds of knowledge across grade levels and disciplines (Hogg, 2011). Several of these studies have described pedagogical principles for teachers who are interested in connecting students' funds of knowledge to disciplinary learning in the engineering-related disciplines of science and mathematics. For example, in the context of nutritional science, Calabrese Barton and Tan (2009) described how a science teacher reoriented the learning space along *physical* domains when the classroom was reorganized to resemble students' out-of-school worlds; *political* domains when students had more power; and *pedagogical* domains when tasks were designed to mirror out-of-school activities and were designed

[1] We use the term "multilingual" instead of "English learner" to honor minoritized students' full linguistic repertoires (González-Howard & Suárez, 2021; Martínez, 2018).

to be relevant to students' everyday lives. In mathematics, Civil (2002; 2016) learned of parents' workplace-derived funds of knowledge, for example, those related to construction, and used them as the basis for mathematics learning. With an elementary teacher, she co-designed a construction unit in which parents were core intellectual resources that shared their knowledge of measurement and other target mathematical concepts. Collectively, these studies illustrate that families' sociohistorically derived bodies of knowledge and skills are "bona fide cultural resources for teaching and learning in schools" (Moll, 2019, p. 132) across multiple STEM (science, technology, engineering, and mathematics) disciplines.

Funds of Knowledge in Engineering

Based on work with Latinx families on the US–Mexico border, Moll et al.'s (1992) original outline of funds of knowledge included categories such as knowledge of equipment operation and maintenance, market values, building codes, budgets, construction, design and architecture, repair, and ethics. Although Moll and colleagues did not explicitly connect these funds of knowledge to engineering, many of these categories bear direct relevance to engineering practices, and for this reason, engineering may be an especially promising discipline for foregrounding Latinx students' funds of knowledge (Wilson-Lopez et al., 2018). Under this assumption, we designed a study to better understand the engineering-related funds of knowledge of Latinx youth who were designated by their schools as English learners (Wilson et al., 2012). In Table 1, we draw from the first publication that stemmed from this work (Wilson et al., 2013), which was subsequently developed into later models (e.g., Wilson-Lopez et al., 2016) that described the engineering-related funds of knowledge of multilingual Latinx youth.

Other scholars have offered different frameworks for understanding engineering-related funds of knowledge. For example, building from Smith and Lucena's (2015, 2016) research on first-generation, low-income undergraduate engineering students, Verdín et al. (2021) created and validated survey measures to identify the funds of knowledge of engineering undergraduates. Their funds of knowledge themes included drawing from students' home environments to scaffold engineering learning; tinkering knowledge; perspective taking; reading people; mediational skills; and community networks.

While these categories of funds of knowledge are useful, few studies have applied these categories by illustrating how engineering teachers can build from funds of knowledge as they enact assets-based learning approaches for Latinx students. One study on this topic (Mejia et al., 2021) suggested that middle school teachers perceived barriers, such as lack of time or institutional support, which prevented them from fully integrating funds of knowledge with engineering. To further explore whether and how engineering teachers might enact funds of knowledge pedagogies, even when faced with institutional and

Table 1
Latinx youths' engineering-related funds of knowledge.

Fund of knowledge category	**Illustrating example from Wilson et al. (2013)**
Workplace	Ariana's, Isabel's, and Sofia's parents worked at meatpacking plants where employers valued profit above worker safety. For example, the company did not pay for additional equipment to help workers lift heavy objects because the equipment was too expensive. Through witnessing their parents' workplace injuries, they developed a deep sense of the importance of ethics and value judgments in engineering and the importance of valuing people above profit. These guiding values helped them prioritize trade-offs when designing devices for people from minoritized groups.
Health	Tito helped his younger brother with muscular dystrophy to get in and out of a shower chair because his mother did not have the muscular strength required to do so. He used this experience to design a shower chair that could be used by caregivers with a wider range of body types.
Transnationalism	Karina helped her father design a house for her grandmother in El Salvador. She explained how differences between the two locations (El Salvador and her current location in the US) resulted in the selection of different materials and design features.
Household/yard care and construction and maintenance	Elena helped her father lay stones in the backyard outside their porch to prevent erosion. They used this knowledge to design a playground with features that prevented erosion. Silvia watched their data install metal fence and gates. She knew he had experience with metal working and asked for his expertise when choosing a metal for a cat restraint device she designed.
Popular culture	Eduardo watched *Design Squad,* a show on PBS that featured diverse youth solving different problems through engineering via a process of considering the merits and drawbacks of each potential solution.
Digital technologies	Silvia played with fashion apps in which she read clients' specifications and made designs that met those specifications. She also looked at the clothes that the client had worn in the past, noting the materials and colors used in those clothes. She used this material to fashion designs that were desirable to clients. This skill is relevant to engineering as engineers consider clients' specifications when planning designs.

temporal constraints, we worked with middle school teachers by using these initial frameworks of funds of knowledge as heuristics, while also affirming the imperative to foreground specific community knowledges and resources.

Translanguaging Pedagogies

Although the aforementioned descriptions of funds of knowledge did not address multilingualism, other writings by Moll (1992, 1998) foregrounded the role of bilingualism as a vital resource in learning for many Latinx youth. If schools and educators embrace the ethical imperative to sustain rather than erase minoritized students' home cultures, then sustaining home languages is vital to education in a democracy (Paris, 2015). Accordingly, translanguaging has gained prominence as an important approach across academic disciplines (García & Kleifgen, 2020).

Translanguaging is based in the principle that multilingualism is a resource for learning, doing, and imagining at all times (García & Kleyn, 2016). In translanguaging classrooms, educators seek to leverage students' full linguistic repertoires. They provide multimodal and multilingual resources as students work in purposefully planned collaborative/juntos structures wherein they have opportunities to speak their home languages with others (García et al., 2017). Translanguaging is thus consistent with funds of knowledge pedagogies in the sense that translanguaging pedagogies seek to explicitly sustain home cultures and foreground students' existing resources as core assets for learning.

Translanguaging pedagogies challenge the idea of "levels" by recognizing that each student uses a distinctive linguistic repertoire that can be leveraged in the classroom as they have opportunities to learn with others (García & Kleyn, 2016). This approach requires teachers to be flexible and to follow the language corrientes that naturally emerge in multilingual classrooms as students speak, listen, read, and write in multiple languages and hybrid languages with each other. These language corrientes may not fall within the boundaries of named languages (Spanish or English). Instead, students can use their full linguistic and communicative repertoires—including gestures, images, and fluid intermixing of named languages and language forms as well as the creation of new language forms—to construct and communicate meaning.

Translanguaging pedagogies challenge the common assumption that technical subjects, such as engineering, must use "academic English" as the instructional medium and end goal for students designated as English learners. Many scholars (Baker-Bell, 2020; Lemmi et al., 2019) have begun to question this assumption because it privileges White Mainstream English (Alim & Smitherman, 2012), or language practices historically introduced and used by the upper white middle class. White Mainstream English is commonly called "Standard English," which is indicative of how it is naturalized as the invisible standard against which other language practices are judged (Lippi-Green, 2012), as contrasted with (for example) languages such as Black English (Kinloch, 2010), Appalachian English (Hasty & Childs, 2021), or dynamically fluid Spanish/English (Flores & Schissel, 2014). Because translanguaging pedagogies fundamentally denaturalize White Mainstream English as the standard within K-12 schools, translanguaging is recognized as a pedagogy of equity for students who have been minoritized on the basis of language (Yilmaz, 2017).

Translanguaging in Engineering

As contrasted with other disciplines, engineering holds unique potential for valorizing the linguistic and communicative strengths of multilingual students (Cunningham et al., 2021; Paugh et al., 2018). As a human-centered discipline, engineering fundamentally values—not just science and mathematics—but users' experiences of the designed solutions (Cunningham & Carlsen, 2014). For these reasons, the ability to speak in clients' or users' languages, and to develop deep relationships with and understandings of the people served through the design solution, is a tremendous strength (Wilson-Lopez et al., 2018). Translanguaging pedagogies in engineering may extend beyond classroom walls as multilingual students communicate with the people served by the designs and as they share what they learned with their classmates. Thus, engineering has the potential to foster relational equity (DiGiacomo & Gutiérrez, 2015) when monolingual teachers position themselves as learners who rely on their multilingual students' linguistic repertoires to define the problem fully from clients' perspectives. Additionally, engineering is fundamentally multimodal (Roth, 2017), in the sense that it entails communication through gestures, physical prototypes, and images, in addition to written and oral language. This multimodal nature provides multilingual learners with opportunities to use their full communicative repertoires to share ideas (Cunningham et al., 2021).

While translanguaging in engineering is relatively new, studies have begun to illustrate how teachers might enact translanguaging in the related disciplines of science (e.g., Infante & Licona, 2021; Pierson et al., 2021) and mathematics (e.g., Tai & Wei, 2021). These studies have uniformly indicated that translanguaging provides multilingual students with opportunities to engage more deeply in disciplinary content, as contrasted with monolingual instruction. In a study framed as science (not engineering) education, Suárez (2020) engaged elementary students in iteratively designing electrical circuits during activities that could be considered as engineering. He found that "students engaged more deeply with each other's ideas and content when they could move freely between them [Spanish and English]" (p. 800).

Despite these initial studies that indicate the promise of translanguaging pedagogies in engineering, questions remain as to how monolingual English-speaking teachers can sustain translanguaging in traditional public schools that do not have bilingual or dual language education programs (Hansen-Thomas et al., 2021). Questions also remain regarding how to sustain translanguaging in classrooms wherein numerous languages are spoken, as contrasted with classrooms in which Spanish/English are the primary languages spoken (Ticheloven et al., 2021). Approximately three-quarters of students designated as English learners in the US speak Spanish as a home language (Ruiz Soto et al., 2015). Accordingly, while many classes across the US include students who speak Spanish/English as primary languages, other classes include students who speak many different languages, which may not be spoken even by bilingual educators.

Thus, while translanguaging may be a promising pedagogy for advancing equity in engineering education, many questions remain as to how teachers with different linguistic backgrounds might enact translanguaging in linguistically diverse classroom contexts. This study therefore seeks to contribute to the literature in engineering education by describing how two engineering teachers with different linguistic backgrounds sought to foster multilingualism through translanguaging in classrooms with their own distinctive linguistic compositions.

Summary and Research Question

Translanguaging and funds of knowledge pedagogies are complementary pedagogies that are designed to sustain linguistically minoritized students' linguistic and cultural knowledges and practices. Given this background, our study sought to answer the following research question: How do middle school technology and engineering teachers enact pedagogies rooted in funds of knowledge and translanguaging?

Context of the Study

To answer this question, we conducted a comparative case study of two middle school technology and engineering teachers who taught in two school districts in the western United States. Both teachers taught in traditional public middle schools, which did not offer bilingual or dual language education programs. Alex described himself as a "Hispanic male" and taught a mandatory technology and engineering class in a middle school in which 62% of the students identified as Latinx. Alex further described his school: "In the school, historically we've struggled with a lot of disparity in socioeconomic opportunity." We observed Alex's class over seven trimesters; for the trimester that we describe in this paper, he reported that one-third of the students in his class were currently receiving English as a Second Language (ESL) services, and most of the students in his class were bilingual or multilingual. Although a majority of his students spoke Spanish and English, his classes also included students who spoke Arabic, Chinese, Farsi, Nepali, and Korean.

Alex wanted to become a technology and engineering teacher in part because his father was an engineer in Mexico, and he wanted to inspire other youth to consider similar fields. Alex had also lived for several years in Peru. To pursue his life-long interest in Latinx cultures, he had taken several Latin American studies courses in college as an undergraduate. He lived in a different city from his students, but at the time of the study, he had taught in the school for ten years and was known as a passionate advocate for Latinx youth.

Andrew, who identified as a "white male," taught a mandatory technology and engineering course in a middle school in which about 40% of the students identified as Latinx. He further described his school as, "We have about a 22% mobility rate. One out of four of the kids are gone and new kids have replaced them." We observed Andrew's class over five trimesters; for the trimester that we describe in this paper, he reported that one student in his class was receiving ESL services, although over one-third of his class was bilingual (Spanish and English).

Andrew had taught in the same school for decades and grew up in the same town as his students. He described his experiences growing up: "My background was I worked at a dairy. We drove tractors when we were 11. They put us in trucks. We were shifting and operating the clutch. We went through the process of making mistakes. We dumped hay bales over." Over the summers, when he was not teaching, he described how he sought to "build that relationship" with different community stakeholders, such as industries and educators at the local technical college, in order to better support his students' career pathways in the community.

Although González and colleagues (2005; cf. Moll, 2019) recommended that teachers visit students' homes to learn about their funds of knowledge, both teachers worked in school districts whose policies prohibited middle school teachers from visiting students in their homes. Given this constraint, Andrew and Alex both participated in a multiyear professional development project in which they read articles about pedagogies for linguistically diverse students, including funds of knowledge pedagogies and honoring and incorporating students' home languages and linguistic repertoires through using strategies recommended in translanguaging approaches. They also observed other teachers as they taught in ways designed to foreground students' funds of knowledge and home languages. For over one year, they participated in ongoing

professional development in which they reflected on student work or transcripts of their own teaching and discussed and identified ways for better supporting multilingual students, especially those who were receiving ESL services.

During the time that we worked with Alex and Andrew, their teaching schedules were subject to frequent change. They both taught seven or eight periods of engineering-related courses (e.g., robotics or exploring technology); each period was comprised of a different set of students. Additionally, some (but not all) classes changed every trimester, so that they had an all-new set of students per trimester. Given these scheduling shifts, although we worked with them for multiple years, our study only reports on their instruction during one trimester because this duration of time usually represented a complete curriculum for their students. Furthermore, for both teachers, we conducted this study in a mandatory, introductory technology and engineering course because these courses reflected the larger demographics of the schools and included students who were not necessarily interested in engineering as a career (as contrasted with their schools' optional, nonintroductory engineering courses, which tended to be overwhelmingly male and overrepresented by monolingual students). The research team includes people who identify as white, and as Latinx and multilingual.

Methods

For the trimester reported in this comparative case study, we observed each teacher daily for a minimum of four instructional units. These instructional units were each comprised of one engineering design challenge and ranged from a few days to a few months in duration. This study also draws from four interviews per teacher, designed to better understand why they made pedagogical decisions.

We conducted inductive thematic analyses of these interviews and observations to explore the ways in which each individual teacher enacted funds of knowledge pedagogies and translanguaging pedagogies. Specifically, we discussed individual excerpts of data and developed themes based on these excerpts for each individual case (Saldaña, 2021). We then conducted a cross-case analysis by identifying similarities and differences across cases. The themes that we identified represent ways in which the teachers sought to enact funds of knowledge pedagogies; each theme is indicated in italics below.

Findings: Similarities in Pedagogies

Despite their different linguistic backgrounds and despite differences in the languages spoken in their classes, the two teachers enacted funds of knowledge pedagogies and translanguaging pedagogies in similar ways. Specifically, both teachers selected engineering design challenges that enabled and encouraged students to draw from familial and community knowledge and expertise, thereby encouraging students to speak in home languages with their families and to draw from their funds of knowledge. Furthermore, both teachers promoted bilingualism through providing curricular materials in Spanish and English. We elaborate more on these similarities below.

Selecting Community-Oriented Engineering Design Challenges

Both Andrew and Alex sought to foreground students' funds of knowledge through co-selecting engineering design challenges with students, and/or through selecting engineering design challenges they believed were likely to leverage local community knowledge. This community-based approach is consistent with Moll's (2019) later writings, which described funds of knowledge pedagogies as being grounded in "community-oriented practices" (p. 130). As much as possible, Alex and Andrew both sought to contextualize their instruction within "real" engineering design challenges, which enabled students to address actual issues that were part of students' lifeworlds (Moll, 2019), and which enabled students to develop and communicate solutions for implementation.

For example, Alex worked at a middle school that was relocating to a new building. In response to a petition put forth by some of Alex's students, the district superintendent agreed to have a community garden at the school. Alex's students were responsible for designing the garden. In his words:

> We're preparing to have a community garden at the new school. What's going to be grown? And what kind of responsibilities going forward do you think the people will need to know about? Like cleaning, planting, harvesting, selling. Are we gonna sell it? Are we gonna donate it? So there was an open-ended question is what are we gonna grow? Where are we gonna grow it? What are we gonna do with all the food? And so we've been wrestling with those questions that are still not defined. …I was suggesting the foods that you see locally, that are grown locally rather than try to greenhouse them, so the seasonal crops that are typical for our area. And honestly, I have not read all of what they've [the students have] produced, but what I did note was that they were very active on their research.

Alex's students conducted Internet research in Spanish and English in order to learn more about local fruits and vegetables they might grow in their garden. Additionally, they talked with their parents and family members in both their English and/or their home languages to learn additional ideas about where they should place their garden and the individual plants within it, how they should care for the plants, and which plants they should choose. Alex further explained:

> We're promoting that garden and so we're using our business and marketing knowledge skills to inform, at this point, people have been persuaded that this is a good thing, so now their job is to inform the public that we will have a garden. So we've talked about the stakeholders, the parents, the students themselves, the administrators and so they've created posters, flyers and other formats of advertisements.

In this example, both funds of knowledge and translanguaging pedagogies were enabled by the selection of the design challenge, which addressed a topic that many parents were familiar with (gardening), and thus enabled parents to share their expertise with the class in their home languages. Alex positioned the students' multilingualism as a strength when they talked with relatives in their home languages to learn more information, and when they created and posted flyers in their home languages that would communicate with specific neighborhood audiences who spoke those languages.

Andrew, too, sought to foreground students' funds of knowledge, first, by co-selecting local problems with students and/or by grounding engineering design challenges in local contexts. As an example, most of his students reported problems with congestion and safety issues beside their school, so they identified solutions for improving traffic flow. Andrew encouraged them to interview parents, peers, and teachers in multiple languages to collect information about the problem, and/or to collect data through other means (e.g., photographs from cell phones). In his words:

> And Eduardo said, my mom can get this stuff for us. He was involved, so he went to the only person he knew that could help solve his problem and he did a little research. He started off with his mother, that's a great place to start. So it was very good.

A parent visited Andrew's classroom and shared what he knew about the site's economic constraints for the students' further consideration. Another parent, whose background was in construction, shared the differences in pricing and characteristics between concrete and asphalt. Andrew's students then developed solutions to the problem of traffic congestion and presented them to a committee that included local parents and the principal. These solutions were in English because this was the language expected within Andrew's school, as described in more detail later, and because all committee members spoke English as at least one language.

In both of these cases, common themes emerged. First, where possible, the teacher's selection of the engineering design challenge was *driven by student interest* and *was contextualized within the community*. Additionally, the teachers *positioned parents as core intellectual resources* by inviting them to the classroom and/or by encouraging the students to learn from their expertise as they gathered information about the design. Finally, the teacher encouraged the students to share their proposed solutions with *real audiences* in the languages spoken by those audiences.

Promoting Multilingualism

In accordance with recommendations for translanguaging pedagogies, Alex and Andrew regularly provided multilingual, multimodal resources for their students. They showed pictures of words that represented core vocabulary words with examples in Spanish and English. They also routinely provided bilingual resources, such as Spanish and English informational materials related to the engineering design challenges. By providing bilingual (Spanish/English) materials, both teachers indicated that they recognized and valued multilingualism. However, although both teachers provided resources for receptive bilingualism (e.g., Spanish/English texts), only Alex's class regularly engaged in expressive multilingualism through writing and speaking. We describe the differences between the two teachers' pedagogies below.

Findings: Differences in Pedagogies

While both teachers elicited community knowledge and provided bilingual materials, there were also differences in how they enacted funds of knowledge and translanguaging pedagogies. These differences were shaped in part by school-level policies and stances, by the teachers' varying abilities to actively foster multilingual corrientes through talking with students in their home languages, and by the different languages spoken in each class. We elaborate more on the differences between the teachers' pedagogies below.

Alex's Pedagogies

Alex's school included students who had immigrated from dozens of countries, and the school fostered a stance where multilingualism was welcome. In this school, posters in different languages were posted throughout the hallways, including the posters that Alex's class had made that promoted the community garden. Alex frequently mentioned that, as a native Spanish speaker who had lived in Central and South American countries himself, he could use his cultural and linguistic repertoire to build relationships with students who were navigating new institutional, linguistic, and cultural norms. The following section describes how he sought to build relationships and elicit funds of knowledge through narratives and through intentionally initiating and fostering translanguaging corrientes.

Sharing and Encouraging Narratives

Alex frequently shared stories, including stories that described his experiences in Mexico and Peru, as a means of building connections with multilingual students. For example, his school required that one of his engineering design challenges should relate to medical technologies. To meet this requirement, he gave students bones from turkeys' legs from a butcher shop. Students used lab equipment to break these bones, which bore similarities to human bones. Then, given the unique nature of each break, students worked in collaborative groups to engineer a way that they could keep the bones stable and help them heal. To scaffold this process, Alex shared different medical technologies and techniques that were used to treat different kinds of breaks in the US, such as rods and screws.

However, he also encouraged students to draw from their families' knowledge of healing as they considered how they would treat a patient with a broken bone. He then told a story, drawn from his experiences in Peru, in which he "entered the home of a man who was bedridden." Specifically, he described a man who:

> Needed his bone fixed from the outside of his leg. This gentleman had the framework on the outside of his leg, holding it together while the bones were growing together and that required a lot of healing time. And he went to his local healers, and the belief was that the tree sap from a parasitic tree, which wrapped itself around the other trees, would do the same to his leg. The healer prepared a concoction that he would drink, and his belief was that the sap would behave the same way in his leg.

In this narrative, the man's leg healed due both to the external framework on the outside of his leg, as well as his confidence in the healer and the care provided to him by his family and a caring community. After sharing his own story with providing healing care to his bedridden neighbor, Alex encouraged his students to share their own familial stories of healing and to consider how these stories of healing might inform their solution for healing the broken leg.

His narrative-based approach validated students' knowledge of folk medicine—a category of funds of knowledge initially outlined by Moll et al. (1992)—and encouraged them to use this knowledge to inform their solutions for healing the hypothetical patient with the broken leg, while still meeting school expectations of introducing students to medical technologies.

Encouraging and Following Translanguaging Corrientes

In addition to providing bilingual Spanish/English resources, Alex explicitly sought to foster translanguaging corrientes through placing students who spoke the same languages together (at times) in carefully planned groups, without reifying divisions based on language. For example, he explained that he paired Gabriela, a student who had recently enrolled in the school after moving from Mexico, with Daniela, a student who spoke both Spanish and English, because he thought they might develop a friendship and that they could work productively together, in Spanish, when developing solutions to design challenges. Through being judicious about how he formed groups, he sought to foster productive language corrientes in which students had opportunities to use their home languages with each other while engineering.

While students were developing solutions in these groups, he also frequently walked around the room and initiated conversations in Spanish. He described his interactions with Gabriela during one moment in class:

> I asked her in Spanish. She answered in Spanish. Then I asked the same question in English and then answered in English for the class. It's [speaking Spanish] really really helpful for me. Then when I have students from the Middle East who speak Farsi or Afghanistan, who speak another language…while I'm not able to provide those types of literature that are in their first language, I find myself trusting on their resiliency. I might provide an organizer, or…say, "Respond in your native language. Express, interpret for me, what you read."

While this quote illustrates how Alex initiated and fostered translanguaging corrientes in Spanish/English, it also highlights some of the difficulties he perceived in fostering translanguaging corrientes in other languages. We believe that, by speaking Spanish in the classroom, he indicated to students that home languages were valued. He also explicitly communicated to students that all home languages were welcome resources for written and oral responses. Further, he made an effort to learn and use core vocabulary words in multiple languages, such as Farsi.

At the same time, despite Alex's explicit efforts to encourage multilingualism relative to all languages, we did not observe translanguaging corrientes in languages such as Farsi. Although he provided bilingual materials in Spanish/English, he stated that his greatest challenge as a teacher was not having enough time to plan and find materials in all of the languages spoken by his students. Given the time constraints he faced—as an active leader and contributor in his school, community, and family—he perceived it was not feasible for him to locate or generate instructional materials in languages he did not speak, and the school did not provide these materials for him. Additionally, some languages in his class were only spoken by one student, and therefore he could not plan engineering groups that fostered multilingualism in those languages through pairing same-language speakers together. Accordingly, while we observed students speaking Spanish/English in class, we did not observe them speaking other languages. This finding therefore highlights challenges faced, even among bilingual teachers, when they seek to sustain languages in highly multilingual classrooms.

Andrew's Pedagogies

Unlike Alex's school, which encouraged and proudly displayed multilingual artifacts, Andrew's school discouraged communication in languages other than English. Andrew described a professional learning experience, sponsored by the administrators at his school, which stated, "You make the ESL learners or Spanish-speaking students read English. You're actually hurting them by giving them the Spanish." In this school, therefore, students were accustomed to submitting all assignments in English and using English as the primary medium of instruction. Despite this school culture, Andrew made moves to incorporate funds of knowledge and translanguaging pedagogies into his instruction. The following section describes these pedagogies.

Experiential Learning in Place and Popular Culture

Andrew had a deep knowledge of many landmarks in the town in which he and his students lived. One of his phrases that he used to describe himself was "when you're local…" He described his teaching philosophy as being tied to experiential learning. He explained that when concepts were too abstract, then his students "don't have any basis to relate to" them, but when "they were experiencing it, it gave more success that way." In his words, going to local places

> makes it different. You can't get that from a video. They got to smell it. They got to feel it. They got to touch it. I need to walk them over to [company name] in the mechanic shop. They need to feel that it's cold there in the wintertime. They need to feel that it's hot there in the summer. They need to go out to [construction company's] pit in [name of city]. They need to get in and out of those big trucks. They need to see stuff welding. They need to see guys with their coveralls on and half of them be smoking. They need to see the operators and the equipment running. They need to hear it. They need to feel it. You can't do that with video.

Accordingly, several of his engineering design challenges were associated with local places. He took his students outside to observe, discuss, and share their experiences with the places; he also encouraged students to take photographs of each place and to learn of other people's experiences with each place. He used local landmarks, close to the school, as topics for critique and discussion, such as "why they put roundabouts instead of a stoplight or why Walmart is located where it's at." Consistent with this place-based and experiential approach, he developed an engineering design challenge in which students developed a nature walk around a local pond beside the school so they could use their personal and familial experience with this local place as the basis for their designs.

As another example of a design challenge that drew from students' experiences, he was aware he had held occupations in the community that shared similarities with some of his students' parents. He therefore taught a workplace safety unit in which students designed safety procedures for a workspace. Andrew asked them to draw from their own experiences in working alongside their parents, or to draw from the stories their parents had told them about their workplaces, to better understand the different workplace hazards that might occur and to develop procedures for avoiding them.

Although Andrew repeatedly emphasized that experiences were better sources of learning than videos, he also regularly shared blockbuster movie clips, or used high-interest popular cultural events (e.g., the engineering of the Superbowl stadiums), as another means of connecting students' popular cultural knowledge to engineering. In his class, students shared

what they learned from movies, TV shows, or popular events, and Andrew asked them to draw parallels between the characters' actions and those of engineers.

In all, Andrew sought to ground several engineering design challenges either in students' or their families' *experiences in local places*, as a potential means of foregrounding students' funds of knowledge in the context of design challenges. Secondarily, Andrew believed *using popular cultural texts* as a discussion point would also engage his students more fully in engineering.

Reading But Not Writing in Spanish and English

As noted previously, Andrew's school, in effect, embraced English-only philosophies through its professional development recommendations and through other expectations communicated to teachers. In the context of the professional learning experiences provided by this project, Andrew changed his practices to include providing bilingual Spanish and English materials relative to each engineering design challenge. He also tried to encourage the use of Spanish through strategies such as asking students to share and discuss their designs ideas with undergraduate Spanish-speaking students from a local chapter of the Society for Professional Hispanic Engineers.

However, as a monolingual teacher, Andrew was unable to initiate translanguaging corrientes through speaking to his students in Spanish. Moreover, he did not consider language when placing students into engineering design teams because many of his students spoke only English. With the exception of one student who received ESL services, the bilingual students in his class were also designated as proficient in English, and they had been accustomed to using only English after 1.5 years of being at this school. Andrew did not encourage students to submit assignments in their home languages because he could not understand their responses and because his school had adopted the stance that students should submit assignments in English. We speculate that these factors provided challenges to his ability to sustain and encourage multilingual practices.

Discussion

This study paints a picture of how different teachers enacted pedagogies, which had the potential for sustaining multilingual students' funds of knowledge and languages, in different ways. As a general finding, both teachers considered the context of the design challenge to be a centrally important consideration. By selecting relevant challenges that could draw from familial experiences, both teachers were able to position parents as core intellectual resources, and they valued students' home languages in the context of fostering parent–child conversations.

Despite these similarities, the teachers also enacted funds of knowledge pedagogies in ways that were unique to their personal histories. Alex, a teacher with transnational experiences, frequently drew from stories and knowledges generated outside of the US, and he encouraged his students to do the same. Andrew, by contrast, was a proud "local" who had lived and taught in the community for decades. Accordingly, his approach to funds of knowledge pedagogies was much more localized as students walked (or took field trips) to various places in their communities to further observe, explore, and experience these places they defined problems in engineering and as they learned more about technologies.

As another similarity, although both teachers made moves to incorporate pedagogies that foregrounded students' funds of knowledge as resources for learning, they both found it more difficult to foreground students' languages as resources for learning. Alex reported challenges in finding multilingual resources for students from the Middle East, whereas Andrew reported that leadership at his school thought that speaking in Spanish would hinder students' ability to learn English. Even in the face of resource constraints, Alex's class, which included many Spanish/English speakers, was able to sustain translanguaging corrientes in these languages at least to some extent, whereas Andrew's class was primarily conducted through White Mainstream English. While we do not necessarily position both teachers as exemplars, we think their efforts to incorporate funds of knowledge and translanguaging may help to inform others in similar contexts, as we describe in more detail below.

Implications

At the classroom level, teachers can use their own unique strengths and resources as tools for grounding engineering design challenges in funds of knowledge and as tools for fostering multilingualism. Alex used his transnational experiences and fluency in Spanish to achieve these purposes. Andrew, by contrast, used his knowledge of community places and his extensive local connections (e.g., with organizations such as the Society for Professional Hispanic Engineers) to achieve these purposes. Despite significant differences in the teachers' and students' languages and experiences, both case studies suggest that selection of engineering design challenges may play a central role in pedagogies that encourage funds of knowledge and translanguaging. When design challenges are relevant to students' or community members' daily lives and

experiences, they hold the potential for eliciting funds of knowledge and for encouraging conversations in multiple languages with community members whose expertise is relevant to the solution.

In addition to holding implications at the classroom level, this study also holds implications at the school level. This study joins a growing body of research (Allard, 2017; Menken & Sánchez, 2019) that suggests translanguaging may be difficult to sustain at the classroom level but easier to sustain at a school level. Specifically, it was easier for Alex to encourage expressive multilingualism (e.g., posters in students' home languages) because it cohered with his school climate, but it was difficult for Andrew to encourage expressive multilingualism when his students were accustomed to several years of English-only instruction as enforced by the school administration. We therefore envision professional learning efforts that include administrators, in addition to engineering teachers, with the end goal that administrators understand the ethical and academic importance of multilingualism instead of viewing it as "hurting" students.

As another implication at the school level, we speculate that Alex may have been able to foster additional translanguaging corrientes if a few students who spoke the same language (e.g., Farsi) were allowed to enroll in the same class (e.g., sixth-period technology and engineering). This speculation is based on the assumption that robust corrientes are difficult to maintain with only one speaker of a particular language and no resources available in that language. While we caution against reifying tracking systems based on languages (Callahan, 2005), we wonder if administrators, counselors, teachers, and families might partner together to evaluate whether existing structural approaches—for example, course schedules and translation resources—actively encourage the sustenance of multiple languages. Together, these partners might think creatively about how to use existing institutional resources to actively sustain home languages for students who do not speak dominant languages within the school.

In all, this study suggests that it is possible for middle school teachers—even those who teach in typical and constrained contexts in traditional public middle schools—to incorporate funds of knowledge pedagogies and translanguaging pedagogies. Thoughtful selection of engineering design challenges, and the active incorporation of multilingual parents' expertise, seem like core mechanisms for achieving these goals. At the same time, this study also suggests that these pedagogies may be enhanced with institutional and administrative support. We ultimately envision engineering education that recognizes multilingual students' funds of knowledge and languages as valued epistemological resources that can be mobilized toward purposes that matter to students. We believe that Alex and Andrew teach us that this vision can be achievable if teachers have the right supports.

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