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Elementary Teacher learning of Engineering for Translanguaging Infusion (Fundamental)

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ABSTRACT

This paper presents our project regarding teacher development around engineering and language. Particularly, this work examines how elementary teachers engage in teaching engineering to their classrooms which contain multilingual students, using the lens of translanguaging.

Literature on professional development projects with US public school teachers has shown that sustained professional development programs have more impact on teacher learning. As the new Next Generation Science Standards (NGSS) emphasize the role of pre-college engineering, and since public school teachers rarely have familiarity with engineering concepts, they need more knowledge of engineering. Further, the number of multilingual learners in US public school classrooms are rapidly increasing, necessitating new practices by teachers and support structures to better assist these students' learning. A major motivation for our work is to counter the assumption often made within formal education in the US that these emergent multilingual students do not have the capacity or linguistic skills to engage in conceptually challenging topics such as science, engineering, or STEM inquiry.

Our work emphasized a sustained professional development project with elementary school teachers in US Public schools who have multilingual learners in their classrooms. Teachers were recruited for a summer Professional Learning Experience (PLE) and several half-day workshops throughout the school year. In PLE sessions, we worked with the teachers to introduce key concepts about engineering, translanguaging, and how to apply these topics within their classrooms. Translanguaging is an inclusive language ideology for multilingual learners which empowers them to leverage their full language repertoires (in whatever language or dialect), rather than forcing them to use exclusively the language of instruction. This allows students to engage in learning with the language resources they currently possess rather than delaying participation until a higher proficiency in English is acquired.

This paper examines the engineering knowledge growth and usage of translanguaging techniques via a case study of one third-grade teacher who developed and delivered an engineering unit within her classroom. To present this case study, we analyzed interviews, transcripts and recordings of our PLE sessions, and informal discussions, along with classroom observation data. We examine her changing positions related to engineering and her usage of language within this project and across one year of participation in the program. We consider her as a learner of engineering topics and also an experienced teacher who is applying these ideas into her own practice and classroom setting.

Preliminary findings show how the teacher went from being a novice in engineering to understanding that problem solutions require multiple iterations. Furthermore, we discovered that this teacher was already infusing some translanguaging practices in her class environment. Implications of this work include a better understanding of how elementary teachers navigate the challenge of teaching engineering to students and how these teachers specifically plan for, scaffold, and include the engagement of their multilingual students within these lessons.

Introduction

Multilingual students comprise 10.1% of US students, and this number is projected to increase [1]. Often emergent English speakers are not afforded the same opportunities as monolingual English speakers due to deficit-oriented beliefs that children must be fully proficient in English before they can participate in intellectually challenging STEM activities and learning. As a result, students classified as emergent bilinguals are often placed in tracks with low-level content and low expectations [2], [3], [4], [5]. This leads to fewer opportunities to participate in math, science, or engineering lessons, thus exacerbating the inequities between multilingual students and their monolingual English peers [6], [7]. This deficit mindset is detrimental to the learning opportunities of these students. In contrast, asset-based pedagogies (such as translanguaging) for multilingual students are engaging, effective, and often benefit every student in a classroom.

In seeking to introduce engineering to elementary school contexts, another barrier commonly encountered is teachers' expressed discomfort and unfamiliarity with engineering (insert TPD lit review citations). Many elementary teachers are content generalists, having significant preparation in childhood education but lacking extensive preparation in science, math, engineering or technologies associated with STEM subjects [8], [9], [10]. However, this presents a unique opportunity to create an equitable learning environment for students. Engineering is equally unfamiliar to all learners, regardless of their linguistic expertise, and to the teacher. As such, engineering is a promising discipline for adopting an asset-based pedagogy for multilingual students and a context where students can develop their language skills, and conceptual understandings through their engagement with engineering.

This paper presents our findings as a single case study of one teacher in an NSF-funded project. This project seeks to form a model of sustained professional development for elementary teachers to tackle the dual challenges in teaching emergent bilingual and multilingual students along with a lack of preparation to teach engineering. This project [8], [9] is in year two of three years and is developing better understandings of how teachers (of emergent bilingual and multilingual students) learn to teach engineering. Working within a professional learning community also provides teachers space to reconsider language ideologies through the lens of more equitable, asset-based pedagogies, namely translanguaging.

Background

The two major elements of engineering that are most associated with the field are its focus on solving problems and the engineering design process. Engineering is not typically included in teacher education programs [10], [11], [12], and may be particularly intimidating for elementary teachers who often have little science background. Despite this, according to the *Next Generation Science Standards* [13], "engineering has the potential to be inclusive of students who have traditionally been marginalized in science classrooms" because students can "engage in science in socially relevant and transformative ways" as they "solve problems through engineering in local contexts" [13](Appendix D, pp. 4-5). Subsequently engineering is being integrated into the public-school curriculum; however, teachers of elementary students rarely feel prepared or conceptually confident in the area.

Another area where teachers often report feeling underprepared is in working with emergent bilingual or multilingual students. Teachers often have little preparation in considering language

development or in relation to language ideologies. Language ideologies [14] inform and significantly influence teachers instructional practices. These ideologies can be beliefs about what is standard linguistic structure or what is culturally appropriate. Language ideologies determine classroom environments and influence many instructional decisions made by teachers. For example, these ideologies frame whether teachers believe that students must first learn to speak proficient English before engaging in STEM-related projects (a deficit-based view) or whether teachers believe that children can acquire and develop language through participating in engineering challenges (an asset-based view). Another example would be whether a teacher allows, encourages, or prohibits students speaking a language other than the dominant language of instruction- that is, for US classrooms, a language other than English. One such approach to using multiple languages is referred to as "translanguaging."

Translanguaging is a pedagogical and theoretical construct, or stance [15] that aligns with asset-based views of language. Translanguaging advocates propose that teachers should build a classroom environment that facilitates and encourages use of all language repertoires from learners. Research in multilingual settings has shown that translanguaging can be an integral component of fostering a multilingual ecology during engineering lessons [16]. This ecology is comprised the many languages spoken by students, but can also include vocabulary [17] and various modalities of communication. Multimodal communication (e.g., gesture, artifact manipulation, gaze) has been documented as an integral part of the communicative process for multilingual students and young learners in elementary classrooms [2], [18].

Consequently, we take up the challenge to teach translanguaging as a strategy, stance, and mechanism for facilitating more inclusive language ideologies from elementary teachers, particularly within the context of engineering lessons in their classrooms. Our approach works to provide teachers with sustained time to reflect on what they believe about language, their teaching of linguistically and racially minoritized students, and their interactions with multilingual students around engineering content.

In sum, in this project we seek to understand: How do elementary teachers of multilingual classrooms shift their positions with regard to: language ideologies, understanding and/or application of translanguaging and understanding and implementation of engineering?

Methods

The overall project, funded by the National Science Foundation, follows a cohort of third grade teachers at two elementary schools located in first-ring suburbs of a major city in the northeastern US as they integrate engineering into their classroom practice. Specifically, this project works with teachers who have emergent bilingual students in their classrooms in two highly diverse school districts where over 30 languages are represented. In addition to high numbers of newcomer students, approximately half of district families are considered economically disadvantaged.

In this paper, we use an intrinsic case study design [19] to focus on one teacher-participant, Sarah, in year one of the project. This single-case study draws findings from the rich text of Sarah's interviews and then uses those findings to execute deep analysis on her specific journey with these topics. Intrinsic case studies provide detailed examinations of the texts of a single participant, to allow for depth of analysis and better understanding of the intricate connections

between different topics [20], [21], [22], [23]. As such, single cases are particularly helpful for other educators and researchers investigating teacher professional learning in engineering.

Participant

At the time of the study Sarah was in year one of the Professional Learning Experience (PLE). (The PLE is explained further in the next section). As a teacher certified in childhood education (birth-second grade, and first-sixth grade), Sarah has been teaching for eight years at the elementary level. Sarah has held a variety of teaching experiences, all at the elementary level. Notably, she had a position as a STEM enrichment facilitator, which is her only previous experience with engineering. She has also served as a teacher's assistant, long term substitute, and then gained her current position as a classroom teacher of in a school with many multilingual students. She has held this position for four years. Sarah considers herself to be predominantly an English speaker, although as the daughter of Pakistani immigrants, she grew up hearing Urdu but was discouraged from speaking it at home or in her US schooling.

Professional Learning Experience Format

We invited our cohort of teachers for an initial three-day PLE during the summer and then met for several mid-year half-day PLE sessions throughout the year. These mid-year PLE sessions occurred monthly or bi-monthly, depending on teacher desires. We also provided on-request tailored lesson planning assistance and ultimately performed classroom observations whenever the teachers executed an engineering unit. Further details about the summer PLE can be found in our other publications [8], [9], [24].

In the intensive three-day Summer PLE, teachers were introduced to translanguaging, language ideologies, and engineering. We also explained with the teacher participants the rationale behind this research project, our approach (detailed further in [8], [9], [24]) and the institutionally approved IRB. We explored the engineering design process, providing examples and design process models within elementary school contexts, and gave the teachers several vicarious experiences as students of engineering (e.g., designing container to keep a snowball from melting). We delivered model engineering lessons and created engineering challenges where teachers participated as the novice learners, engaging in structured reflections on our teaching and how the lessons could be adapted. Teachers were asked to incorporate engineering lessons into their own classrooms. The content and design of those lessons was dependent upon their agency. That is, teachers decided the timing, duration, disciplinary connections, and focus for their lessons and design challenges. During the school year in four half-day PLE sessions, we focused on topics that emerged from teacher-directed lessons and teacher questions and in assisting teachers with curricular planning. In particular, we focused on the process of iterating on a design (and testing to failure), and problem scoping or framing. These elements foreground some key differences between engineering design processes and sciences inquiry processes. As such, it is not surprising that the teachers had questions surrounding these area as many teachers approach engineering conceptually through science inquiry which differs conceptually from engineering [25], [26], [27].

We also discussed translanguaging in application. For example, we explored how to establish a translingual ecology in the classroom and specific strategies to introduce translanguaging, as this topic was requested by teachers. Our final PLE during the school year was devoted to purely

planning. Our research team facilitated a three-hour PLE session so the teachers could co-plan their largest engineering unit. Previously, they had independently arrived decided to implement the same project from a text, though they implemented the project in very different ways. As recommended by researchers [25], [26], [27], part of our project was to facilitate the space teachers needed in order to feel confident in their engineering units and designing them. Specifically, we ensured teachers had dedicated time, space, peer support, and expert consultants available during this content design. Sarah used these opportunities to both plan her engineering lessons (which she stated early on would be a longer unit late in the school year) and also to engage in personal reflection around her own experiences as a multilingual child in the US. These experiences primed her for rich engagements with translanguaging. Her own lack of experience with engineering meant the single unit she was developing and teaching would be a rich source of data of an experienced teacher returning to novice status in a new conceptual area. In other words, while Sarah had significant experience as a teacher, she had no experience teaching engineering design or in using translanguaging pedagogies in her classroom.

Data collection and analysis

To address broader project goals, data was collected in Sarah's classroom through multiple mediums: photos, video, audio, and field notes. However, for this case study, the primary data source was the interviews collected with Sarah. Sarah was interviewed at the start of the year (before the first session of the PLE), after the engineering unit she conducted, and again at the end of the school year. Secondary data sources included the two engineering consultations that she requested at her classroom where a member of the research team acted as a knowledgeable other who engaged with Sarah as she planned the engineering unit, and the daily post-teaching debriefings immediately after each day of the engineering unit, capturing Sarah's immediate reflection.

Specifically, we looked at Sarah's interviews and comments made during our PLE, with supplemental analysis provided by classroom observations of the single engineering unit she implemented. We analyzed the shift in her knowledge, understanding, and implementation of engineering, translanguaging, and language ideologies over this first year. We examined audio and video recordings of our PLE sessions, interviews with the teachers, and recordings of their classroom observations.

We used a deductive coding process [28], related to the three project constructs: engineering, translanguaging, and language ideologies. We coded transcripts for instances according to the definitions listed in Table 1.

Table 1: Working definitions of core research vocabulary terms provided to teachers

Term	Working Definition
Engineering Design	A defining characteristic of engineering, the design process is a method for engineers to: scope, generate, evaluate, and realize ideas, with improvements as needed [30]

Translanguaging	Translanguaging is the active use of all repertoires of students' languages, or it's your pedagogy to support learners in use of all of their language repertoires [18], [31]
Language Ideologies	Language ideologies are beliefs, values, and attitudes that surround language structures and practices in classrooms and society. [17], [32]

After isolating these coded segments for each interview, an analytic memo was written to create arguments about the teachers' knowledge, understanding, and implementation of each topic. Thus, memos were written for: the pre-PLE interview, the post-teaching unit interview, end-of-year reflection interview, and one memo across all mini-debriefings of teaching and engineering planning consultations. We used these to examine Sarah's position during this interview towards each of our RQ and can thus track her development across the year. Findings included in the memos were honed through discussions among the research team to identify arguments that needed clarification or more information. After all data were analyzed, Sarah's overall shifts of knowledge, understanding, and implementation were shared with the research team using examples from each memo and interview as evidence for arguments.

Results

Sarah's language ideology has strongly influenced her teaching and organically inspired her use of translanguaging in her classroom. Drawing upon the loss of her own heritage language of Urdu and discussions of translanguaging, over time Sarah articulated that she wants her students to have a different experience than she did.

Sarah was initially unfamiliar with the term translanguaging, though she has unknowingly used many strategies that are espoused by this practice in her classroom already. She struggled to incorporate these same strategies into engineering lessons, though she came to a personal working definition of translanguaging.

Sarah showed a significant shift in terms of her understanding of engineering. Sarah came into the project not knowing definitely what an engineer did. She had basic knowledge of what engineering and the engineering design process was, as she viewed engineering through the perspective of an elementary school educator. Sarah wasn't originally aware of specific terms in engineering design, such as criteria and constraints. She came to understand and state that engineers are problem solvers and that learning from failure is good and an effective way to learn. Further, Sarah realized that solutions to problems are not always visible or obvious immediately and may need to be reworked multiple times to be a successful solution. A major goal in Sarah's teaching was to give space for her students to learn these same lessons, about engineering and for life in general.

Sarah's shifting view of language ideologies

Sarah started out unfamiliar with the term "language ideologies." When provided the working definition, she began a journey of self-exploration and remembering. Sarah represented her language ideologies most clearly when she talked about her own experiences as a child who was an English Language Learner and whose home language was Urdu.

During the first few months of her participation in the study Sarah began to mourn her own loss of her home language of Urdu because of her experiences in United States schools and her parents attempts to help her assimilate. These foundational experiences created a strong affective rationale for her participation in the counteractions, such as inclusive language ideologies.

Commented [MOU1]: This is a powerful paragraph

In her end-of-year interview Sarah revisited her ideologies, her experiences of the views imposed on her during her childhood, contrasting them with her own desires and now her teaching strategies. She stated that "...there's a space for it (translanguaging or language ideologies) everywhere…" by which she is referring to the use of home languages in the classroom. Sarah frequently tells students that "[speaking my home language] is the one thing I wished I never stopped speaking. You're going to forget it. And when you grow up, you're going to want to know it. You're going to want to be able to communicate with everybody else that you have something in common with." She wants her students to know and build an appreciation for their home languages. She doesn't "want to be the reason that these students down the road feel like there's something missing."

Sarah demonstrated her language ideologies, speaking of them in the same breath as her motivation for her classroom environment. She expressed how she works to make sure that "[m]y classrooms are home away from home. I want them [students] to be comfortable. I want them to feel secure and take those chances. Community meaning is a huge, huge component of the classroom." She added, "I feel like I try to do that, really understand where they're coming from, really try and make that home connection, really bring their customs, and traditions, and discussions into the classroom, as much as they're willing to share. I don't ever want to put anybody on the spot and make them to be our token whatever person in the classroom." Sarah further stated that she wants to "expose everybody to everyone's individual identities. I think that's really important. It comes from me personally, growing up where it was almost suppressed..."

Sarah's strong experiences have left her with a motivation to embrace inclusive practices and a welcoming, linguistically diverse ideology. She leaned into this work, seeking to help students. As a way of processing her own childhood, she reflected on her educational journey and how different it could have been with teachers who had the same ideology she aspires to hold. These experiences motivate and empower her to take up new attitudes, perspectives, and practices that embody the more inclusive ideology she wants for her students and wished she had herself experienced. This makes her open to new modalities, spheres of practice, and venues for learning techniques to improve her practice.

Shifting usage of Translanguaging

In her initial pre-PLE interview Sarah stated that she was not familiar with the term translanguaging. Despite this, over time, it became clear that despite lacking the terminology, she

was intentionally using some practices in her classroom that are representative of translanguaging. For example, in her use of daily community meetings, Sarah stated that "[we'll] do our community meetings in the morning, where we'll talk about ways to teach somebody how to say hello… It's usually just something quick like, 'Hi, how are you?' I've had students say that in Arabic, and then we'll practice that. We do it, they'll lead the greeting. They'll lead it, and then they'll say it to [a classmate], and then [that classmate] might ask the person across them."

After teaching the engineering unit, Sarah saw it as a mechanism for connecting students. "It allows kids to communicate in a way that they may be more comfortable with… it allows them to be part of a group and contribute to the group in a way that they typically may not be able to do." She saw it as a way to improve, learn from, and with each other, and seeks to provide those opportunities. A notable example was when she constructed her multilingual word wall.

> "When I did the word wall I was pleasantly... Actually, I was really shocked… I was like, 'Holy cow.' Randomly, one of my kids is using the term… *'basura'.* We were doing something in math, and Charley, he sits at the corner, he goes, 'Can I throw this out in the basura?' And I was like, "Charley, what are you talking about?" And he goes, "The basura. I want to throw it out.' like, "What is that?' Because I have labels around the room. And he's like, 'It's the garbage can.' And then it caught everyone's attention. And the kids are like, 'I wonder what the word in Spanish is for recycling.'

This prompted an entire discussion on words and led to an expansion of the word wall. Sarah was surprised but leveraged this moment to expand the translingual environment. Sarah notably has the word in about a dozen languages for each of the common classroom elements (e.g. garbage can, pencils, pencils sharpener, door, clock) on the item itself. These are small and on most common items in the classroom.

Sarah attempted to engage common first language students in her classroom to use their home language when doing engineering activities yet had to adapt to student unwillingness to engage with the opportunities she opened for them. By grouping two students together she created space for them to use their full language repertoire yet was rebuffed. "And even though I assigned Lulu, who speaks Arabic, and Jack (who speaks a different dialect of Arabic) in the same group, they don't necessarily speak it to each other. (That is, they don't speak to each other in Arabic). So it's not like it's the norm. It's almost like everybody does the normal English talk." This continued even when Sarah suggested to them that they share a home language and could work in that language. Sarah states that "they looked at me and I was so strange…And they just were like, 'No thanks.'" When students failed to follow Sarah's lead as she engaged in translanguaging pedagogies and encouraged multiple languages, Sarah internalized this failure. Despite the introduction of translanguaging supports and strategies in the classroom, Sarah still expressed concerns that she did not fully know how to implement translanguaging.

By the end-of-year reflection interview, her position had shifted in some areas. She now had a personal, working definition for translanguaging.

> "...allowing your students to be able to communicate in either language that they're comfortable with because they're not at a deficit, they're not behind everyone because they're speaking a different language. They're just bringing a different experience to the table in different from a different background. So however they're communicating their

> experiences, it could be in their home language and you could translate it or you could have somebody translate it for them. And they still have a lot to contribute and that might not be the traditional sense, but they still bring value to the table."

Despite being able to articulate what translanguaging is, she expressed uncertainty on how to implement this approach, yet her own work demonstrated otherwise. She was comfortable using translanguaging practices but felt unsure when they were not taken up by students.

We see her classroom as an emergent translingual ecology [16]. This was already present in her classroom and basic practices, so a portion of her claimed uncertainty in the enactment of translanguaging is likely due to the already high baseline implementation in her contexts. The lack of bilingual students taking up opportunities to use their home languages caused Sarah some discouragement. But the lack of student uptake itself is not surprising as children quickly learn that English is the language of schooling and families also often prefer their children to speak more English as this is equated with opportunity and success [32].

Sarah has worked to develop a welcoming translingual space as evidenced by the unexpected engagements such as Charlie's use of *basura*. She has infused translingual practices into her environment, created a welcoming translingual ecology, and enacted many of the small translanguaging techniques in her everyday praxis, even before our PLE.

We present Sarah here to show the difficulty of doing this work, the grapplings, doubts, and the self-discovery that can occur. Practitioners and researchers may have many different views on translanguaging. We can see the many small moments aggregated together to result in a strong translingual environment, yet Sarah does not and claims to "not know how to do translanguaging." She is fully aligned with, supportive of, and desiring to adopt this approach. Thus, from the macro scale she is supportive and subscribed. From the micro perspective we see her practice being successfully aligned, yet she does not see how the accumulated moments result in successful implementation. Both views are equally true, equally valid, and create an uncertainty in the practitioner adoption of the techniques or approach.

Shifting understanding of Engineering

Sarah showed a significant deepening of her views toward engineering. She was unfamiliar with the process or term conceptually prior to the PLE, stating that "I'm not sure, but from what I know from engineering is engineers try to solve real-life problems." Although she had heard the term "Engineering Design Process" during a previous professional development in her time as a teacher. She knew the ideas surrounding engineering only from enrichment experiences she had co-facilitated in a previous role. "We did many STEM activities, and we worked on engineer designs where students brainstormed. They had to come up with an engineering design to incorporate [provided tools] when they were designing."

After teaching the engineering unit, her viewpoint had expectedly shifted. She viewed engineering as a process of nonlinear problem solving. Failure was not only part of the process; failure was expected, natural, and good. She stated that "in school, we have this very black and white structure… I think the engineering unit allowed them to see, … [to be] really able to showcase their creativity and find success in their groups. So I thought that was really great."

She frequently made the assertion to her students that *failing* was not *failure*. She explicitly pointed out from "the beginning that engineering is all about learning from failure and failure is good. *Failing* is actually not *failure* was a great way to set it up, because expecting failure throughout the process was okay, and they were not to be shocked by it because they knew they were going to learn from it."
Sarah also stated how she enjoyed there was "no [conceptual] knowledge, just rational thinking" for students. She felt there was a good clear distinction between failure and failing in engineering, and the process was nonlinear, and the components were clear. She wanted students to problem solve themselves, and even beyond she wanted them to experience framing the problems or creating the problems they wanted to solve. "I wanted to do the modeling that I normally do when I'm teaching a unit. It was pretty much 'I do, we do, you do,' but I had to step away from that a little bit too, because engineering is all about discovering and figuring out things on your own." From this we can see Sarah adapting her standard process of demonstrating, doing together, and then releasing students to allow for the engineering discovery and open-endedness.

At her end of year reflection, Sarah had progressed further in her thinking. She viewed engineering as a process and now knew the stages, components terms, and elements more deeply. She understood that engineering was more of an exploration and discovery process. This deeper understanding was demonstrated through her discussions on what she wants students to learn during the engineering unit. Sarah stated that she "wanted [the students] to come to their own consensus and their own ideas without me leading them completely to the answer. And sometimes [in that] process, you have to step back, because you want them to realize it on their own." Here Sarah was positioning the students as learners and problem framers, and stating she wants them to determine their own problem solutions in their groups, without her guidance or significant interference. This showed her motivation for undertaking engineering, and how her view of an engineer as "figuring things out on your own" has informed her teaching.

Her previous experiences within the PLE helped her understand and learn about engineering and the engineering design process. She explicitly stated how being a learner made her a better teacher. "I thought that was really great to actually go through every single step, come up with the constraints, come up with the restrictions of everything, just to see how it would play out, and the thought process and the discussion process of what was important, and why it was important. What were the parameters we were going to go and try to solve this problem. I really like that, to break it up." Through the engineering design process, she appreciated how it opened and engaged her students, specifically the academically struggling kids. Sarah observed that "it was really impressive that the kids that were the most successful, weren't necessarily the high achieving academically, high testing kids." Sarah also noted that "it was really good to see the positive things that came out of this for the kids that sometimes don't get noticed in the classroom." Sarah later stated it almost "flipped the script almost" and allowed her students that often struggle in traditional academic tasks to thrive, while many of the students who did well in that traditional task setting struggled with the open-endedness and self-directed element of engineering.

Sarah grew in her understanding of engineering. Sarah showed a willingness to take up the challenge and to embrace the difficulty of learning so she can teach engineering. Importantly, Sarah needed multiple opportunities to engage with engineering, to learn about engineering, and

to understand engineering before she was able to effectively teach it. This was not merely multiple exposures to engineering, but an extended engagement with engineering concepts and processes alongside the support from the PLE/research team and the clear positioning as a learner. This combination allowed Sarah to gain conceptual understanding and growth and further solidified her identity as a teacher of engineering; Sarah was severely uncomfortable and not confident going into the PLE, yet at the end of year reflection, after teaching just one intensive unit, Sarah was willing to claim being a "teacher who does engineering."

Discussion

Sarah has shifted her understandings during her engagement with the PLE. Her case study shows the deep reflective practices that teachers must engage in while enacting this work. Sarah grappled with applying what she learned during the PLE in her classroom, with teaching engineering, with incorporating translanguaging tactics, and all within the context of her normally expected load of teaching, curriculum, and assessment.

Engineering

Elementary teachers who learn to teach engineering have many areas of potential difficulty. Many times these teachers focus their energy on the enactment of lessons or the activities of engineering [10], [12], [33]. Sarah revealed new struggles to us. She struggled in two areas that are not reported in the literature: visualization and problem framing. Sarah came to view engineers as problem solvers and wanted her students to have this authentic experience. As such, she set out to organize her unit to allow students significant time on the first few phases of engineering design: problem framing, criteria, and constraints. This is in contrast to patterns common in the literature, where most teachers focus upon the enactment rather than these initial setup phases [34], [35], [36], [37]. Additionally, Sarah struggled to visualize what engineering would look like in her classroom, often asking in our PLE "what will the students do?"

This is echoed by findings around teacher tensions [38] and expected barriers [39] within engineering. When teaching engineering, teachers need to develop responsive teaching practices as there is no prescriptive format or template that engineering will likely ascribe to. Teachers, like Sarah, also worry about their students' ability to perform engineering tasks, their lack of personal knowledge, and the requisite time and space to plan engineering lessons.

Sarah also diverged from common practices in the literature when she focused upon iterations. A major portion of engineering is the iteration and improvements of designs when they are initially unsuccessful, yet this is often neglected in elementary settings [40], [41], [42], [43], [44]. One of Sarah's goals for this lesson, which she mentioned often in her interviews, was for students to experience failing and learn that failing is not failure. With engineering, this is particularly salient as failing is requisite to develop an effective solution. Most engineering experiences within elementary settings follow similar pathways to the science inquiry process, testing a prototype similarly to a hypothesis, and then ending after the evaluation of success criteria [44], [45]. Yet in engineering design, failures of a prototype are the beginnings of the new round of ideation. Sarah focused on this factor and worked to ensure her students had multiple chances to test, evaluate, and improve upon their designs.

We can see the influences of PLE upon Sarah's practices even as she incorporated what she was learning with her own classroom and teaching practices. For example, we demonstrated a PLE lesson on problem framing and helping students identify criteria and constraints and Sarah bridged off that to her own practice taking the ideas and recontextualizing them for her third-grade classroom. Within the PLE, facilitators discussed the use of research texts that provided insights into other classrooms and teachers who had engaged in engineering. At the same time, Sarah leveraged embodied learning and physical simulations of the engineering testing format to help students decide what their prototype should accomplish.

Similarly, the research team provided a demonstration PLE lesson on iterations and leveraging evaluation and iteration into the engineering design and testing process. We focused on detailed evaluation of testing criteria, while Sarah chose to focus on student's identification of what on their prototype worked well and what elements needed to be improved, using scaffolded worksheets. Sarah also used this as a springboard to the life lesson she wanted to convey, that failing is not failure, as this is a part of life. Sarah also spoke in this process about her own experiences as a learner of engineering during the summer PLE, referring specifically back to her first engineering challenge. She failed to meet criteria, resulting in an unsuccessful prototype. Sarah chose to share this experience with the students to model a positive attitude towards failing. This aligns with research that teachers have some of the most impactful moments in PLEs when there is a mixture of moments where they are the learner experiencing the lesson and moments they are the teacher, planning their own lessons [46].

Sarah came into the project not knowing for sure what an engineer did yet now has detailed knowledge of engineering and the engineering design process. Sarah has participated in one teaching unit, a half dozen PLE sessions, two engineering consultations for her lesson development, and several interviews for deep reflective thought have deepened her understanding of engineering and her perceptions of her ability to teach it. Despite all this engagement, she did not cement her confidence or identity as a "teacher of engineering."

Translanguaging

Sarah showed a strong latent translingual ecology in her classroom, unknowingly using many strategies and practices indicative of translanguaging. She also was strongly supportive of the idea when described in our summer PLE. However, she struggled to integrate these practices and strategies to her engineering unit. This highlights the synergistic difficulty of infusing practices to new contexts [47]. Translanguaging is difficult work, even when the teacher's language ideology predisposes them to this practice, as it does with Sarah. Even when teachers are prepared conceptually and methodologically towards translanguaging, they struggle in the implementation [48], [49]. This difficulty in implementation is underscored by the immensely positive and beneficial impact the usage of such inclusive strategies as those espoused by translanguaging [50] can have upon students [51], [52], [53]. Sarah embodies these findings. Despite her language ideologies, personal experiences, and internal motivation to enact these inclusive strategies and translanguaging, she struggles to implement the habits common to her practice and classroom to engineering contexts. Teachers need support, guidance, and examples as they navigate the difficult yet rewarding process of building more inclusive classrooms. Sarah, as a multilingual teacher herself who has been through the process of schooling while being an English language learner, still struggles to implement these inclusive pedagogies. This

suggests how much more difficult other teachers who have not experienced the cognitive difficulty of navigation between linguistic contexts may find this process to be, due to the multiple layers of unfamiliar practices or concepts [49], [50], [51].

Sarah went from being unfamiliar with translanguaging and implicitly using translanguaging practices in her classroom to being able to create her own definition. Sarah now defines translanguaging as noted earlier in her end-of-year definition as students communicating in any language, since they have significant contributions and unique value from their own different experiences. Sarah was intentional through this definition to specifically assert that these students are not at a deficit but drawing from different areas and they bring a lot of value even if it is outside the traditional view.

She has developed an effective and welcoming ecology and environment yet still claims to be unsure of how to do translanguaging in engineering, at least formally. Sarah shows us how an accumulation of small moments, actions, or steps can create a welcoming, fully translingual ecology. Sarah also reminds us that teachers can often struggle to view their practices in context, particularly how their everyday actions can have a significant impact on the messaging about classroom atmosphere and attitudes.

Language Ideologies

Sarah's language ideologies have influenced her teaching and inspired her to use translanguaging in the classroom without knowing the term/practices.

Throughout the PLE's Sarah has been processing and coming to terms with the loss of her home language. Sarah was classified as an English as a new language (ENL) student during her own schooling journey. Her family is from Pakistan; her native language is Urdu. As she grew up, she became more fluent in English, eventually losing most of her speaking fluency in Urdu.

She didn't want to be the reason her students lose their native language and culture, so she tried to create an environment that embraces and accepts them.

> "Looking back at it now as an adult, that moment is so impactful, because I do not speak my home language. I have three children of my own now. My parents still speak Urdu, but my kids don't understand. They'll understand *shoes* and *hello*, but they don't understand the language. I can understand it, but I do not speak it. I do not write it. I do not read it. It's a huge impact. Now my kids do not speak the language…
> I do not want that for my students. That is why I feel like it is so important for these kids to know that who they are matters, who they identify as matters, and their language matters. Their customs matter, their traditions matter. In order for you to be successful in this country, you can be everything. You don't just have to identify as an English language speaker. You can be all of these."

Consequently, Sarah's motivation for taking up this work was derived from her own experiences, the enforced monolingualism during her childhood that led to the loss of her home language and subsequent disconnection from her heritage culture still has immense impacts today. Sarah revealed to us the strong influence of language ideologies[54], [55]. We see her motivation remain consistent, as she continues wanting students to view both or all their languages as assets, which assists her drive as she works to learn engineering. Sarah grew to understand her own

language ideologies, and how strongly they have influenced her classroom practice. We can also see how immensely impactful her own journey within ENL programs, her loss of her home language proficiency, and the grief she feels about that is upon her language ideologies. Sarah reminds us that teachers are willing to undertake challenging work for their personal and professional development, and many of them, like Sarah, are more motivated by the impact it can have upon their classrooms.

Conclusions

Sarah has an especially strong alignment with the inclusive language ideologies espoused by translanguaging, and many of her shifts in this area are a result of her mourning her loss of home language proficiency and the impact that had on her own children. Sarah clarified her language ideology through her time in this project. It remains inclusive, welcoming of students, and viewing their multiple languages as an asset to be nurtured and protected. Sarah works to make her practice and classroom welcoming for her multilingual students and encouraging them to nourish their proficiency in their home language. This is counter to many of the narratives within the American schooling system, particularly the deficit ideology towards emergent bilingual students and the expectation of linguistic assimilation.

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We have observed a strong translingual ecology in her classroom, yet Sarah herself does not acknowledge this as readily. Sarah has tried to pair students together, to normalize the usage of multiple languages, and to lean into the multimodal power of gestures, drawings, images, and collaborative work to support student learning. Despite this, there is a disconnect from her perceptions of translanguaging, her willingness to enact translanguaging practices, her belief in the power of translanguaging, and her understanding of how to use or apply it.

Sarah also shows us how the practitioner and researcher perspectives can differ. As researchers, we see her strong stance towards translanguaging and the practices she has infused to her classroom as an effective ecological development, yet she still reports that she is unsure of how to enact this approach. She also asserts that she does not understand how to apply translanguaging pedagogies to engineering specifically, despite the PLEs focusing on both ideas in tandem, teaching and showing these two concepts interwoven and Sarah's own use of various strategies. This too is not surprising given that research shows that teachers need intentional scaffolding, expert guidance, and repeated opportunities to process their own learning and to deeply connect this to their teaching practice [56].

Sarah has deepened her understanding of engineering. She began as hesitant yet viewing engineering as a way of solving real-life problems; she has become more confident in just this one year of the PLE, only delivering one engineering unit. As such, she will claim the title of "teacher who does engineering" yet not the distinction of "Engineering Teacher." This is consistent with the literature, as teacher identity is shown to be fragile when they are in a conceptually unfamiliar area [18], [29], [57].

We present Sarah so that other teachers of emergent bilinguals can also see how engineering is powerful for the students, providing access for all their learners in various ways. Sarah cites this access as her rationale for continuing this work. Sarah enunciated well the power of engineering in multilingual groups, particularly in the engagement and access provided by the modality and

cooperative environment, and how this is especially enhanced for students, such as emergent bilinguals, who are often labeled as academically struggling.

She says that she would tell fellow elementary teachers considering doing engineering that “it's highly engaging. Everyone's participating. Everybody has something to offer. … And it brings in a lot of different skill sets. It's not just thinking like an engineer. It's the planning. It's the cooperative learning. It's the communication. It's the compromising and the carry out and testing, and knowing that failure's okay and we don't have to have a meltdown or have a breakdown about the fact that we didn't succeed the first time, but we did learn.”

Implications and Continuing Work

Teaching Implications: Improvements to our PLE

Inspired by our detailed inspection of Sarah within this case study we have implemented adaptations to our PLE model for the following years.

We present those adaptations below, considering them as both lessons learned for our PLE going forward into subsequent years and as ideas for other designers of PLE opportunities. We encouraged teachers to start teaching engineering earlier and implement more lessons through the duration of the school year, enabled teacher partnerships alongside peers to share the cognitive and preparatory work, and provided opportunities for teachers to engage with multiple forms of modeled engineering lessons. These modeled lessons draw upon the many forms engineering can take and try to present these various avenues to the teachers. For example, we used source texts from children’s books to leverage a literacy integration, drawing on other exemplary work in elementary engineering [7], [58], [59]as well as community-based problems [60], [61], [62]within our local context.

We are also working with teachers to explicitly discuss how many small actions can create a welcoming translingual environment [16]and looking for clear examples of translanguaging in action within the elementary context.

As researchers in a collaborative PLE with teachers, we have also taken the opportunity to reflect on Sarah’s learning journey and ask ourselves: What changes and improvements can we make to the PLE to better support teachers? We have made a number of direct changes to the PLE. One of the challenges for Sarah was that she continued to feel uncomfortable with both engineering and translanguaging across the year which led her to delay any implementation of her engineering lessons. With our Year 2 teachers, we provided two specific examples (e.g., a one-day lesson and a three-day unit) and encouraged teachers to implement these in the first few months of school with support as needed from university collaborators. This allowed teachers to begin their implementation journey sooner and allowed us to provide scaffolding sooner. Based on Sarah’s personal response and processing of her own language history, a second change is that we created additional spaces for teachers to discuss their language identities. For example, in an early PLE activity, the teachers and researchers illustrated their personal language identities visually. These language identities included multiple areas of discourse such as teacher language, church language, sports language as well as named languages (e.g., Urdu, Spanish, Chinese, etc.) and prompted many discussions around language and identity thus raising discussions language ideologies (i.e., beliefs, values, attitudes toward language). Additionally, we have begun

developing a menu of options for teachers to help scaffold their implementation of engineering and translanguaging. This menu allows teachers to choose lessons and engineering design challenges that they are comfortable with. Based on data collected from teacher classrooms and lessons, we are providing lesson guides for both engineering and translanguaging. These lesson guides can further scaffold teacher learning. While space limits our ability to share all changes made to the PLE sessions, Sarah's case has also helped us fine-tune the PLE experience for the teachers in year two of the grant and to provide more strategic scaffolding for those teachers.

Research Implications: Lessons learned from Sarah

Despite her high-level adoption of practices, Sarah shows how longer-term engagement is required for full uptake of engineering practices. After a year of extended engagement with engineering concepts and pedagogical strategies, she is still not willing to claim the title nor is she fully confident while teaching engineering. This aligns with literary findings, and emphasizes the need for collaborative, longer term PLE programs, rather than information delivery with little follow up [25], [27], [63].

We also see how Sarah struggles to understand applying translanguaging in her classroom practice and how hard it is for her to see the translingual ecology she has developed. Sarah has continued in our PLE program during this second year of the project. She continues to engage with engineering and grapple with how to enact translanguaging, and we look forward to seeing her enact more lessons this coming school year.

Sarah had such an inclusive pedagogy already, she doesn't see the improvements she undertook, as her current practices were already so similar. More teachers of emergent bilinguals can learn from this, to see how the many small actions they do can have an immense impact on students, and how changes can happen one step (or word wall) at a time. Sarah also shows us how teachers' experiences, journeys, and educational history influences their praxis, pedagogy, and ideologies. This is not surprising, yet with Sarah the empathy and protective attitude she takes to her multilingual student's language capabilities shows a level deeper. Her ideology is rooted in her history, clearly informs her practice, and our work with her allowed her to better understand it.

In the paper we presented one case study of many we are collecting and analyzing ([9]).As we continue with our case study analysis we will compare and contrast teacher experiences to build more conclusive evidence of the experiences of teachers implementing engineering and translanguaging.

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